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International Rice Research Institute

ANNUAL REPORT FOR 1983

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International Rice Research Institute

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Leonardo Magaling, *BS, research assistant******
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German O. Turija, *BS, research aide*[+++]

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*Left during the year
**On study leave
***Joined and left during the year
****Joined during the year
*****Transferred during the year
[+]Outreach
[++]On project appointment
[+++]On part-time basis

About this report

This 22d annual report includes research reported during 1983. The department or departments that performed the research are identified in italics below the topic heading. For example:

NATURE OF RESISTANCE
Entomology Department

In collaborative work, the department that did one phase of the research is identified in italics in parentheses following the subtopic. For example, the Plant Breeding and Cereal Chemistry Departments cooperate in the section BREEDING PROGRAM. Because the Cereal Chemistry Department bears responsibility for one phase of that work, its name follows the heading:

Milling quality studies *(Cereal Chemistry).*

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.

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

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 International Rice Testing Program, IRRI.

This report is on a metric basis and uses the International System of Units (SI) abbreviations. All monetary units are as U.S. dollars ($). Unless otherwise stated, *control* or *check* means an untreated control, grain yield is calculated as rough rice at 14% moisture, and protein content is calculated as a percentage of brown rice at 14% moisture.

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

Names and terms often repeated within sections and throughout the publication are abbreviated, e.g. BPH (brown planthopper), GLH (green leafhopper), DT (days after transplanting), DAT (days after treatment), etc. A list of abbreviations is on pages xiv-xv.

The report uses generic names instead of brand names for chemicals. Use of a commercial or brand name when the generic name is unobtainable does not constitute an endorsement of the product.

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.

Acronyms and abbreviations used in this report

A
AC = amylose content
acc no. = accession number
ai = active ingredient
ARFSN = Asian Rice Farming Systems Network
AS = ammonium sulfate

B
B&I = broadcast and incorporation (incorporated)
BB = bacterial blight
B:C = benefit-cost ratio
BGA = blue-green algae
Bl = blast
BLB = bacterial leaf blight
BLS = bacterial leaf streak
BPH = brown planthopper
BRP = brown-rice protein
BS = brown spot

C
CEC = cation exchange capacity
CIMMYT = International Maize and Wheat Improvement Center
cms = cytoplasmic male sterile
C:N = carbon-nitrogen ratio
CW = caseworm

D
DAI = days after inoculation
DAPI = days after panicle initiation
DAS = days after seeding, sowing
DAT = days after treatment
DBE = days before emergence
DBH = days before harvest
DBPI = days before panicle initiation
DBS = days before seeding, sowing
DBT = days before transplanting
DE = days after emergence
DI = days after infection, infestation
DM = dry matter
DS = dry season
DSR = dry-seeded rice
DT = days after transplanting

E
EC = emulsifiable concentrate
EE = ethyl ester
ET = evapotranspiration

F
F = flowable
fb = followed by
FSm = false smut

G
G = granular
GEU = genetic evaluation and utilization
GHC = green hairy caterpillar
GLH = green leafhopper
GM = gall midge
GSV = grassy stunt virus

H
HAI = hours after inoculation or infestation
HI = harvest index
HR = highly resistant
HS = highly susceptible
HT = hours after treatment
HW = hand weeding (hand weeded)

I
I = intermediate
IBPGR = International Board for Plant Genetic Resources
ICRISAT = International Crops Research Institute for the Semi-Arid Tropics
IITA = International Institute of Tropical Agriculture
INSFFER = International Network on Soil Fertility and Fertilizer Evaluation for Rice
INTSOY = International Soybean Program
IPE = isopropyl ester
IPM = integrated pest management
IRAT = Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières
IRCTN = International Rice Cold Tolerance Nursery
IRGC = International Rice Germplasm Center
IRON = International Rice Observational Nursery
IRRSWYN = International Rainfed Rice Shallow Water Yield Nursery
IRSATON = International Rice Salinity and Alkalinity Tolerance Observational Nursery
IRTIP = International Rice Testing and Improvement Program
IRTP = International Rice Testing Program
IRYN-M = International Rice Yield Nursery-Medium
IURON = International Upland Rice Observational Nursery
IURYN = International Upland Rice Yield Nursery

L
LAI = leaf area index
LER = leaf elongation rate
LF = leaffolder
LWP = leaf water potential

M
MC = moisture content
MR = moderately resistant
MS = moderately susceptible
MV = modern variety

N
NBl = neck blast
NBLS = narrow brown leaf spot
NPU = net protein utilization

O
OM = organic matter

P
PE = preemergence
PI = panicle initiation
PR = phosphate rock
PU = prilled urea

R
R = resistant
RB = rice bug
RGA = rapid generation advance
RGS = rice green semilooper
RH = relative humidity
RSV = rice ragged stunt virus
RTBV = rice tungro bacilliform virus
RTSV = rice tungro spherical virus
RTV = rice tungro virus
RWM = rice whorl maggot

S
S = susceptible
SB = stem borer
SCU = sulfur-coated urea
SES = Standard Evaluation System for Rice
ShB = sheath blight
ShR = sheath rot
SMT = soil moisture tension
SR = stem rot
SSB = striped stem borer
SSP = single superphosphate

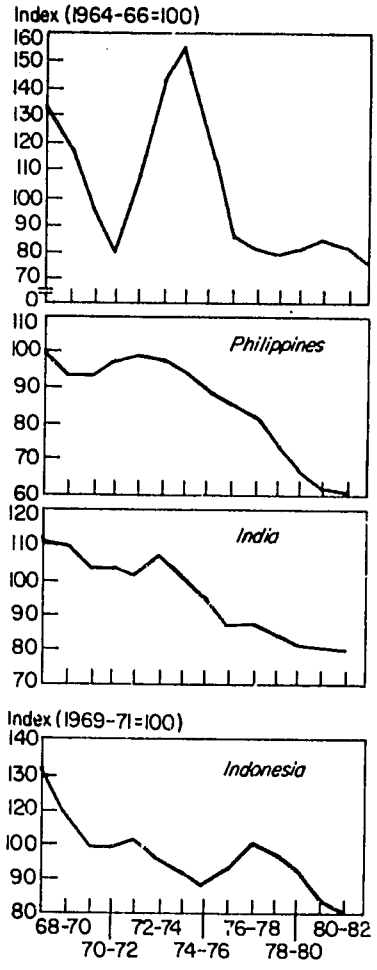
T
TPR = transplanted rice

U
UPLB = University of the Philippines at Los Baños
USG = urea supergranules

W
WAI = weeks after inoculation
WAS = weeks after seeding, sowing
WBPH = whitebacked planthopper
WP = wettable powder
WS = wet season
WSR = wet-seeded rice
WT = weeks after transplanting

Y
YD = yellow dwarf
YSB = yellow stem borer

Research highlights



Trends in real world rice price and in real rice price to consumers in selected, formerly rice importing, countries.

BUILDING NATIONAL PROGRAMS

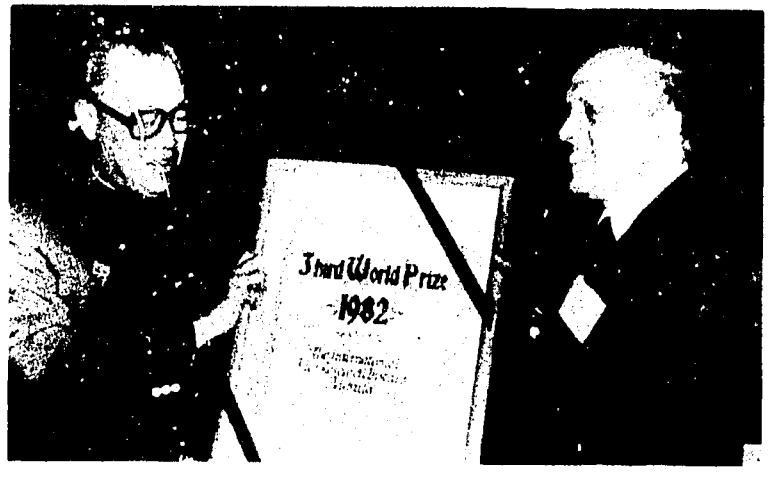
World rice production in 1983 was about 435 million t, 3% more than in 1982 and more than the FAO long-run trend. Production increased in most of Asia, especially in Bangladesh, Burma, China, India, Indonesia, Pakistan, Sri Lanka, and Thailand. Such increases continue the long-term trend of growth in rice production ahead of population. Yields have become the major source of growth, as the 1970s saw further improvements in the MVs first introduced in the mid-1960s. Many traditional rice importing countries have become self-sufficient in rice, and the real price of rice in those countries and the world market has declined. In Latin America production increased slightly, but it declined in Africa.

When Premier Zhao Ziyang of China presented the 1982 Third World Prize to IRRI in April 1983, he described IRRI's role in increasing rice production:

> IRRI has developed many good strains to help developing countries increase rice yield and improve quality. Those strains not only can increase the yield markedly, but also can resist plant diseases and insect pests, shorten the maturing period, and save water. IRRI has made important advances in rice genetics, physiology, and soil science. Its achievements have spread far and wide in the Third World.

In 1983 IRRI worked to strengthen collaborative research with national research systems and other international agricultural research centers, and to magnify the impact of the International Rice Testing Program, the International Network on Soil Fertility and Fertilizer Evaluation for Rice, and the Asian Rice Farming Systems Network.

We also organized collaborative research planning meetings with scientists and institutions in Bangladesh, Burma, China, Egypt, India,



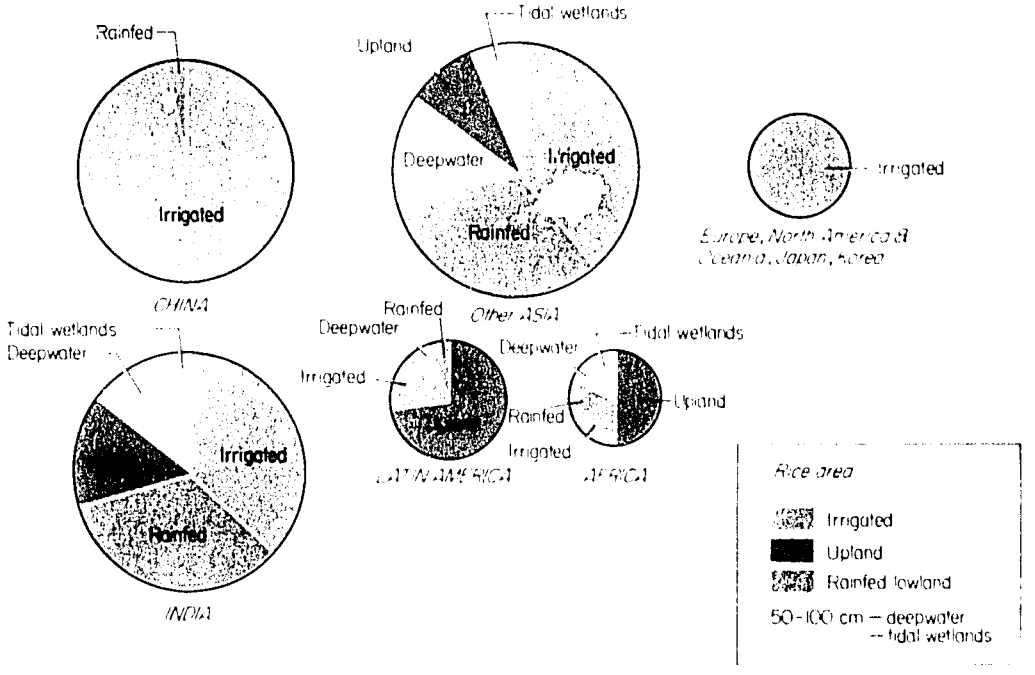
Premier Zhao Ziyang of the People's Republic of China presents the 1982 Third World Prize scroll to Dr. M. S. Swaminathan, IRRI director general.

IRRI scientists joined rice scientists from IITA, Zambia, Zimbabwe, Tanzania, Kenya, and Madagascar to observe rice growing areas of southern and eastern Africa. Here, they are examining rice grown in hydromorphic areas near the Lusaka Agricultural Research Institute, Mansa, Zambia.

Proportional area of rice grown in different cultural systems. IRRI is intensifying efforts to categorize environments and inventory rice growing areas around the world.

Indonesia, Korea, Pakistan, and Thailand. With the Philippine Ministry of Agriculture, we sponsored two technology transfer workshops for extension workers from the 12 agricultural regions of that country.

Collaborative research with national scientists is the foundation for many major research projects. IRRI staff work with national scientists at selected agroclimatic sites where they conduct in depth research using similar methodology, and frequently exchange research results and materials. For example, by comparing the interactions of local BPH populations on 10 selected rice varieties, entomologists in China, India, Indonesia, Sri Lanka, Thailand, and IRRI established that there are at least 4 distinct BPH biotypes. Cultivation of BPH resistant varieties has



Deepwater rice workers take plant samples in Thailand. The Thai Department of Agriculture and IRRI have a long history of cooperation in deepwater and other rice projects.

become the principal method of controlling that insect.

In 1983, in addition to Los Baños staff, IRRI supported 22 scientists in 8 countries. We laid the foundations for a new cooperative program with the Malagasy Republic, brought our team in Egypt up to full strength, and developed closer ties with CIAT, IITA, and WARDA for rice research in Africa and Latin America. In October 1983 the IRRI Board of Trustees visited Malagasy and Tanzania and met in Egypt, where they visited the Rice Research and Training Project, which is a cooperative venture with the Universities of California and Arkansas.

A memorandum of agreement was signed by CIAT, IITA, IRAT, IRRI, and WARDA that established an intercenter coordinating committee for upland rice research. The committee, to be chaired by each center in turn, will promote communication among cooperators by publishing an upland rice newsletter in English with French and Spanish translations. EMBRAPA, a national agricultural research center in Brazil, is also participating.

At the 1983 International Rice Research Conference, we agreed to use an operational classification of rice growing environments that lists major environments as irrigated, rainfed lowland, deepwater, upland, and tidal wetland. Within those five categories are 20 subcategories. Our goal is to sharpen the precision of that system through continued environmental research and cooperation with rice scientists around the world.

In 1983 IRRI signed a memorandum of agreement with Bhutan to train Bhutanese scientists. Site visits and discussions with local farmers are important in all cooperative projects with national programs.

At the request of the Chinese Ministry of Agriculture and the Chinese Academy of Agricultural Sciences, IRRI is assisting in the development of the Chinese National Rice Research Institute at Hangzhou. Our long-term cooperation with the Bangladesh Rice Research Institute, Thai Department of Agriculture, and the Indonesian Central Research Institute for Food Crops continued to yield substantial returns.

In 1983 we signed a memorandum of agreement with Bhutan for training of Bhutanese scientists at IRRI, exchange of genetic materials and research information, collaboration on research projects, and exchange of visits of Bhutanese and IRRI scientists.

As we develop collaborative relationships in more rice growing countries, we continually collaborate in the collection of rice varieties for conservation in the IRRI germplasm bank (renamed in 1983 as the International Rice Germplasm Center). In cooperation with the International Board for Plant Genetic Resources and major national research systems, we developed and immediately implemented a second 5-year plan for germplasm collection, conservation, and utilization (1983-87).

We also strengthened collaborative work with research organizations in developed countries. Joint research, particularly in biotechnology, was initiated with universities and institutions in the Federal Republic of Germany, France, United Kingdom, and the United States. Social science research was intensified in association with the Agricultural University of Wageningen, Netherlands.

Among several seminars, workshops, and conferences sponsored during 1983, two deserve special attention. The Conference on Women in Rice Farming Systems examined the impact of new technologies on

The Conference on Women in Rice Farming Systems examined the role of women in rice farming and stressed their importance in the technology development and transfer process.

IRRI trainees are instructed how to use a knapsack sprayer to apply herbicides.

women-specific operations and sought to identify where and how women can play a greater role in technology development and transfer. The Workshop on Copublication: Strategies for Multilanguage Publication in Agriculture brought together communication specialists from international, national, and commercial organizations to discuss publication and dissemination of agricultural information in the many languages of the developing world.

Our training programs are extremely important in our role of institution building. About 3,500 IRRI-trained scientists work as members of national rice research and development teams. Since IRRI was founded, we have collaborated with the graduate education program of the University of the Philippines at Los Baños. To strengthen training in national programs, we now have similar collaborative arrangements with Cairo University, Egypt; Institut Pertanian Bogor, Indonesia; Universiti Pertanian Malaysia, Malaysia; Central Luzon State University, Philippines; Postgraduate Institute of Agriculture, Sri Lanka; Faizalabad Agricultural University, Pakistan; Kasetsart University, Thailand; Asian Institute of Technology, Thailand; and Cornell University, United States. We are discussing similar agreements with seven other universities.

In addition to graduate training, we conduct several annual short courses. In 1983 we added an Upland Rice Training Course. There are special courses in multilocation testing and varietal screening for upland

crops. To maintain high standards of relevance and excellence in our educational programs, we formed, in 1983, an IRRI Academic Council composed of IRRI staff and outside experts.

Rice scientists and scholars around the world depend on the IRRI communications program and library for current information on rice science. In 1983 the Information Services Department was redesignated the Communication and Publications Department. This change reflects an increasing mandate not only in publishing and providing information support for IRRI scientists but also in institution-building and development of agricultural communication capabilities in national programs.

IRRI released 15 new books in 1983 and distributed about 70,000 copies of major books. Book publishing is self-sustaining; new titles are funded by sales.

IRRI and the German Agency for Technical Cooperation organized the first book exhibit of the international agricultural research centers at the 1983 Frankfurt Book Fair. Seventeen centers displayed about 1,000 titles. The fair attracted more than 500,000 visitors, mostly librarians and book buyers.

In 1983 the Library and Documentation Center published the 1982 supplement to the *International Bibliography of Rice Research*, a 5-year cumulative index to the *Bibliography*, *The International Directory of Rice Workers*, and the *1983 Supplement to Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute*.

The IRRI Communication and Publications Department, in association with GTZ and CGIAR, organized the first book exhibit of the international agricultural research centers at the 1983 Frankfurt Book Fair, the world's largest publication rights market. CGIAR and other international agricultural research centers participated.

The number of books and journals borrowed from the library increased markedly and, as in previous years, requests for copies of Japanese literature on genetics and breeding exceeded those for literature on all other topics.

We acquired 4,106 new volumes, bringing the collection to 66,528 monographs, 196 serial titles, maps, translations, and microfilm. The library continued to purchase and distribute books to IRRI research scholars and other trainees.

Genetic evaluation and utilization (GEU) program

Genetic resources program

International Rice Germplasm Center and Statistics Department

RICE GERMPLASM CONSERVATION WORKSHOP 8
FIELD COLLECTION 8
INTERNATIONAL EXCHANGES 8
INVENTORY, CHARACTERIZATION, AND DATA PROCESSING 9
SEED INCREASE, REJUVENATION, AND DISTRIBUTION 9
PROCESSING SEED FOR MEDIUM- AND LONG-TERM STORAGE 9
COMPUTERIZED DATA MANAGEMENT AND DISSEMINATION 10
ENZYMATIC POLYMORPHISM IN RICE GERMPLASM 10
TRAINING GENETIC STOCK OFFICERS 11

In 1983, the IRRI Genetic Resources Program was reorganized as the International Rice Germplasm Center (IRGC), a global research service, to emphasize its international dimensions. An advisory committee will guide the center's worldwide activities.

RICE GERMPLASM CONSERVATION WORKSHOP

International Rice Germplasm Center

A 2-d workshop on the conservation of rice germplasm was cosponsored by IRRI and IBPGR on 25-26 April. Thirty-five scientists from 21 countries, 9 staff members from 6 other international agricultural research centers and international agencies, and IRRI staff participated.

Progress in field collection from 1977 to 1982 was reviewed and papers on conservation methodology, the wild *Oryza* species, and seed storage equipment for national centers were presented. Interinstitutional collaboration between the United States Department of Agriculture, the National Institute of Agrobiological Resources of Japan, and IRRI was assessed.

The following areas will receive priority:

- completion of land race collection,
- conservation of wild species,
- systematic evaluation and characterization,
- seed storage (primarily medium-term),
- documentation at national centers,
- personnel development,
- security of seed stock under long-term storage, and
- free germplasm exchange.

Participants from South Asia, Southeast Asia, and Africa drafted a 5-yr collection plan and estimated funding requirements. IRRI will continue to coordinate field operations and provide an advisor or field collector. Small-scale collection in Latin America and Oceania will be separately developed.

Copies of the published workshop proceedings were distributed at the XV International Congress of Genetics to celebrate the theme: Genetic conservation — microbes to man.

FIELD COLLECTION

International Rice Germplasm Center

After the workshop, IRRI contacted national program directors of participating countries and heads of international and regional centers to begin action on the 1983 plan. Most countries and centers responded positively.

The IBPGR provided IRRI with an advisor who joined field operations in Bangladesh and Bhutan to participate in national germplasm collection. They assembled 91 varieties from 5 districts of Bangladesh. Canvassing in the high-altitude belt of Bhutan netted 84 varieties, 23 of which grew above 2,000 m.

During the second half of 1983, Burmese cooperators expanded their collections, and three agencies in Thailand concentrated on collecting upland hill rices.

Since the first 5-yr plan, formulated at the 1977 Workshop, 12,657 seed samples have been added to IRGC with IRRI participating in field canvassing and collection of 3,038. Workers in 10 Asian countries gathered 9,619 samples, often with financial and technical aid from IRRI and IBPGR (Table 1).

INTERNATIONAL EXCHANGES

International Rice Germplasm Center

Many countries continue to deposit their old and new rice germplasm in the IRGC seed vaults for safekeeping and use. During 1983, IRGC received 3,873 samples from these major donors:

National and state centers

- Bangladesh Rice Research Institute — 97 varieties.
- Bhutan Department of Agriculture — 88 varieties.
- Fujian Province, China — 541 varieties.
- Fiji — 22 varieties.
- Orissa University of Agriculture and Technology, India — 68 varieties.
- Indonesia — 68 samples collected by anthropologists and missionary and service volunteers.
- Zimbabwe — 83 varieties collected by the Royal Botanical Garden, Kew, UK.
- Philippines — 62 varieties.
- Thailand Ministry of Agriculture and Cooperatives — 1,184 varieties.

Table 1. Indigenous rice varieties collected with direct or indirect IRRI participation in 14 collaborating countries, 1978 to 1983.

Country	Years	Indigenous varieties collected (no.) with IRRI's	
		Direct participation	Indirect participation
Bangladesh	1978-83	703	306
Bhutan	1981-83	185	5
Burma	1981, 1983	561	21
India	1981-83	–	1939
Indonesia	1978-83	738	632
Kampuchea		–	–
Laos		–	–
Malaysia	1979-82	–	538
Nepal	1978-82	–	1042
Pakistan	1982	–	4
Philippines	1978-83	238	1710
Sri Lanka	1978-80, 1982	613	146
Thailand	1979-83	–	3276
Vietnam		–	–
	Total	3038	9619

Other international or regional centers

- IITA, Nigeria — 108 *O. glaberrima* accessions.
- IRAT, France — 14 varieties.

The IRTP furnished 451 promising international nursery entries from 20 countries.

Replacement samples also were obtained for 835 accessions which had become nonviable during storage before the projected longevity expired.

INVENTORY, CHARACTERIZATION, AND DATA PROCESSING

International Rice Germplasm Center and Statistics Department

At the end of 1983, the IRGC had registered 63,490 accessions of *O. sativa*, 2,826 accessions of *O. glaberrima*, 1,200 populations of wild species, and 691 genetic testers and mutants. About 5,038 recently received seed samples await initial planting and seed increase. During the past 12 yr, more than 14,780 additional seed samples were not counted as registered accessions because the seeds either did not germinate or were obvious duplicates.

During 1983, IRGC systematically described morphoagronomic traits of 4,090 accessions in the field and completed laboratory measurements of panicle and grain characters on 2,322 accessions. By the end of the year, field records of 62,998 accessions had been made, but only 47,421 accessions were completely characterized because of shortage in laboratory personnel.

Computerized files now contain data on 59,343 accessions of *O. sativa*.

SEED INCREASE, REJUVENATION, AND DISTRIBUTION

International Rice Germplasm Center

In DS, 4,104 plots were grown for initial seed increase and 7,868 accessions were rejuvenated to provide seed for canning. In the WS, 4,090 plots were planted for characterization and 6,447 accessions were rejuvenated. About 60% of the plantings during 1983 were moved to a 5.1-ha rented farm in Barrio Masapang, Victoria, Laguna Province. The farm produced more and cleaner seeds because it has less insect and disease pressure than the IRRI farm.

As one of its primary functions, IRGC continued to supply seed to rice researchers throughout the world. In response to 150 requests, it sent 3,756 seed samples of *O. sativa* to foreign researchers. In response to 287 requests within IRRI, it furnished 28,443 samples for GEU tests. It distributed 814 samples of African rices and wild species in response to 58 requests. The total number of seed samples supplied in 1983 was slightly less than the average of the last 5 yr although the number of requests was comparable (Table 2).

National center and IRRI field collectors have assembled a large collection of traditional cultivars locally known to have special characteristics. IRRI's GEU scientists receive seeds for evaluation soon after completion of the initial cycle of seed multiplication. During 1983, the total number of special types rose to 9,464.

PROCESSING SEED FOR MEDIUM- AND LONG-TERM STORAGE

International Rice Germplasm Center and Statistics Department

Vacuum-packing rice seeds in aluminum cans for medium- and long-term storage began in mid-1980. By the end of 1983, 14,458 of the 48,758 accessions grown for this purpose had been packed. In 1983, 5,125 accessions were canned, 2,087 more than in 1982.

Table 2. Progress in the preservation and distribution of seed of *Oryza sativa* cultivars at the International Rice Germplasm Center, 1973 to 1983.

Year	Distinct accessions in germplasm bank	Requests received (no.) from		Samples supplied (no.) to	
		IRRI	National programs	IRRI	National programs
1973	24,162	66	95	8,275	9,777
1974	26,818	108	83	20,498	2,603
1975	30,332	151	150	22,155	4,043
1976	34,229	194	137	40,200	4,819
1977	36,956	196	148	50,354	4,126
1978	40,768	182	142	31,941	7,316
1979	47,743	268	157	26,694	3,260
1980	53,431	337	156	29,734	3,659
1981	57,027	319	206	29,053	4,376
1982	60,181	279	154	33,975	11,075
1983	63,490[a]	287	150	28,443	3,756

[a]About 5,038 recently received seed samples are still to be grown and registered; 9,831 duplicate accessions and 4,950 nonviable seed samples were removed from the registry during 1973-83.

When an accession has produced sufficient seed for canning, a second 30-g seed lot is sealed in aluminum-foil envelope and sent to the U.S. National Seed Storage Laboratory in Ft. Collins, Colorado. This duplicate storage increases the collection's security. During 1983, 3,891 duplicates were processed. Records on seed rejuvenation and canning were entered in the computerized files.

COMPUTERIZED DATA MANAGEMENT AND DISSEMINATION

Statistics Department and International Rice Germplasm Center

The year 1983 saw a significant rise in the use of the computerized data retrieval system in locating appropriate accessions by rice researchers at IRRI and from national and international research organizations. Most frequently requested traits are early maturity, resistance to blast, tolerance to cool temperatures, flood tolerance, drought resistance and tolerance to acid soils. Frequently, a clear specification of desired traits does not accompany the request for seeds. In such cases, one or more lists of retrieved accessions, with their associated information, were sent to the requesting scientist.

For each seed request for screening purposes received from IRRI's GEU scientists, a computer-generated data sheet is produced. The data sheet contains accession number, name, and origin as well as column headings for traits to be screened. This procedure facilitates seed preparation by IRGC staff, data gathering by GEU staff, and encoding the computerized data. More importantly, it ensures data accuracy, especially of accession number and name entered in the IRGC master file.

In the last quarter of 1983, the Interactive Germplasm Bank Information Retrieval system was installed at the newly established IRRI Computer Center (IBM 4331). The system provides speedier information retrieval and allows IRRI researchers wider access to the system.

ENZYMATIC POLYMORPHISM IN RICE GERMPLASM

International Rice Germplasm Center

Isozymes provide convenient marker genes to study the genetic structure of a species and have potential in breeding programs.

A simple method to analyze the enzymatic polymorphism of Asian cultivars was developed. Two to five plants of a given variety were individually analyzed. Proteic extracts were prepared from the plumule and coleoptile of seedlings a few days after germination. The proteins were separated by electrophoresis in starch gels and 10 enzymes were studied. Fifteen polymorphic genes having two to eight alleles per locus were identified (Table 3).

To represent Asian diversity, 1,161 varieties

were chosen from 21 countries (Table 4), with particular attention to local varietal groups and crop environments.

Simple data analysis produced a discriminant axis that accounts for the main part of the variability. The distribution of the varieties along the axis (Fig. 1) shows two major groups with few intermediates.

The first group, having negative scores, embraces tropical varieties, such as the *hsien* rices from China, the *cere* rices from Indonesia, and the *aman* rices from Bangladesh and northeastern India. It coincides with the *indica* group.

The second group, having positive scores, comprises temperate varieties such as those from Japan and Korea, the Chinese *keng* rices, and most high elevation rices in the Himalayas. It also includes tropical rices such as the Indonesian *bulu* and most Southeast Asian upland rices.

Two rice families, each defined by the presence of a particular allele, are noteworthy (Fig. 1).

The first family includes the *aus* rices from Bangladesh and northeastern India and some others from Nepal, Pakistan, Afghanistan, and Iran. Within this distribution, the *aus* rices have the lowest scores on the discriminant axis while the others have scores near zero.

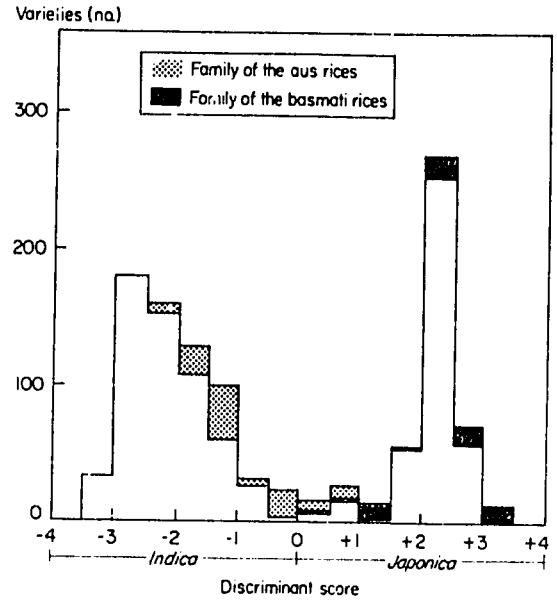
The second family covers most of the aromatic rices from northwestern India, Pakistan, and Iran, including Basmati rices. Many of these fall into the second overall classification group, but some are intermediate.

Table 3. Enzymes studied and marker genes identified in Asian cultivars.

Enzyme	Loci (no.)	Alleles (no.)/locus
Catalase	1	3
Shikimate dehydrogenase	1	5
Phosphoglucose isomerase	2	2, 6
Alanine aminopeptidase	1	5
Arginine aminopeptidase	1	5
Leucine aminopeptidase	2	8, 4
Alcohol dehydrogenase	1	3
Esterase	4	2, 2, 2, 3
Acid phosphatase	1	2
Isocitrate dehydrogenase	1	3

Table 4. Origin of varieties chosen to represent Asian diversity.

Origin	Varieties (no.)
Afghanistan	17
Bangladesh	59
Bhutan	34
Burma	88
China	142
India	234
Indonesia	102
Iran	34
Japan	33
Kampuchea	13
Korea	31
Laos	30
Malaysia	48
Nepal	42
Pakistan	47
Philippines	26
Sri Lanka	33
Taiwan	57
Thailand	49
Vietnam	42



1. Histogram showing the score distribution for 1,161 varieties on an axis given by the analysis of allelic combinations of 15 genes coded for 10 enzymes.

TRAINING GENETIC STOCK OFFICERS

International Rice Germplasm Center

IRRI continued to provide short-term training on rice genetic resources management. The trainees were responsible for maintaining local rice collections at their home stations. One scientist from Senegal spent 6 mo with the staff of the germplasm bank to learn about different aspects of genetic

conservation. Two staff members from the Rice Research Institute of Thailand stayed 1 mo to observe the laboratory management of conserved accessions. Two Vietnamese scientists spent the last 2 mo of 1983 studying seed technology and production techniques.

Genetic evaluation and utilization (GEU) program

Agronomic and physiological characteristics

Agronomy and Plant Physiology Departments and International Rice Germplasm Center

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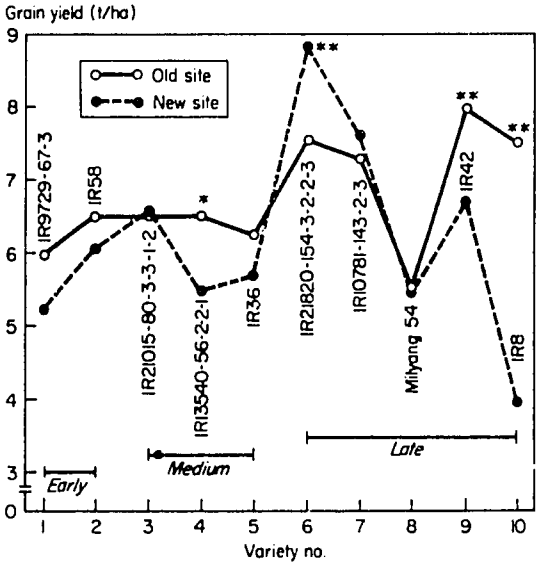
MAXIMUM YIELD EXPERIMENT

Agronomy Department coordinating

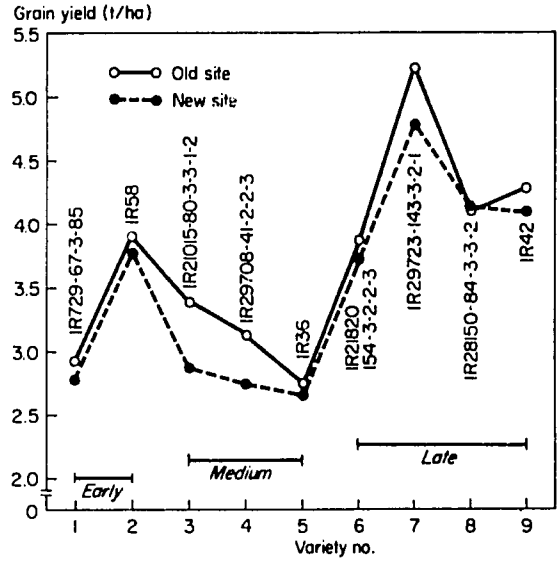
Ten varieties representing three maturity groups received corresponding N rates. The first N application was deep-placed USG with subsequent PU topdressings as required. Planting dates were staggered for a uniform ripening period at two IRRI sites.

In DS, IR21820-154-3-2-2-3 yielded highest (8.88 t/ha) at the lowest N rate in its maturity group at the new site (Fig. 1), significantly higher than others tested. N rate increase did not increase yield significantly in either site except for IR58 at the old site. Most maximum yields came from the lowest N rates. The mean yield for the old site was higher (6.45 vs 5.92 t/ha). IR13540-56-3-2-1 and IR21820-154-3-2-2-3 were most susceptible to lodging at higher N rates, especially at the new site. Here, hopperburn lowered IR8 yield.

During WS, late maturing IR29723-143-3-2-1 consistently yielded highest at both sites at the lowest N rate (Fig. 2). IR58 yielded highest among early varieties and IR21015-80-3-3-1-2 among the medium-maturing varieties. Except for IR42, which yielded more at 88 kg than at 59 kg N/ha at both sites, varieties had either negative or flat response to N. Each variety yielded equally at both sites, but RTV was moderately severe in IR42 and severe in IR8.



1. Highest yields at lowest dose of N (except for IR58 where yield at the highest dose was used) at 2 IRRI sites. IRRI maximum yield experiment, 1983 DS.



2. Highest yields at 2 IRRI sites. IRRI maximum yield experiment, 1983 WS.

YIELD PERFORMANCE AND NITROGEN RESPONSE OF VARIETIES AND SELECTIONS

Agronomy Department

Irrigated rice. Yield performance of IR varieties and promising lines were evaluated at IRRI, in a farmer's field in Laguna Province, and at Philippine Bureau of Plant Industry (BPI) stations in Bicol, Iloilo, and Nueva Ecija. Rices were tested at different N levels with WS application lower than DS.

IRRI. Table 1 shows the response of 42 rices to 5 N levels. In DS, IR13540-56-3-2-1 and IR28128-45-2 produced the highest yields at high N rate and also at low N rate.

Without fertilizer N, 5 promising lines yielded 4.0 t/ha or more while most early-maturing lines yielded below 3.0 t/ha. IR28128-45-2 outyielded all test varieties and lines.

All yields during WS were low compared to those in DS (Table 1). IR13525-43-2-3-1-3-2 gave the highest WS yield of 4.8 t/ha. IR19672-140-2-3-2-2 and IR25604-99-1-3-2-2 yielded 3.2 t/ha without N fertilizer.

Table 1. Yield of IRRI varieties and promising lines at 5 N levels (0-150 kg N/ha) in irrigated plots. IRRI, 1983.[a]

Variety or line	DS						WS					
	Duration (d)	Yield (t/ha)					Duration (d)	Yield (t/ha)				
		0	60	90	120	150		0	30	60	90	120
IR8[b]	148	1.8	2.0	3.6	2.7	2.6	137	1.5	1.6	1.9	1.5	2.0
IR20	119	2.0[c]	3.5	3.9[c]	4.6[c]	4.5[c]		d	d	d	d	d
IR36	107	2.4	4.3	4.6	5.1	5.2	118	2.4	3.1	3.6	4.0	4.4
IR42	148	3.4	3.6	4.1	5.8	5.3	137	2.9	2.9	4.4	4.2	4.4
IR9729-67-3	100	1.5	2.6	3.0	4.1	4.4	113	2.8	3.4	4.3	4.3	4.1
IR13429-299-2-1-3-1 (IR60)	100	2.2	3.7	4.1	4.9	5.2	—	—	—	—	—	—
IR13525-43-2-3-1-3-2	107	2.7	4.4	5.6	5.4	5.3	125	2.5	3.4	3.8	4.5	4.8
IR13540-56-3-2-1	119	3.5	5.5	6.3	6.5	6.1	127	2.8	3.6	3.8	4.2	4.5
IR18350-175-2-3	106	2.8	5.0	6.0	6.4	6.3[e]	—	—	—	—	—	—
IR19672-140-2-3-2-2	136	1.7	3.3	3.1	4.5	4.7	133	3.2	3.9	4.4	4.4	3.9
IR19672-155-2-1-1-3	—	—	—	—	—	—	133	2.8	3.9	3.9	4.2	3.3
IR21015-80-3-3-1-2	106	2.5	4.8	5.5	5.8	5.9	125	2.8	3.4	3.9	4.7	4.1
IR21820-154-3-2-2-3	107	2.4	4.0	3.5	4.6	5.3	127	3.0	3.9	4.3	4.3	4.7
IR21848-65-3-2-2	107	2.4	4.5	4.9	5.3	5.3	128	2.4	3.7	3.8	4.0	3.1
IR22082-41-2	119	3.5	4.8	5.2	6.2	6.0	—	—	—	—	—	—
IR24637-38-2-2-1	106	3.4	4.2	5.5	5.8	5.8	—	—	—	—	—	—
IR25560-132-2-3	107	2.2	3.7	4.8	4.8	5.9	—	—	—	—	—	—
IR25587-133-3-2-2-2	—	—	—	—	—	—	133	2.9	3.8	4.2	4.1	4.1
IR25588-7-3-1	119	3.7	4.8	6.4	5.9	6.0	107	2.3	3.2	3.2	4.6	4.1
IR25603-20-2-1-3-2	119	2.3	4.5	5.1	5.4	5.7	—	—	—	—	—	—
IR25604-99-1-3-2-2	—	—	—	—	—	—	128	3.2	3.8	4.2	4.7	4.3
IR25621-135-1-1	—	—	—	—	—	—	113	2.4	3.3	4.0	4.5	4.0
IR25861-64-3-2	129	2.8	4.7	5.6	5.6	5.7	—	—	—	—	—	—
IR25890-82-5-3	129	4.1	5.2	5.2	5.4	6.2	—	—	—	—	—	—
IR25924-51-2-3	129	4.0	5.0	5.8	6.3	6.4	—	—	—	—	—	—
IR25924-92-1-3	134	4.1	4.4	4.8	5.3	5.9	—	—	—	—	—	—
IR27316-96-3-2-2	—	—	—	—	—	—	128	2.8	3.5	4.0	4.0	4.2
IR27325-63-2-2	119	4.0	5.2	6.3	6.2	6.3	—	—	—	—	—	—
IR28128-45-2	136	4.4	5.6[e]	5.9	6.5	6.0	—	—	—	—	—	—
IR28150-84-3-3-2	—	—	—	—	—	—	128	2.4	3.3	3.6	3.9	3.8
IR28178-111-1-2-3	—	—	—	—	—	—	127	f	3.3	4.0	4.0	4.3

Continued on next page

Table 1 continued

Variety or line	DS						WS					
	Duration (d)	Yield (t/ha)					Duration (d)	Yield (t/ha)				
		0	60	90	120	150		0	30	60	90	120
IR28210-96-4-3-3	136	3.2	4.0[e]	4.4	5.2	5.6	–	–	–	–	–	–
IR29512-81-2-1	136	3.9	5.3	5.7[e]	6.1	5.7	–	–	–	–	–	–
IR29692-65-2-3	134	3.1	5.4	5.6[e]	5.4	5.0	106	2.3	3.2	3.1	3.9	3.6
IR29692-94-2-1-3	–	–	–	–	–	–	106	2.3	3.4	3.8	4.1	3.2
IR29692-99-3-2-1	–	–	–	–	–	–	107	2.8	2.7	3.2	3.7	3.3
IR29708-41-2-2-3	–	–	–	–	–	–	113	2.5	3.0	3.8	3.9	4.1
IR29723-143-3-2-1	–	–	–	–	–	–	137	3.0	3.9	4.2	4.6	4.6
IR29725-3-1-3-2	–	–	–	–	–	–	113	2.4	2.9	2.7	3.4	3.8
IR29725-22-3-3-3	–	–	–	–	–	–	113	2.7	2.7	3.8	3.7	4.1
IR31917-31-3-2	–	–	–	–	–	–	137	2.9	3.4	4.0	4.0	4.0
Peta[g]	147	2.5	2.2	2.0	2.1	1.0	142	1.6	1.5	2.1	1.3	1.5

[a]Av of 3 replications. Each treatment includes 30 kg N/ha topdressed 5-7 DBPI in DS and 10 kg N/ha topdressed 5-7 DBPI in WS. – = not tested. [b]Infected with RTV and RSV. [c]Infested with BPH. [d]No harvest due to hopperburn. [e]Lodged in 1 replication. [f]Missing data. [g]All plots lodged, some with bird damage.

Among early-maturing varieties, IR25588-7-3-1 yielded 4.6 t/ha at 90 N.

Farmer's field. With low insect and disease infestation, IR8 can yield more than other MVs. During DS, IR8 yielded 6.8 t/ha, more than all other varieties in all N levels. Yield was 4.2 t/ha without N fertilizer (Table 2).

In WS, IR21820-154-3-2-2-3 gave the highest yield, but IR42 outyielded it and other MVs without N. Most entries show minimal yield response to increasing N levels.

BPI stations. Four varieties and 13 promising breeding lines were evaluated at BPI stations in Maligaya, Bicol, and Visayas.

At Maligaya during DS, all entries except IR9729-67-3 and Peta yielded 7.0 t/ha or more at one or more N levels (Table 3). IR8 had the highest, 8.2 t/ha at 90 kg N/ha. IR21820-154-3-2-2-3 and IR22082-41-2 yielded 8.0 t/ha. IR21820-154-3-2-2-3 appeared outstanding compared with other promising lines and had better N response at lower rates.

In WS, yield increase for most varieties and lines was from 30 to 60 kg N/ha. Only IR19672-140-2-3-2-2 yielded 6.0 t/ha. Six promising lines and IR42 had comparable yields at zero N.

At Bicol during DS, promising lines had comparable or better yields than named IR varieties at zero N (Table 4). Five lines yielded more than 7.0 t/ha. IR21820-154-3-2-2-3 yielded highest at 7.9 t/ha with 150 kg N/ha.

During WS, heavy rainfall caused severe lodging in plots with applied N, and BLB affected most entries. Therefore, yield response to applied N was low. Breeding lines IR13525-43-2-3-1-3-2, IR28150-84-3-3-2, IR29708-41-2, IR29723-88-2-3-3, and IR9729-67-3-85 yielded more than named varieties at zero N.

The experiment in the Visayas began in DS but was abandoned at PI because of lack of irrigation water. In WS, yield at zero N was high (Table 5). Most varieties and lines increased yield with 30 kg N/ha.

Rainfed rice. *IRRI.* Four IR varieties and eight promising lines were evaluated at five N levels. IR42 was eliminated during maximum tillering because of severe infestation of RTV and GSV. RSV and ShR reduced IR46 yields.

A promising new line, IR32809-26-3-3, yielded 4.9 t/ha at 90 kg N/ha, the highest recorded yield in

Table 2. Yields of IR varieties and promising lines at 4 N levels (0-150 kg/ha) on an irrigated farm, Laguna, Philippines, 1983.[a]

Variety or line	DS yield (t/ha)				WS yield (t/ha)			
	0	50	100	150	0	40	80	120
IR8	4.2	5.6	5.8	6.8	3.9	4.2	5.0	5.1
IR36	3.5	3.5	3.6	5.7	3.1	4.0	4.2	4.5
IR42	3.5	4.8	5.7	5.4	4.1	4.1	5.0	5.2
IR13429-299-2-1-3-1	3.6	5.0	5.3	5.1	–	–	–	–
IR13525-43-2-3-1-3-2	3.8	4.7	5.7	5.0	3.5	4.6	4.6	5.0
IR19672-140-2-3-2-2	3.7	5.1	5.6	6.0	3.5	4.6	4.3	4.9
IR19672-155-2-1-1-3	–	–	–	–	3.7	4.8	4.8	4.8
IR21820-154-3-2-2-3	–	–	–	–	3.9	4.8	5.0	5.5
IR21848-65-3-2-7	–	–	–	–	3.5	3.9	4.4	5.2
IR22082-41-2	3.2	4.4	5.2	5.2	–	–	–	–

[a]Av of 3 replications. Each treatment includes 20 kg N/ha topdressed 5-7 DBPI in both seasons.

the same plot for the last 5 yr. The same line outyielded all MVs tested except at zero N (Table 6).

Yields of early-maturing line IR9729-67-3-85 were low compared to those of medium-maturing lines.

IR42. In the last 8 yr, IR42 without N fertilizer yielded higher than other MVs in DS and WS in 4 experimental sites.

SOURCES OF SEMIDWARFISM

International Rice Germplasm Center

New sources of semidwarfing genes among recent IRGC accessions were evaluated to determine whether they have an identical gene for semidwarfism, and to identify new promising sources to broaden the genetic base of MVs. Every new semidwarf was crossed with one of the IR varieties carrying sd_1, the gene derived from Dee-geo-woo-gen.

Sources identified were Chai-yeh-ching, Tung-ting-wan-hsien 1, Kwang-er-ai 5, and China 1039 mutant from PROC; M401, M302, and Calmochi 202 from California; Pulut Unggul from Indonesia; and Dwarf B. Theega, Dwarf J. Sanna, and Dwarf Jenugudu from the University of Agricultural Sciences, Bangalore, India.

PREPARATION OF *ORYZA* POLLEN GRAINS FOR THE SCANNING ELECTRON MICROSCOPE

Plant Physiology Department

Oryza pollen grains have almost uniform morphological features. They are usually spheroid or ovoid having a single aperture with a conspicuous operculum at or near its center. The scanning electron microscope (SEM) was used to resolve different descriptions of the rice pollen grain surface. Different tests used pollen grains of six *Oryza* species to ascertain the best sample preparation for SEM to show surface sculpture well.

These treatments were used:

A. Pollen collection and preservation.
   - A1. Anthers and pollen grains air-dried.
   - A2. Anthers and pollen grains fixed in Carnoy's fluid 2-3 h and transferred to 70% ethanol.
   - A3. Samples fixed in 4% glutaraldehyde for 16 h (0-4° C) then washed with phosphate buffer 1 or 2 times and stored in the same solution.
   - A4. Pollen grains placed in vial and refrigerated.

B. Pollen grain cleaning or dehydrating after treatment A.
   - B1. Sample placed in acetolysis mixture (9 parts acetic anhydride and 1 part sulfuric acid) and heated in water bath (100° C) for 1 min, then washed with distilled water 3-4 times and air-dried.
   - B2. Sample washed with glacial acetic acid, then with distilled water 3 times, and air-dried.
   - B3. Sample dehydrated serially by different concentrations of ethanol.
   - B4. Untreated pollen grains were spread on double sticky tape directly from anthers.

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, Muñoz, Nueva Ecija, Philippines, 1983 DS and WS.

Variety or line	DS							WS						
	Duration (d)	Yield (t/ha)						Duration (d)	Yield (t/ha)					
		0	60	90	120	150	180		0	30	60	90	120	150
IR8	132	5.1	5.7	8.2	7.3	7.8	7.4	129	4.3	4.2	4.8	3.9	3.9	4.4
IR20	118	3.9	5.8	6.3	7.3	7.7	7.8	129	4.4	4.9	4.5	4.7	4.7	4.1
IR36	112	4.0	6.7	7.8	7.6	6.8	6.7	117	4.3	5.1	5.3	5.1	5.4	4.7
IR42	132	4.3	6.8	7.7	7.1	6.8	7.7	133	4.8	5.0	5.7	5.8	5.8	5.3
IR9729-67-3	104	3.8	4.6	6.3	6.9	6.9	6.5		–	–	–	–	–	–
IR9729-67-3-85		–	–	–	–	–	–	110	4.0	3.9	4.0	3.2	3.2	2.3
IR13429-299-2-1-3-1 (IR60)	104	3.8	6.0	6.4	7.4	7.0	7.2		–	–	–	–	–	–
IR13525-43-2-3-1-3-2	112	4.3	6.5	7.2	7.3	6.4	7.0	122	4.8	5.3	5.5	4.9	5.7	5.0
IR13540-56-3-2-1	112	4.1	6.9	7.6	7.6	6.4	6.2	123	5.0	5.0	4.8	5.2	5.4	3.8
IR18350-175-2-3	112	3.1	5.4	7.1	6.7	7.0	6.4		–	–	–	–	–	–
IR19672-140-2-3-2-2	132	4.4	6.6	7.6	7.6	7.3	7.1	133	4.8	5.0	5.3	6.0	5.6	4.0
IR19672-155-2-1-1-3		–	–	–	–	–	–	133	5.1	4.6	4.9	5.2	4.6	4.6
IR21015-80-3-3-1-2	118	4.3	6.6	7.8	7.7	7.7	7.9	122	4.3	4.7	4.9	5.0	5.1	4.4
IR21820-154-3-2-2-3	125	4.0	7.5	8.0	7.8	7.6	7.0	129	4.8	5.4	5.3	5.0	4.9	4.4
IR21848-65-3-2-2	132	4.1	5.7	7.1	6.8	6.7	7.2	129	4.2	4.5	5.1	4.9	4.8	4.5
IR22082-41-2	125	4.3	6.1	6.8	7.2	7.2	8.0		–	–	–	–	–	–
IR25588-7-3-1	109	4.2	6.6	7.3	7.7	7.5	6.9	110	3.7	3.9	4.1	4.2	3.5	4.0
IR25924-51-2-3	109	4.0	5.1	7.0	7.3	6.9	7.2		–	–	–	–	–	–
IR28128-45-2	109	3.8	5.1	6.6	7.3	7.1	6.7		–	–	–	–	–	–
IR28150-84-3-3-2		–	–	–	–	–	–	122	4.7	4.7	5.2	5.3	5.2	5.3
IR29692-65-2-3-3		–	–	–	–	–	–	110	2.6	3.0	2.6	2.9	2.6	2.8
IR29708-41-2		–	–	–	–	–	–	110	4.1	3.9	4.0	4.4	3.7	3.7
IR29723-88-2-3-3		–	–	–	–	–	–	133	4.8	5.4	5.5	5.6	5.4	5.2
Peta (traditional check)	136	4.0	4.1	4.4	3.6	3.7	3.6	133	3.7	3.3	2.2	2.6	2.5	2.2

[a]Each treatment included 20 kg N/ha topdressed 5-7 DBPI in both seasons.

Table 4. Yields of IRRI varieties and promising lines at 6 N levels[a] (0-180 kg/ha) in irrigated plots. Bicol Experiment Station, Pili, Camarines Sur, Philippines, 1983 DS and WS.

Variety or line	DS							WS						
	Duration (d)	Yield (t/ha)						Duration (d)	Yield (t/ha)					
		0	60	90	120	150	180		0	30	60	90	120	150
IR8	133	1.7	1.8	4.0	2.9	4.0	3.0	125	2.4	3.2	3.3	3.9	1.9	2.3
IR20	115	3.4	5.2	6.2	6.6	6.2	3.2	123	2.3	4.8	3.6	3.5	3.1	3.6
IR36	102	2.9	4.9	6.1	6.5	5.8	4.9	107	3.8	3.3	3.6	2.4	2.8	2.7
IR42	138	2.6	5.2	4.9	3.8	4.7	4.7	132	3.5	4.3	5.4	4.8	4.0	3.7
IR9729-67-3	96	3.4	4.4	5.9	5.8	5.8	5.1		–	–	–	–	–	–
IR9729-67-3-85		–	–	–	–	–	–	100	4.0	3.4	3.5	3.8	3.0	2.6
IR13429-299-2-1-3-1 (IR60)	105	4.2	4.8	6.1	6.6	6.4	5.6		–	–	–	–	–	–
IR13525-43-2-3-1-3-2	107	4.3	5.5	6.5	5.8	5.9	4.9	111	4.2	4.2	3.4	3.0	2.4	2.5
IR13540-56-3-2-1	105	3.8	5.5	5.1	6.0	6.9	5.8	112	3.8	4.5	4.8	3.1	3.2	2.1
IR18350-175-2-3	105	3.7	4.6	6.7	5.7	6.6	6.4		–	–	–	–	–	–
IR19672-140-2-3-2-2	108	3.4	4.6	6.2	5.8	5.8	6.8	132	2.9	5.1	4.8	5.2	4.9	3.4
IR19672-155-2-1-1-3		–	–	–	–	–	–	127	3.1	4.5	5.3	4.1	2.9	2.7
IR21820-154-3-2-2-3	114	4.3	6.1	6.7	6.2	7.9	6.0	118	3.0	5.7	3.2	2.3	2.9	2.5
IR21828-65-3-2-2	120	3.1	3.5	4.1	3.8	4.9	5.3	125	3.7	3.9	3.6	3.2	3.6	2.2
IR22082-41-2	122	4.2	5.9	7.3	6.2	7.7	7.6		–	–	–	–	–	–
IR25588-7-3-1	105	4.3	5.2	7.1	6.8	7.1	6.4	100	3.6	4.0	3.7	3.8	3.7	3.2
IR25924-51-2-3	105	3.9	5.3	6.4	5.3	6.6	7.6		–	–	–	–	–	–
IR28128-45-3	133	4.6	6.0	7.2	5.9	6.6	6.1		–	–	–	–	–	–
IR28150-84-3-3-2		–	–	–	–	–	–	125	4.5	5.2	4.8	4.9	4.3	4.4
IR29692-65-2-3-3		–	–	–	–	–	–	100	2.5	3.9	4.2	3.9	4.3	3.1
IR29708-41-2		–	–	–	–	–	–	100	4.0	4.5	5.0	4.8	3.7	3.6
IR29723-88-2-3-3		–	–	–	–	–	–	125	4.2	5.2	3.8	4.6	2.6	2.7
Peta (traditional check)		–	–	–	–	–	–	142	4.2	2.6	1.9	1.9	1.8	1.7

[a]Each treatment included 20 kg N/ha topdressed 5-7 DBPI in both seasons.

Table 5. Yields of IRRI varieties and promising lines at 6 N levels[a] (0-180 kg/ha) in irrigated plots. Visayas Experiment Station, Jaro, Iloilo, Philippines, 1983 WS.

Variety or line	Duration (d)	Yield (t/ha)					
		0	30	60	90	120	150
IR8	124	5.8	6.2	5.9	5.8	5.0	4.0
IR20	112	4.7	5.2	4.7	3.3	3.2	2.7
IR36	103	5.9	6.6	6.6	6.3	5.9	5.4
IR42	126	5.7	5.9	5.3	4.1	3.5	6.1
IR9729-67-3-85	94	4.5	4.7	4.2	4.0	2.8	3.3
IR13525-43-2-3-1-3-2	110	6.9	7.2	5.7	5.7	4.5	4.6
IR13540-56-3-2-1	110	5.2	4.9	4.0	3.9	3.8	3.9
IR19672-140-2-3-2-2	118	4.9	5.1	5.1	5.4	5.4	4.6
IR19672-155-2-1-1-3	122	4.5	5.2	4.5	3.8	3.4	2.9
IR21015-80-3-3-1-2	110	5.7	6.2	4.7	3.9	3.5	2.8
IR21820-154-3-2-2-3	118	5.8	6.3	5.0	3.9	3.5	3.4
IR21848-65-3-2-2	118	4.9	5.2	4.6	4.3	3.0	3.0
IR25588-7-3-1	103	6.7	6.8	6.5	6.6	5.7	5.2
IR28150-84-3-3-2	118	6.3	6.3	6.7	5.4	4.8	5.2
IR29692-65-2-3-3	94	3.6	3.9	3.3	3.4	2.4	2.1
IR29708-41-2	94	5.6	6.0	5.9	5.4	5.2	5.4
IR29723-88-2-3-3	124	6.5	5.5	5.7	3.9	3.4	3.7
Peta (traditional check)	132	3.6	3.6	2.9	2.9	2.9	2.5

[a]Each treatment included 20 kg N/ha topdressed 5-7 DBPI.

Table 6. Yield of IR varieties and promising lines at 5 N levels (0-120 kg/ha) on rainfed farms.[a] IRRI, 1983 WS.

Variety or line	Yield (t/ha)				
	0	30	60	90	120
IR36	1.8	2.2	2.7	2.7	2.9
IR42	–	–	–	–	–
IR46	2.5	2.8	3.0	2.6	3.2
IR58	1.9	3.1	3.1	3.5	4.0
IR9729-67-3-85	1.9	2.0	3.4	2.6	2.3
IR21015-80-3-3-1-2	3.4	3.3	3.8	4.0	3.6
IR21820-154-3-2-2-3	3.4	3.2	4.5	3.7	3.6
IR21848-65-3-2-2	3.5	3.4	4.3	4.5	3.8
IR24637-207-3-2-3-2-2	2.5	3.1	3.5	3.2	3.1
IR29506-60-3-3-2	2.8	3.5	3.8	3.4	3.3
IR32809-26-3-3	3.5	4.1	4.7	4.9	4.4
IR32819-37-3-2	2.9	3.0	3.5	3.7	3.5

[a]Av of 3 replications. Each treatment included 20 kg N/ha topdressed 5-7 DBPI. – = completely damaged by RTV.

C. Critical point drying after treatments A and B.

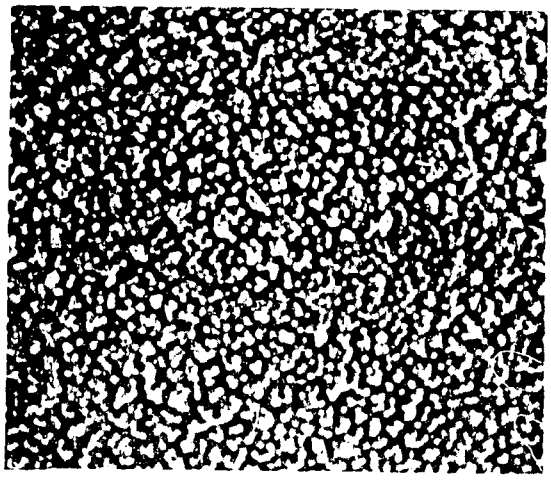
C_0. Critical point dryer not used.

C. Critical point dryer used.

All pollen collection and preservation methods can be used depending on convenience.

B1 can be used to clean specimens; critical point drying is unnecessary. The samples did not collapse under the SEM even at 12.5 kV or higher. The 2000X to 10000X photomicrographs showed surface sculpture very clearly (Fig. 3) but all opercula were lost.

B3 can be used (particularly after A2 or A3) but critical point drying is necessary. Pollen grains including opercula can be observed with clear surface sculpture at 7000X (Fig. 4). When magnified 10000X, clarity was less than that of acetolyzed samples (B1). It is possible that the matrix was not



3. Pollen grain of *Oryza barthii* showing surface texture (7000X). Sample was acetolyzed without critical point drying.

removed and it affected clarity. Granules of B3 seem to be shallower than those of B1. To compare surface texture, however, 4500X magnification is sufficient.

Without critical point drying, pollen grains from B2 and B4 collapse and crack easily when exposed to vacuum and the SEM electron beam except at 1000X for a very short time. However, the surface texture is unclear.

To compare surface textures of different *Oryza* species, acetolysis with magnification ranging from 2000 to 4500X is preferable.

SCREENING FOR SHADE TOLERANCE IN RICE SEEDLINGS

Plant Physiology Department

In the shade of coconut trees, in forest clearings, and in mixed cropping with cassava or banana, rice may suffer from insufficient solar radiation. Varieties in these areas need some shade tolerance to improve yield.

To screen for shade tolerance, 10 pregerminated seeds of 10 varieties and lines from earlier trials were sown in a row in a plastic tray filled 6 cm deep with fine soil. In the greenhouse, 10 varieties were randomly grown in each tray with three replications per treatment. Ten-d-old seedlings were transferred into 3 grades of shade: 45, 28, and 14% of normal light for 14 d. The trays were shaded by wooden frames covered with various layers of fish net. To compare shade-tolerant with submergence-tolerant varieties, one set of plants was placed in the darkroom for 7 or 14 d. Another was submerged in 30 cm water for 6 d with continuous light intensity of 60 lux. Control plants were unshaded.

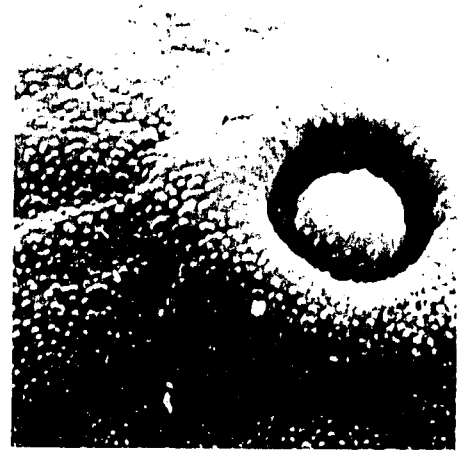
Dry weight. As solar radiation decreased, total DM also decreased in shaded seedlings. IR20, IR42, and IR1529-680-2-20, which produced less DM at all levels, lacked shade tolerance. At 55% shading Kurkaruppan had highest DM and one of the highest relative growth rates.

Plant height. With 55% shading, most seedlings were slightly taller than the control. As light intensities decreased to 28, 14, and 0%, height also decreased (Table 7). Only RD19, Kurkaruppan, and Thavalu grew in complete darkness.

Decreasing solar radiation gradually reduced leaf number per seedling, and the number of leaves did not increase during the dark treatment.

Leaf area and specific leaf weight. Lower light intensities greatly reduced leaf area. The varieties which had high DM weight also had high leaf area, except Thavalu which had high DM because of thicker leaves. Leaf area was positively correlated ($r = 0.965^{**}$) with total DM in all levels of shading (Fig. 5) indicating its importance in DM production in shade.

Leaves become thinner with shading. Thin leaves



4. Pollen grain of *Oryza longistaminata* showing intact operculum after glutaraldehyde fixation and serial dehydration in ethanol (7000X). Critical point drying was used.

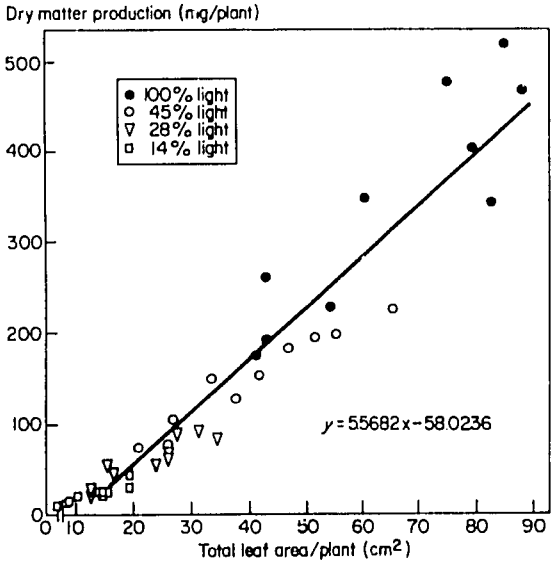
Table 7. Effect of 14-d shading and 7-d darkness on seedling height. IRRI, 1983.

Variety	Seedling ht (cm)						
	Before treatment	Shading (%)				Darkness (d)	
		0	55	72	86	7	14
IR1529-680-3-2	16	37	39	32	24	16	15
IR52	18	39	42	37	31	17	17
RD19	15	40	42	37	29	20	21
Thavalu (Acc. 15314)	23	63	59	53	40	24	25
Leb Mue Nahng 111	20	59	63	52	42	22	22
Kurkaruppan	21	58	60	52	42	25	25
Nam Sagui	22	57	63	52	39	23	24
FR13A	22	56	60	47	39	22	22
IR42	18	36	41	31	27	16	16
IR20	15	36	34	30	23	16	16
Mean	19	48	50	42	34	20	20

are characteristic of varieties suitable for low solar radiation such as FR13A, IR52, and RD19. FR13A had large thin leaves in all shade treatments while Thavalu had thick leaves at all levels.

Leaf area and thickness at later growth stages need evaluation as they can serve as important selection criteria.

Submergence tolerance vs dark tolerance. The performance of RD19, Kurkaruppan, Thavalu (Acc. 15314), and FR13A shows that plant survival at 7 d of darkness is positively correlated with survival at 6 d of submergence ($r = 0.780^{**}$). In testing to see if submergence tolerance can be determined by complete darkness, IR52 showed higher survival in darkness for 7 d but not when submerged. Almost all seedlings died after 14 d dark treatment.



5. Relationship between total leaf area/plant and DM production. IRRI, 1983.

Varieties tolerant of shade and submergence have some common characteristics. Screening for shade tolerance can be conducted at seedling stage using a 7-d dark treatment but needs testing with a large number of entries. Similarly, varieties should be tested for submergence tolerance to find out the degree of correlation between dark tolerance and submergence tolerance.

EVALUATION OF HYBRID RICES FOR RATOONING ABILITY

Plant Physiology and Plant Breeding Departments

China currently plants about 6 million ha to F_1 hybrids which yield 20-30% higher than the best semidwarf nonhybrid varieties. A successful ratoon from the hybrid rice crop would be advantageous. It would also help compensate for the hybrid seed cost which is three to four times more than that of conventional varieties.

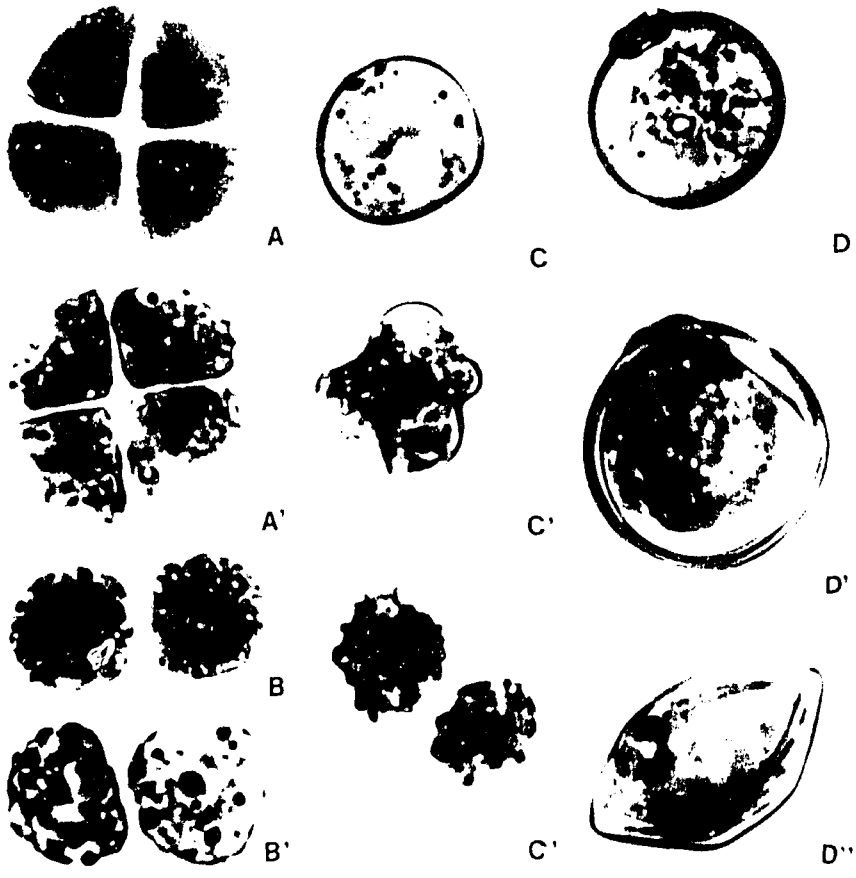
To investigate the possibility of ratooning hybrid rice in the tropics, 57 rice hybrids and 5 check varieties were evaluated at IRRI during 1983 DS.

At maturity, stalks were cut 15 cm above ground and entries were rated for ratooning ability 3 wk later.

Table 8. Plant characters of rice hybrids screened for ratooning ability.[a] IRRI, 1983 DS.

Hybrid and variety	Regeneration (%)	Plant ht (cm)	Total tillers (no./m²)	Tillers (no./hill)	Total panicles (no./m²)	Panicles (no./hill)	Viral disease rating
IR19657-34-2-2-3-3A/IR56[b]	70	65	279	11	189	8	1
IR56 (check)	81	62	284	10	179	6	0
IR19657-34-2-2-3-3A/IR36[b]	97	65	515	15	423	12	1
IR19657-34-2-2-3-3A/IR42[c]	81	60	389	14	145	6	0
IR19657-34-2-2-3-3A/IR19735-5-2-3-2-1[b]	93	64	485	15	420	13	0
IR19657-34-2-2-3-3A/IR19729-67-3	83	68	301	10	246	8	0
IR19799-17-3-1-1A/IR13420-6-3-3-1	83	55	349	12	231	8	0
IR19799-17-3-1-1A/IR2797-125-3-2-2	81	70	353	12	274	10	1
IR56 (check)	93	60	348	11	294	9	0
MR365A/IR48	80	65	378	14	307	9	1
IR56 (check)	93	56	348	11	307	9	0

[a]Av of 3 replications. [b] In one replication plants were mostly vegetative; flowering started. [c]Based on two replications. In third replication, flowering did not occur.



6. Effects of different treatments on the anthers from the same spikelet (eyepiece 6.7X, objective 40X). A-D: distilled water or aceto-carmine for fresh anther squash; A'-D': 3% glutaraldehyde; C'' and D''. Carnoy's fluid. A, B, C, D are different spikelets. A and A', etc. are different anthers from the same spikelet.

The ratooning ability of the hybrids and check varieties varied widely. A total of 14 hybrids and IR56 were selected. Mean regeneration for hybrids varied from 62 to 97%, but 8 showed regeneration of 70% or more (Table 8). IR56 had few missing hills, but in some hybrids with poor regeneration, missing hills were compensated by the high number of tillers and panicles per hill. Hybrid ratoons were more vigorous than those of IR56.

Hybrid IR19657-34-2-2-3-3A/IR36 had the most tillers and panicles/m^2. Hybrids with IR19657-34-2-2-3-3A as a parent line showed high regeneration and vigorous ratoons.

Varied hybrid response in replications suggests cultural management might be as important as genetic factors in controlling ratooning. Subsequent studies will evaluate parents and F_2 populations of the selected hybrids.

CONFIGURATION OF THE RICE MICROSPORE IN THE FORMATIVE PROCESS

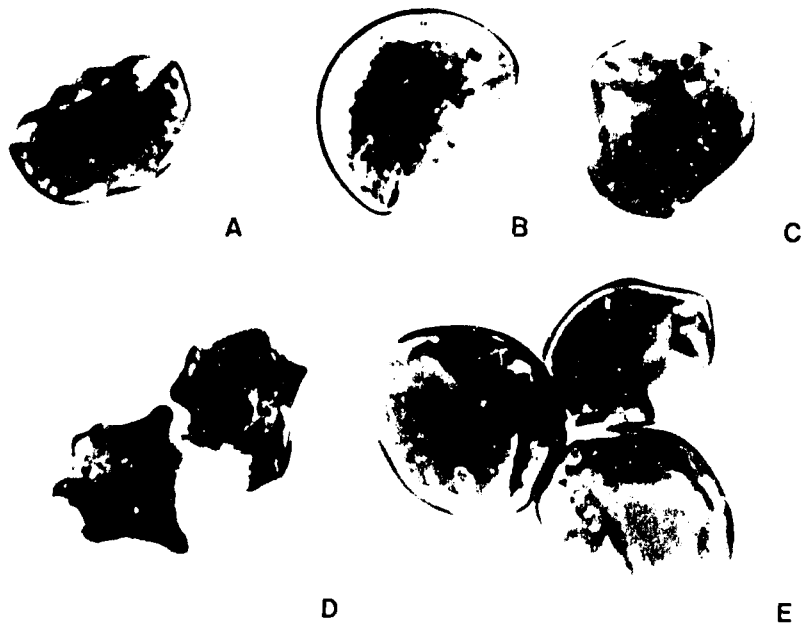
Plant Physiology Department

Studies of rice microspores showed configurations different from those previously reported. To learn their real structure during formation, six IR36 anthers from the same spikelet were treated with:

1. distilled water or phosphate buffer for fresh anther squash slide preparation,
2. aceto-carmine for fresh anther squash slide preparation,
3. Carnoy's fluid as fixative for 24 h and transferred to 70% alcohol for preservation or for 15 min before using aceto-carmine to make the anther squash slide, or
4. 3% glutaraldehyde as fixative for 1 h and then rinsing twice (20 min each) with phosphate buffer (pH 6.8) before making the anther squash slide.

The first and second contractive stages by Kihara and Hirayoshi's classification in rice microspore formation were not evident in the few microspores in treatments 1 and 2. As tetrads matured into pollen grains, they grew larger and changed from a fan-like to a global shape. Cell wall thickness increased, and the pore became more visible (Fig. 6).

As the microspore grows, the number of vacuoles decrease but their size increases. Finally a central large vacuole forms during the uninucleate stage but gradually disappears as nutrients accumulate. Filled pollen grains are opaque and sperm nuclei



7. Other different features of contracted microspore (eyepiece 6.7X, objective 40X). A, B, and C from 3% glutaraldehyde; D and E from Carnoy's fluid.

are invisible if dyed with aceto-carmine. The chemicals caused different shaped contractions with Carnoy's fluid showing fewer contractions at the tetrad stage and glutaraldehyde showing fewer at the young microspore stage (Fig. 7).

There were fewer uncontracted microspores in treatments 3 and 4. Regardless of the 1-h or 3-d fixing time, or whether fixed anthers were serially dehydrated or rehydrated to 70% alcohol before staining with aceto-carmine, microspore contractions were evident throughout growth until vacuoles almost disappeared.

Sometimes normal and contracted microspores appeared on the same slide showing that contraction cannot identify growth stage sequence. The first and second contraction reported by Kihara and Hirayoshi are not actually development stages of the microspore. The first and second "recovering phase" reported by Satake is also irrelevant. All contracted configurations result from fixative acting on young microspores with various cell wall thickness, sizes, and numbers of vacuoles.

Instead of the long, expensive, and tedious paraffin sectioning process to check microspore development stages, fresh anther (or Carnoy's fluid fixed anther) aceto-carmine squash technique can be used. It is also cheaper than the glutaraldehyde method.

Treatments 1 and 2 show the shape of the cells better while 3 and 4 reveal the cell contents. These treatments should be re-examined for study of other cereal crop microspore contractions.

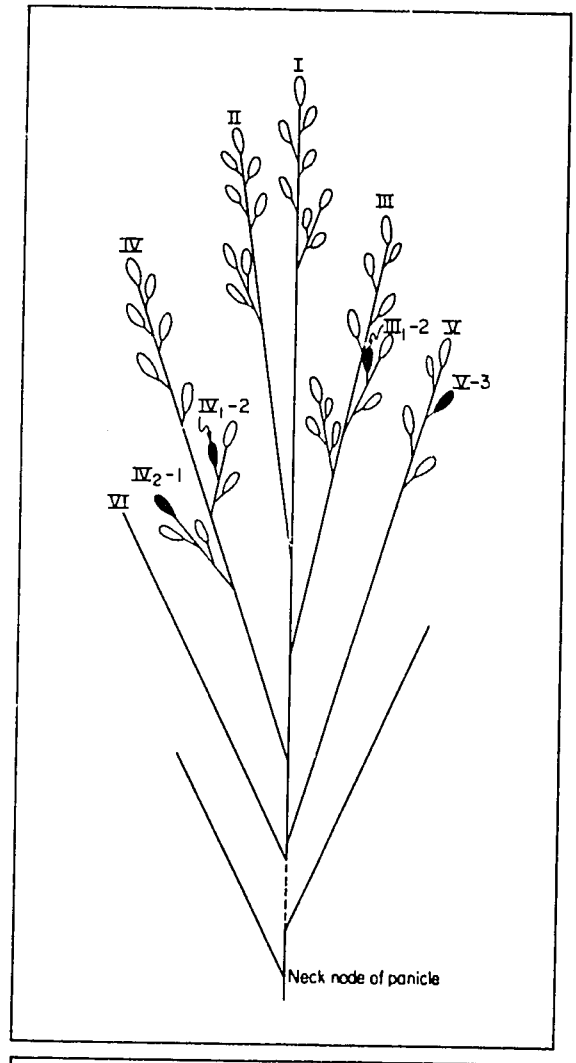
DETERMINING THE REDUCTIVE STAGE OF RICE USING A REPRESENTATIVE SPIKELET

Plant Physiology Department

Since the reductive division stage is the most critical growth period of the rice plant, its correct identification is important in rice cultivation and in resistance screening. Although the anther squash method is precise, which and how many spikelets should be sampled is difficult to determine.

IR36 and IR42 panicles with flag leaf auricle distance of -0.35 cm to 4.0 cm were sampled and fixed in Carnoy's fluid. Anthers were squashed with aceto-carmine and the growth stage was identified.

Spikelet designation. The first of the two-part



Order	Primary branches	Secondary branches			Spikelets
Top	I	I_1	II_1	IV_1	1
	II	I_2	II_2	IV_2	2
	III			IV_3	3
	.				.
	.				.
	.				.
	.				.
Bottom	.				.

Spikelets connected directly to primary branches		Spikelets connected directly to secondary branches		
I-1	II-1	I_1-1	I_2-1	II_1-1
I-2	II-2	I_1-2	I_2-2	II_1-2
I-3	II-3	I_1-3	I_2-3	II_1-3

8. Diagram of a panicle.

Table 9. General morphology of IR36 and IR42 panicles.[a] IRRI, 1983.

Primary branches			Secondary branches											
	IR36	IR42		IR36	IR42		IR36	IR42		IR36	IR42		IR36	IR42
I	√	√	I_1	√	√	I_2	√	√						
II	√	√	II_1	√	√	II_2	√	√						
III	√	√	III_1	√	√	III_2	√	√	III_3		√			
IV	√	√	IV_1	√	√	IV_2	√	√	IV_3	√	√	IV_4		√
V	√	√	V_1	√	√	V_2	√	√	V_3	√	√			
VI	√	√	VI_1	√	√	VI_2	√	√	VI_3	√	√			
VII	√	√	VII_1	√	√	VII_2	√	√	VII_3	√	√			
VIII	√	√	VIII_1	√	√	VIII_2	√	√						
IX		√	IX_1		√	IX_2		√						

[a] √ = present.

Table 10. Growth stages and representativeness of specific spikelets.

Panicles		Spikelets (%) at given growth stage				III_1–2		Vo-3		IV_1–2		IV_2–1	
No.	Auricle distance (cm)	Pollen mother cell (M)	Reduction division (R)	Pollen ripening (Ri)	Others[a]	Growth stage	Checking[b]	Growth stage	Checking	Growth stage	Checking	Growth stage	Checking
							IR36						
1	−3.5	51	49	0	0	M	√	M	√	M	√	M	√
2	−3.3	41	54	5	0	R	√	R	√	M	X	R	√
3	−0.5	12	55	33	0	R	√	R	√	M	X	R	√
4	0	13	54	32	1	R	√	R	√	R	√	Ri	X
5	0.2	24	68	8	0	R	√	R	√	M	X	absent	
6	0.4	6	56	35	3	R	√	R	√	R	√	Ri	X
7	1.0	12	53	35	0	R	√	R	√	R	√	R	√
8	4.0	0	13	87	0	Ri	√	Ri	√	Ri	√	Ri	√
9	4.1	3	37	59	1	Ri	√	Ri	√	R	X	Ri	√
							IR42						
1	−3.4	43	49	8	0	R	√	R	√	M	X	R	√
2	0	28	57	15	0	R	√	R	√	M	X	R	√
3	0	29	50	21	0	R	√	M	X	R	√	R	√
4	3.5	0	10	90	0	Ri	√	Ri	√	Ri	√	Ri	√

[a] Missed spikelets. [b] √ = growth stage of this spikelet is the same as that of most spikelets. X = opposite of √.

Table 11. Length of floret in reductive division stage.

Panicle No.	Panicle Auricle distance (cm)	Length of palea[a] (mm)	Minimum and maximum limits (mm)	CV
2	-3.3	3.31 ± 0.72	2.2-4.8	21.78
4	0	4.37 ± 0.83	2.3-5.6	18.98
7	1.0	4.24 ± 0.76	2.8-5.5	18.02
8	4.0	4.75 ± 0.93	3.0-6.1	19.59

[a]Exclusive of rachilla.

spikelet designation indicates the primary branch bearing the spikelet (Fig. 8). Branches are numbered from top to bottom with subscripts indicating secondary branching. A spikelet directly from the first primary branch is I_0. That from a secondary branch on the first primary branch will be I_1 depending upon the position of the secondary branch.

The second part of the designation indicates the spikelet position within a branch numbering from the top down. Thus, I_0-5 is the fifth spikelet of the first (topmost) primary branch; II_1-3 is the third spikelet on the first secondary branch of the second primary branch.

General morphology of IR36 and IR42 panicles. Table 9 gives the general morphology of IR36 and IR42 panicles. By comparing the model with sampled panicles, abortive spikelets (as high as 20% of the total) can be separated from the normal ones.

Most representative spikelet. Panicles with different flag leaf-penultimate leaf auricle distances were sampled. In IR36, the auricle distance of -3.3 to -3.5 cm contained most spikelets in the pollen mother cell (M) and reductive division stages (R). Panicles with auricle distance of -0.5 to 1.0 cm had most spikelets in the reductive division stage. When auricle distance was 4 cm or greater, spikelets were mostly in the pollen ripening stage (Ri).

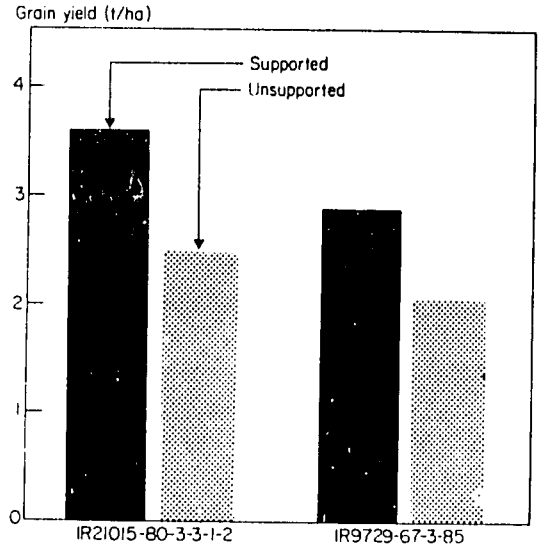
Spikelet III_1-2 was the most representative spikelet; its growth and development coincided with those of 50-70% other spikelets. The pattern holds true for IR42, with spikelets III_1-2 and IV_2-1 being the most representative at all stages (Table 10).

Correlation of floret length with reductive division stage. The length of 68% of spikelets in reductive stage (from synizesis up to and including tetrad) was 2.6 to 5.2 mm (Table 11). The 2.2 to 6.1 mm range was wider than in previous reports. Since the spikelet can start reductive division when it is 2.2 mm to 4.0 mm long, spikelet length can only estimate growth stage.

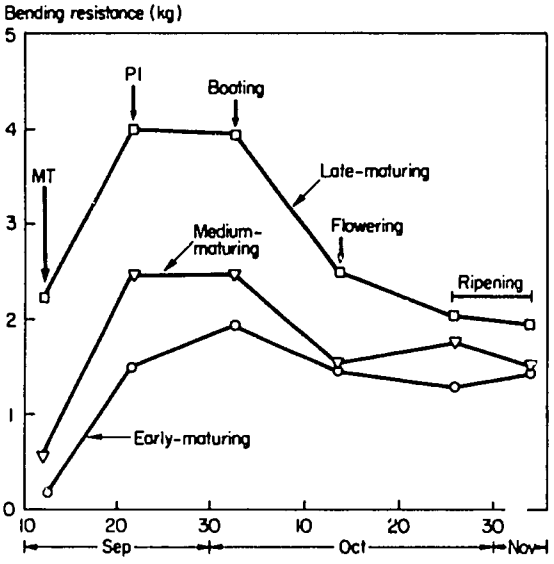
A panicle in reductive division has spikelets in different developmental stages: pollen mother cell, reductive division, and pollen grain ripening. It is important to know which spikelet coincides with the panicle growth stage. A crop is at its reductive division stage if examination of III_1-2 spikelets of about 10 panicles shows at least 50% of the panicles are in reductive division.

LODGING IN RICE GRAIN YIELD REDUCTION AND MEASUREMENT TECHNIQUE

Agronomy Department



9. Yield response of rice in supported and unsupported treatments, IRRI, 1983 WS.



10. Bending resistance of plants of 3 maturity groups: late IR21820-154-3-2-2-3, IR29723-143-3-2-1, IR21850-84-3-3-2, IR42; medium IR21015-80-3-3-1-2, IR29708-41-2-2-3, IR36; and early IR9729-67-3-85, IR58. MT = maximum tillering, PI = panicle initiation. IRRI, 1983 WS.

Lodging is a major cause of reduced grain yield and quality and is common even in modern semidwarf varieties.

Grain yield reduction. IR9729-67-3-85 and IR21015-80-3-3-1-2 were used in a study to determine the degree to which lodging reduces yield in semidwarf plants. A 9-m^2 steel frame support with nylon mesh to prevent crop lodging was placed in the plot adjacent to an equal sized unsupported plot. Grain yields were significantly higher in the supported treatment for both breeding lines (Fig. 9). Lodging in WS can reduce yield as much as 1 t/ha. A rapid quantitative technique is needed to screen MVs for lodging resistance.

Resistance to bending. Bending resistance is the force required to push 3 hills 30° above the water level. Another experiment in 1983 WS tested nine varieties and breeding lines for bending resistance at various growth stages (Fig. 10). Seeding dates were staggered to synchronize flowering. Actual crop lodging started between the flowering and ripening growth stages. Average bending resistance was 1.28 kg for the early-maturing group and increased to 2.78 kg in the late-maturing group. Observed crop lodging percentage and grain yield were 37% and 2.98 t/ha for the early-maturing group, 22% and 2.75 t/ha for the medium-maturing, and 14% and 4.05 t/ha for the late-maturing. Bending resistance cannot presently be used to predict lodging resistance because it needs to be studied with the time and degree of actual lodging as well as other plant mechanisms and environmental variables.

Genetic evaluation and utilization (GEU) program

Grain quality

Cereal Chemistry, Plant Breeding, and Agricultural Economics Departments

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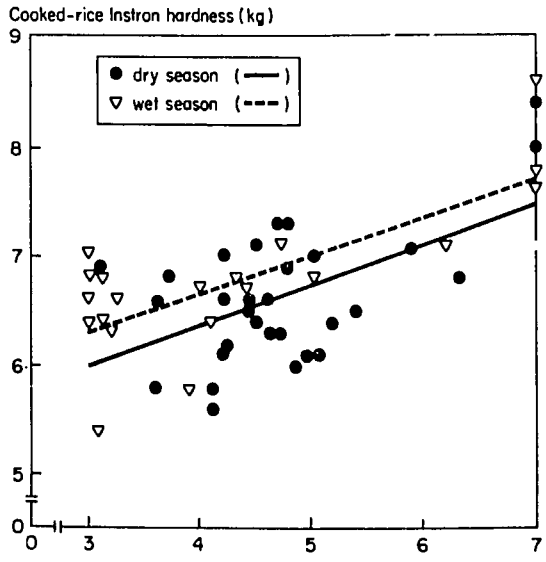
BREEDING PROGRAM

Plant Breeding and Cereal Chemistry Departments

With intermediate-amylose content as a breeding objective, these types of lines continue to be evaluated.

Cooked rice hardness of intermediate amylose rices (*Cereal Chemistry and Plant Breeding*). The relationship of various quality factors with cooked rice Instron hardness was further investigated in 32 intermediate amylose elite IR lines in DS and 22 in WS. Besides the negative relationship with gel consistency (GC) (r = -0.54** and -0.45*), cooked rice Instron hardness values in both seasons were positively correlated with alkali spreading value (Fig. 1). This trend probably reflects the 1978 annual report observation: BPI-121-407 cooked rice was about 1 kg harder (alkali spreading value 7) than C4-63G cooked rice (alkali spreading value 3-4). Both varieties are important sources of intermediate-amylose lines.

With these samples, GC values were hard to medium at 100 mg rice/2 ml 0.2 N KOH, and soft to medium at 90 mg rice/2 ml 0.2 N KOH. Only 8 medium-gel rices out of 32 were identified in the DS crop and 1 hard and 6 medium-gel rices out of 22 in the WS crop. Thus selection among intermediate-amylose lines should be for intermediate alkali spreading value (3-5) and soft GC (>60 mm) to ensure soft cooked rice.



1. Relationship between alkali spreading value and cooked rice Instron hardness value among intermediate-amylose IR lines in DS and WS.

Milling quality studies (*Cereal Chemistry*). Agronomy Department elite lines continued to be screened for milling quality of aged grain to better understand factors involved and discover ways of predicting them. Because of its good milling quality and high market price, IR42 remains the check variety.

Although hull percentage and total milled rice yield were not affected by season, head rice yield showed extreme variability particularly for the 1983 DS crop (Table 1). Percentage of light grains removed by winnowing varied considerably and correlated positively with hull content and total milled rice yield. However, light or immature grains did not significantly affect total rice yield. A large proportion of grain breakage during milling results from fissures already in the grain. Therefore, a study of grain fissures in different varieties under controlled stress conditions should supplement milling studies.

Amylose analysis of defatted rice (*Cereal Chemistry*). Starch chemists have shown that refluxing with water-saturated butanol more effectively defats starch than refluxing with 95% ethanol or 85% methanol. A comparison was made of the effect of defatting using these three aqueous alcohol solutions, on amylose content (AC) of nonwaxy milled rice and of undefatted milled rice. A 67% butanol: 33% water mixture at 92°C completely gelatinized rice starch in contrast to 85% methanol and 95% ethanol. Using an amylose/amylopectin mixture for a standard curve at pH 4.5-4.8, methanol and ethanol defatting increased AC by a mean of 1.1 to 1.5% for nonwaxy milled rices, but refluxing water-saturated butanol in-

Table 1. Range of milling properties of aged IR elite lines. IRRI, 1983.

Property	1982 WS	1983 DS
Samples (no.)	14	17
Hull (% of rough rice)	21.6-26.9	20.8-26.6
Total milled rice (% of rough rice)	64.6-68.8	62.2-71.0
Head rice yield (% of rough rice)	29.0-57.0	2.3-53.3
Light grains (% of rough rice)	1.5- 8.3	–
Milled rice whiteness (%)	33.3-45.5	38.8-47.4

Table 2. Comparison of amylose values of undefatted milled rice and milled rice flour defatted by refluxing 85% methanol, 95% ethanol, and 67% butanol in water.[a] IRRI, 1983.

Sample	Apparent AC (% dry basis)			
	Un-defatted	Defatted with		
		95% ethanol	85% methanol	67% butanol
IR29	0.3	0	0.1	0
IR3351-38-3	10.3	11.6	11.8	11.7
IR480-5-9	19.4	21.0	21.0	21.7
IR8	23.2	23.6	24.4	25.2
Mean[b]	17.6	18.7	19.1	19.5

[a]Using amylose/amylopectin standard curve at pH 4.5-4.8.
[b]Nonwaxy samples only.

creased AC by 2 ± 1% (Table 2). Thus, with 85% methanol, interference of milled rice lipids is still 2%, as reported in 1980 annual report. The International Standards Organization has proposed the simplified amylose test using amylose/amylopectin standard and acetate buffer pH 4.5-4.8 as an ISO standard method for milled rice amylose.

GRAIN QUALITY FACTORS

Cereal Chemistry and Agricultural Economics Departments

Country samples (*Cereal Chemistry*). Research fellows characterized representative milled rices from their own countries at IRRI as part of their training.

Japonica and indica/japonica Korean rices. Because Korean consumers continue to prefer traditional japonica rice over modern indica/japonica crosses, the properties of these rices were examined in the 1981 and 1982 Korean crops. Japonica rices were shorter and coarser than indica/japonica rices although some overlap was evident (Table 3). Protein and AC and alkali spreading value in 1.15% potassium hydroxide overlapped; however, mean protein content tended to be lower for japonica rices. Gel consistency and cooked rice hardness and stickiness were similar. The results suggest that the major difference between japonica and indica/japonica rices is in grain size and shape.

Amylograph pasting viscosity of japonica and indica/japonica milled rices was measured on selected samples using 12% pastes. In four samples

Table 3. Physicochemical properties of Korean japonica and indica/japonica milled rices from 1981 and 1982 Korean crops. IRRI, 1983.

Grain property	Japonica				Indica/japonica			
	1981		1982		1981		1982	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Samples (no.)	21		22		21		25	
Length (mm)	4.7-5.2	4.9	4.6-5.4	4.9	4.9-6.1	5.6	4.9-6.4	5.7
Width (mm)	2.7-3.1	2.8	2.6-3.0	2.8	2.2-2.7	2.4	2.3-2.7	2.5
Length:width	1.6-2.0	1.7	1.6-1.9	1.8	1.9-2.8	2.3	1.9-2.6	2.2
Protein (% at 14% moisture)	6.8-10.3	8.5	6.4-8.5	7.4	8.9-11.1	9.8	6.9-9.8	8.4
Amylose (% dry basis)	17.5-19.6	18.8	16.7-22.6	18.3	17.0-19.4	17.9	15.5-19.0	17.7
Alkali spreading value (1.15% KOH)	4.5-7.0	5.7	2.4-6.5	4.4	3.9-6.8	5.1	2.2-6.0	3.8
GC (mm)	48-71	61	50-84	71	49-75	59	52-83	70
Cooked rice hardness (kg)	4.2-5.8	5.0	3.6-5.3	4.5	4.5-5.9	5.1	3.6-5.2	4.5
Cooked rice stickiness (g.cm)	0.8-3.0	1.6	1.0-4.0	2.1	1.2-3.5	1.8	1.0-5.0	2.3

of each from the 1981 Korean crop, Amylograph viscosity was lower for japonica than for indica/japonica rices. Peak viscosity was 765-890 Brabender units (BU) for japonica samples and 970-1,135 BU for indica/japonica. The trend was less consistent for the 1982 Korean crop samples: 740-1,330 BU (mean 888 BU) for 11 japonica samples and 970-1,215 BU (mean 1,129 BU) for 13 indica/japonica samples. IRRI-grown Korean rices in 1982 showed a similar trend in amylograph peak viscosities: 925-995 BU (mean 945 BU) for 4 japonica rices and 1,070-1,190 BU (mean 1,149 BU) for 6 indica/japonica rices. This difference in amylograph viscosity was not reflected in cooked rice hardness or stickiness and is the reverse of what is expected from relative protein contents of the flours. Korean researchers have also reported conflicting relative amylograph viscosities of starch of Korean japonica and indica/japonica rices.

Pakistani and Vietnamese rices. An examination of fine and coarse Pakistani rices from Faisalabad and Lahore confirmed that the four Basmati rices had intermediate amylose and the two coarse varieties high amylose. All samples had hard GC and low to intermediate gelatinization temperature (GT) based on alkali spreading values. Cooked rice hardness was 0.9-1.2 kg/cm^2 for the fine varieties and 1.3-1.4 kg/cm^2 for the coarse. Two promising fine-grain lines and one promising coarse-grain line came close to standard varieties in properties, but the coarse line has harder GC than Mehran 59 (IR6-156-2).

A waxy and 14 nonwaxy Vietnamese rices were assessed for quality characteristics. All nonwaxy samples were high amylose (27.0-29.5%). Protein content was 5.9-8.6%. Eleven had low GT (alkali spreading value 6-7) and 3 had intermediate GT. GC was soft for 1, medium for 6, and hard for 6. Cooked rice hardness ranged from 10.5 to 13.4 kg for nonwaxy rice and was 8.0 kg for the waxy rice. The waxy variety had low GT.

Consumer demand for grain quality (*Agricultural Economics and Cereal Chemistry*). To determine the value consumers place on chemical and physical charateristics of milled rice, 108 rice samples were collected in three retail markets in the Philippines, Nepa-Q (Cubao, Metro Manila), Calamba (Laguna), and Baguio City, during the first 2 wk of June 1983. Samples included both poor and high quality rices, generally with 30-50% brokens. Ninety-seven samples had high AC, indicating that they were probably IR varieties.

Physical and chemical quality characteristics together explain 70% of price variances showing that grain appearance and cooking quality influence much consumer demand. Lower AC and percent brokens were the most important price determinants, accounting for 53% of variation (Table 4). Samples with low-intermediate (18-23%) AC were mainly aromatic Azucena and Denorado; both sold above the government price support of ₱3.10/kg. However, even among high-amylose (26-30%) rices, AC remained a very significant price determinant. Other price-related factors are grain length, whiteness, translucency, and alkali spreading value.

Popped rice (*Cereal Chemistry*). Three Nepalese varieties used in popped rice processing had high AC, intermediate to low GT, and soft gel. To assess for popping quality, raw rough rice of different amylose types was heated with 207° C air for 45 s. Waxy rice had the highest popping quality and also the lowest mean density of popped grains by xylene displacement (Table 5). Values overlapped among nonwaxy rices. Aged rice samples showed decreased popping percentage (also reported by Indian scientists) and the few popped grains showed poor volume expansion. In addition, dehulling reduced the popping percentage of 5 intermediate AC rices from 51-88% to 2-18% with a decrease in volume expansion as indexed by popped rice density of 0.25-0.40 g/ml in rough rice and 0.37-0.72 g/ml in brown rice.

ICC Working Group 21-II (*Cereal Chemistry*). The International Association for Cereal Chemistry

Table 4. Relationships between grain quality measures and price of milled rice.[a] IRRI, 1983.

Grain characteristic measure	Expected relationship to price	Estimated value (₱/kg per unit)
Whiteness (%)	+	0.04
Brokens (%)	–	–0.01
Length (mm)	+	0.37
Chalkiness score (1 to 9)	–	–0.04
Alkali spreading value (1 to 7)	–	0.24
AC (%)	–	–0.10
GC (mm)	+	n.s.

[a]All t-statistics estimates significant at the 1% level, except for GC.

Table 5. Popping quality of various amylose types of rice.[a] IRRI, 1982-83.

Amylose type	Samples (no.)	Popped grains (%)	Density of popped grains (g/ml)	
			Range	Mean
Waxy	4	65-76	0.20-0.33	0.24
Low	4	47-61	0.29-0.35	0.32
Intermediate	7	41-85	0.24-0.36	0.30
High	6	46-66	0.25-0.32	0.29

[a]Includes only samples with more than 40% popping.

(ICC) Working Group 21-II "Test Methods for Rice-Cooking Properties" analyzed and reported its cooperative tests in 1982-83. This included research on grain elongation during cooking, Amylography of rice flours, and the effect of cooking and measurement methods on texture (mainly hardness) of cooked rice with 75% water content. The methods were those used in each laboratory for measuring texture — a Texturometer, Instron, and taste panel. Viscoelastograph was not run on bulk sample since the method employs three discrete grains.

Cooperative studies on rice starch (*Cereal Chemistry*). In a cooperative study with starch chemists at Kagoshima University in Japan, the mean chain length ± standard deviation was measured as 19.4 ± 0.6 glucose units for IR32 and IR36 starches and 19.0 ± 0.6 glucose units for IR42 starch. Japanese waxy rice amylopectin had a mean chain length of 17.1 ± 0.2 glucose units and those of two other Japanese rices had 17.5 ± 0.6 and 18.3 ± 0.2. A low-angle laser light-scattering technique verified the presence of <5% very high molecular weight fraction in once-recrystallized amylose.

Japanese starch scientists compared high-amylose milled rices with medium (IR36) and hard (IR42) GC to Amylomaize (high amylose cornstarch) for use as paste for water-resistant corrugated fiberboard. Rice flour was inferior to Amylomaize in adhesive strength, but similar to nonwaxy cornstarch as carrier starch. High protein content (>2-3%) may have contributed to heavy foaming of the paste, poor water-holding ability, and unstable paste viscosity against mechanical shearing.

Genetic evaluation and utilization (GEU) program

Disease resistance

Plant Pathology Department

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EVALUATION OF GERMPLASM, BREEDING LINES, AND IR VARIETIES

IRRI continued to evaluate rice germplasm, breeding lines, and IR varieties for resistance to bacterial, fungal, and viral diseases. In 1983, researchers performed 85,028 tests for BB; 37,192 for Bl; and 11,026 for RTV, GSV, and RSV. Among the rice germplasm collection evaluated, 882 of 4,090 entries were resistant to BB race 1; 208 of 2,435 were resistant to Bl (Table 1, 2); 50 of 2,701 were resistant to RTV; 110 of 1,762 were resistant to

Table 1. Summary of screening of breeding materials and varieties for BB resistance, IRRI, 1983.

Source	Total entries tested	Race	Entries (no.) rated as					NP[b]
			R	HR	MS	S	R/S[a]	
Germplasm material	4,090	I	882			3,102	100	6
Hybridization block	584	I	244	67	139	106	23	5
	584	II	48	110	299	115	11	5
Replicated yield trial	1,050	I	767	181	53	24	25	
	1,050	II	92	442	342	170	4	
Observational yield trial	2,827	I	1,619	360	236	506	68	38
Pedigree nurseries[c]	76,209	I	58,310	205	45	7,890	9,468	29
Elite lines	137	I	6	30	61	40		
	137	II	0	4	32	101		
	137	III	4	13	37	83		
	137	IV	1	13	35	88		
Other materials								
Genetic studies (Plant Breeding)	52	I	36	5	4	4		7
	52	II	1	2	13	2		34
	52	III	11	–	3	4		34
	52	IV	11	1	2	4		34
Chinese breeding materials	33	I	7	7	1	18		
Cuban materials (IRTP)	46	I	0	1	1	44		
	46	II	0	0	13	32		
	46	III	0	0	4	42		
	46	IV	0	2	2	42		
	85,028		62,039	1,443	1,322	1,417	9,699	454

[a]R/S = segregating. [b]NP = no plant. [c]No available data for October, November, and December pedigree nurseries.

Table 2. Screening for Bl resistance. IRRI, 1983.

Source	Total entries tested	Entries (no.) rated as		
		R (0-2)	M (3-4)	S (5-9)
Elite breeding lines	69	2	5	62
Observational yield trials[a]	1,925	139	166	1,620
Replicated yield trials[a]	977	31	43	903
Hybridization blocks[a]	540	69	55	416
Medium deepwater yield trial	73	2	3	68
Pedigree nurseries	30,686	3,403	3,913	23,370
International Upland Rice Observational Nursery '83	201	35	47	119
International Rice Blast Nursery '83	286	57	19	210
Germplasm bank	2,435	208	255	1,972
Total	37,192	3,946	4,506	28,740
%	100	10.6	12.1	77.3

[a]2-3 tests.

RSV; and 37 of 83 were resistant to GSV. The entries that were resistant to the three virus diseases are shown in Table 3.

Of 107 elite breeding lines and IR varieties evaluated for disease resistance, 30 were intermediate or resistant to RTV or RSV (Table 4).

BACTERIAL BLIGHT

New resistance sources. A total of 425 rice entries were tested against the 7 races of *Xanthomonas campestris* pv. *oryzae* occurring in the Philippines (Table 5). Kalimekri 77-5, Aus 303, AC19-1-1, and Raital were resistant to all seven races. Many of the entries were moderately susceptible to race 7, presently of minor concern.

Adult plant resistance. Rice seedlings are often susceptible to BB, but as they grow older, they may

Table 3. Entries with resistance to 3 virus diseases using the mass-screening method in the greenhouse. IRRI, 1983.

Disease	Acc. no.	Variety or line
Tungro	16684	Utri Rajapan
	17204	Balimau Putih
	19680	ARC10963
	21473	ARC11554
Grassy stunt 1		IR13540
		IR17494
		IR19735
		IR24637
		IR27327
		5207
		5218
		5299
Ragged stunt	15278	Mahamawee 2
	15307	Kaharamana
	15488	Suduhathiyal
		IR13524
		IR13540
		IR19661
		IR25603

Table 4. Disease reactions of 30 GEU elite lines and IR varieties, 1983.

	Disease reaction							
	ShB	ShR	Bl	BLB	BLS	RTV	GSV	RSV
IR36	M-MS	MS-S	S	S	MR	I-S	R	I
IR54	M	R-S	S	MR-S	MR	I	R	I
IR58	M	MR-VS	MR	MR-S	MR	I	R	I
IR60	M	M	MR	R-S	–	R	–	–
IR6115-1-1-1	M	MS-VS	R-S	S	MR	I-S	R	I
IR8455-78-1-3-3	M	MS	S	MS-S	–	R	–	–
IR9729-67-3-85	M	R-MS	–	MS-S	–	R	–	–
IR9729-67-3-87	M	R-MS	–	MS-S	–	I	–	–
IR13429-299-2-1-3	M	MS-S	–	MS-S	–	–	I	R
IR13540-82-2-3-2-3-1	M	MR-MS	–	MS-S	R	–	R	R
IR17494-32-1-1-3-2	MS	R-MS	S	MR-S	MS	–	R	I
IR18348-36-3-2	M	R-MS	S	MR-S	R	S	R	I
IR18350-175-2-3	M	MS-S	–	MR-S	R	–	R	I
IR18818-87-2-2-2	M	R-S	–	MS-S	MR	I	I	I
IR19058-107-1	M	MR-MS	–	S	MR	–	R	R
IR19661-131-1-3-1-3	M	R-VS	S-I	S	MS	I	I	R
IR19670-263-3-2-2-1	M	MR-MS	S	MS-S	S	–	R	R
IR19735-5-2-3-2-1	M	R-MS	–	S	MR	–	R	R
IR21015-196-3-1-3	M	R-S	–	S	MR	S	R	R
IR21912-131-3 3-2-2	M	MR-VS	S	MS-S	R	S	R	R
IR25572-87-3-3	M	MR-S	S	S	MS	–	R	R
IR25603-20-2 1-3-2	M	R-MS	–	MR-S	MR	–	I	R
IR25924-51-2-3	M	R-MS	S	MS-S	MR	–	R	I
IR25926-87-1-2	M	MR-S	–	MR-S	S	–	I	S
IR27325-63-2-2	M	MR-MS	–	MS-S	MS	–	R	R
IR28118-138-2-3	M	R-S	–	MS-S	MS	–	R	I
IR28128-45-2	M	R-MS	S	MS-S	R	–	R	I
IR28143-51-3-3-1	M	R-MS	–	MS-S	MR	–	–	–
IR29512-81-2-1	M	R-MR	–	MR-S	MS	–	R	I
IR29692-65-2-3	M	R-MS	–	MS-S	MR	–	R	S

Table 5. Reaction[a] of 76 selected rice germplasm samples to 7 races of BB in the Philippines, 1983.

Acc. no.		Reaction to *Xanthomonas campestris* pv. *oryzae* race						
		1	2	3	4	5	6	7
		Group 1						
6613	Kalimekri 77-5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
29091	Aus 303	1.0	1.0	1.0	1.0	1.0	1.0	1.0
32753	AC19-1-1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25915	Raital	1.0	1.0	1.0	1.0	2.0	2.0	2.0
		Group 2						
12366	ARC7325	1.0	1.0	1.0	1.0	1.0	5.0	3.0
11484	Chinsurah Boro 2	1.0	3.0	1.0	1.0	5.0	4.0	6.0
17366	Camor	3.0	1.0	1.0	3.0	1.0	4.0	5.0
8555	DZ78	1.0	3.0	1.0	5.0	1.0	4.0	5.0
29035	Aus 230	1.0	1.0	1.0	1.0	2.0	3.0	4.0
3711	BJ 1	1.0	3.0	1.0	1.0	1.0	2.0	5.0
26511	Mura Bazal	1.0	1.0	1.0	1.0	2.0	3.0	5.0
6594	Kalimekri 391	1.0	1.0	1.0	1.0	1.0	5.0	6.0
6607	Laki 462	1.0	1.0	1.0	1.0	3.0	5.0	5.0
6540	Bazail 407	1.0	1.0	1.0	1.0	4.0	4.0	5.0
32745	AC 10-38	1.0	1.0	1.0	1.0	4.0	5.0	7.0
12346	ARC7260	1.0	1.0	1.0	1.0	4.0	5.0	7.0
17153	Andel	1.0	1.0	1.0	1.0	1.0	5.0	7.0
12712	ARC11094	1.0	1.0	2.0	1.0	4.0	6.0	7.0
		Group 3						
12426	ARC10303	1.0	1.0	1.0	1.0	4.0	9.0	7.0
28878	Aus 15	1.0	1.0	1.0	1.0	5.0	9.0	7.0
25853	Gambir	1.0	2.0	1.0	1.0	1.0	3.0	9.0
29075	Aus 287	1.0	1.0	1.0	1.0	2.0	4.0	9.0
12682	ARC10952	1.0	1.0	1.0	1.0	2.0	5.0	9.0
27051	AsePulut Cella Ringgi	1.0	2.0	1.0	3.0	2.0	5.0	9.0
5811	Baishbish	1.0	2.0	2.0	1.0	3.0	6.0	9.0
25862	Himolee	1.0	1.0	1.0	1.0	5.0	6.0	9.0
12653	ARC10843	1.0	1.0	1.0	1.0	4.0	7.0	9.0
12560	ARC10657	1.0	1.0	1.0	1.0	3.0	5.0	9.0
12678	ARC10945	1.0	1.0	1.0	1.0	2.0	7.0	9.0
29014	Aus 190	1.0	1.0	1.0	1.0	1.0	9.0	9.0
29008	Aus 176	1.0	1.0	1.0	1.0	3.0	9.0	9.0
31835	Kalmi Lata	1.0	1.0	1.0	1.0	3.0	9.0	9.0
29007	Aus 175	1.0	1.0	1.0	1.0	3.0	9.0	9.0
29025	Aus 207	1.0	1.0	1.0	1.0	4.0	9.0	9.0
28986	Aus 133	1.0	1.0	1.0	1.0	4.0	9.0	9.0
28932	Aus 69	1.0	1.0	1.0	1.0	4.0	9.0	9.0
28911	Aus 48	1.0	1.0	1.0	1.0	4.0	9.0	9.0
28999	Aus 156	1.0	1.0	1.0	2.0	4.0	9.0	9.0
3687	PI 180060-1	1.0	1.0	1.0	2.0	4.0	9.0	9.0
28940	Aus 77	1.0	1.0	1.0	1.0	5.0	9.0	9.0
28992	Aus 143	1.0	1.0	1.0	1.0	5.0	9.0	9.0
28995	Aus 152	1.0	1.0	1.0	1.0	5.0	9.0	9.0
29002	Aus 168	1.0	1.0	1.0	1.0	5.0	9.0	9.0
29024	Aus 206	1.0	1.0	1.0	1.0	5.0	9.0	9.0
29036	Aus 233	1.0	1.0	1.0	1.0	5.0	9.0	9.0
28945	Aus 253	1.0	1.0	1.0	1.0	7.0	9.0	9.0
28963	Aus 104	1.0	1.0	1.0	1.0	7.0	9.0	9.0
28920	Aus 57	1.0	1.0	1.0	1.0	7.0	9.0	9.0
28903	Aus 40	1.0	1.0	1.0	1.0	9.0	9.0	9.0
28936	Aus 73	1.0	1.0	1.0	1.0	9.0	9.0	9.0
28939	Aus 76	1.0	1.0	1.0	1.0	9.0	9.0	9.0
32819	Bazail 1187	2.0	2.0	2.0	1.0	9.0	9.0	9.0

Table 5 continued

Acc. no.		Reaction to *Xanthomonas campestris* pv. *oryzae* race						
		1	2	3	4	5	6	7
		Group 4						
29348	Gasmal 734	7.0	9.0	1.0	7.0	6.0	9.0	4.0
25916	Rambuga	5.0	3.0	4.0	5.0	5.0	5.0	5.0
26547	Bali Ray	7.0	4.0	4.0	1.0	9.0	9.0	5.0
24907	Dara Maman	7.0	4.0	4.0	5.0	5.0	7.0	7.0
15749	Sudu Heenati	5.0	5.0	9.0	6.0	9.0	7.0	7.0
31803	Hori Gachi	7.0	4.0	4.0	5.0	5.0	9.0	7.0
28184	Ratru 139	3.0	3.0	3.0	2.0	5.0	5.0	9.0
17513	Djawa Sendang	4.0	3.0	3.0	1.0	1.0	4.0	9.0
31211	Tower (A4-2)	2.0	6.0	6.0	7.0	5.0	6.0	9.0
26975	Adina	6.0	4.0	5.0	5.0	4.0	7.0	9.0
3358	Early Prolific Sel 1028 P	4.0	2.0	3.0	4.0	4.0	7.0	9.0
30673	Compleh (A 4-25)	3.0	5.0	9.0	9.0	4.0	7.0	9.0
16652	Tjina	5.0	7.0	7.0	3.0	5.0	9.0	9.0
17350	Bulu Putih	3.0	7.0	7.0	2.0	5.0	9.0	9.0
19970	Ketan Untup	3.0	7.0	7.0	3.0	5.0	9.0	9.0
30384	Ngankhao	1.0	4.0	9.0	7.0	2.0	9.0	9.0
30411	IR28	2.0	5.0	7.0	3.0	5.0	9.0	9.0
29406	Sailboro 385	5.0	7.0	4.0	5.0	5.0	9.0	9.0
30757	Kortue (A2-265)	3.0	5.0	5.0	7.0	3.0	9.0	9.0
30847	Liberian Coll. Y77	2.0	5.0	9.0	5.0	3.0	9.0	9.0
31179	Quilligama (A2-258)	2.0	5.0	7.0	7.0	5.0	9.0	9.0
31296	Ch 1111	4.0	3.0	3.0	5.0	4.0	9.0	9.0
28582	Tnau 6484	9.0	9.0	9.0	3.0	9.0	9.0	9.0

[a]Group 1 = resistant to all 7 races; group 2 = moderately resistant to race 5, 6, or 7; group 3 = susceptible to race 5, 6, or 7, or all 3; group 4 = with differential resistance to all races.

become resistant at flowering. This process is called adult plant resistance and is a synonym for horizontal plant resistance. The resistance gene *Xa 6* of Zenith and Malagkit Sungsong confers adult plant resistance. In tests for this resistance, TN1 was susceptible to four races at all growth stages. IR1545, which carries the *xa 5* resistance gene, was resistant to races 1, 2, and 3 but susceptible to race 4 at all growth stages. However, Zenith and Malagkit Sungsong and their progeny lines IR1695 and IR944 were resistant from 11th leaf stage. Their resistance was stable in different temperature conditions but TN1, infected with the four BB races, had lesions which appeared longer and developed faster in high temperature conditions (21-33°C). Temperature did not affect interactions between the races and varieties with adult plant resistance.

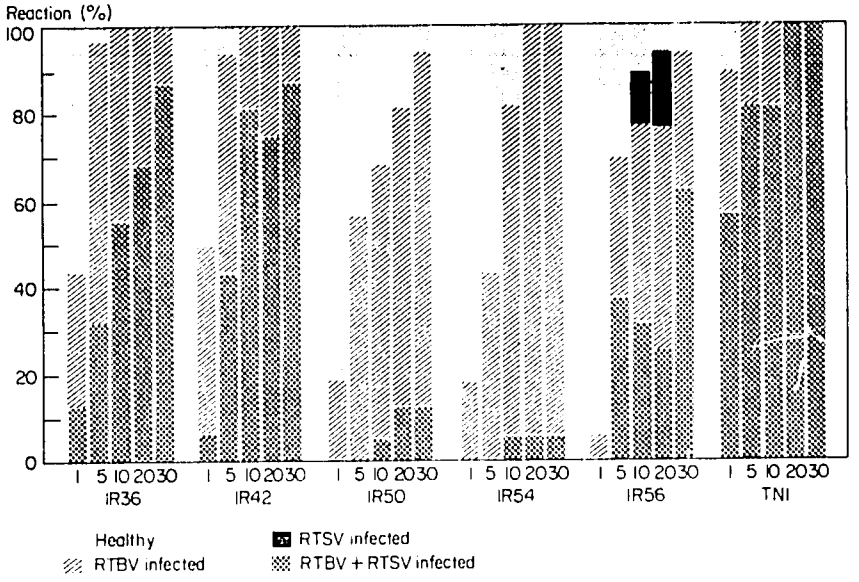
SHEATH BLIGHT

In 1983, 3,092 entries from elite lines, upland replicated yield trials, upland observational yield trials, and the germplasm bank were screened for ShB resistance in the field. Although no variety was highly resistant, 1.5% were moderately resistant; 98.4%, moderately susceptible; 0.03%, susceptible; and 0.03%, very susceptible.

RICE TUNGRO DISEASE

Rice tungro virus complex as influenced by insect pressure. Five IR varieties were tested for their reaction to RTV complex after inoculation with 1, 5, 10, 20, or 30 viruliferous *Nephotettix virescens* per plant. Individual plants in mylar-enclosed clay pots were inoculated for 24 h 1 mo after planting. They were tested for RTBV and RTSV with the latex test 1 mo after inoculation.

RTBV/RTSV infection increased in moderately resistant varieties IR36 and IR42 when the number of insects increased from 1 to 30 (Fig. 1). In the highly resistant IR50 and IR54, only RTBV infec-



1. Reaction of IR varieties to RTV complex when inoculated with 1, 5, 10, 20, or 30 viruliferous insects per plant. IRRI, 1983.

tion increased. However, these plants are not a virus source for the spread of the disease, because the virus cannot be recovered by the vector insect. IR56 had an almost equal infection of RTBV + RTSV and RTBV alone.

The test varieties, however, may not be immune to RTSV because preliminary results using RTSV alone resulted in infection (Table 6).

Reaction of green leafhopper-resistant varieties to rice tungro virus complex. GLH-susceptible variety Habiganj DW8 and resistant varieties Ptb 18, Palasithari, Gam Pai 30-12-25, Gam Pai 30-12-30, ASD7, Jingasail, and ARC11554 were tested for their reaction to RTV complex. Test varieties were planted individually in clay pots and enclosed in mylar cages. One mo after transplanting, the plants were inoculated for 24 h with 1, 5, 10, 20, or 30 RTV *N. virescens* per plant. The latex test was done 1 mo after inoculation to determine the presence of RTV complex in the inoculated plants.

Habiganj DW8, Ptb 18, and ARC11554 showed stable resistance to RTV complex by their low infection rate from RTBV + RTSV or RTBV alone, regardless of number of insects per plant (Fig. 2). However, RTBV infection alone in Palasithari, Gam Pai 15, Gam Pai 30, and ASD7 increased as the number of insects per plant increased from 1 to 30. Jingasail had mild symptoms but a high RTBV + RTSV infection rate, while ASD7 exhibited severe symptoms but had a high infection of RTBV alone.

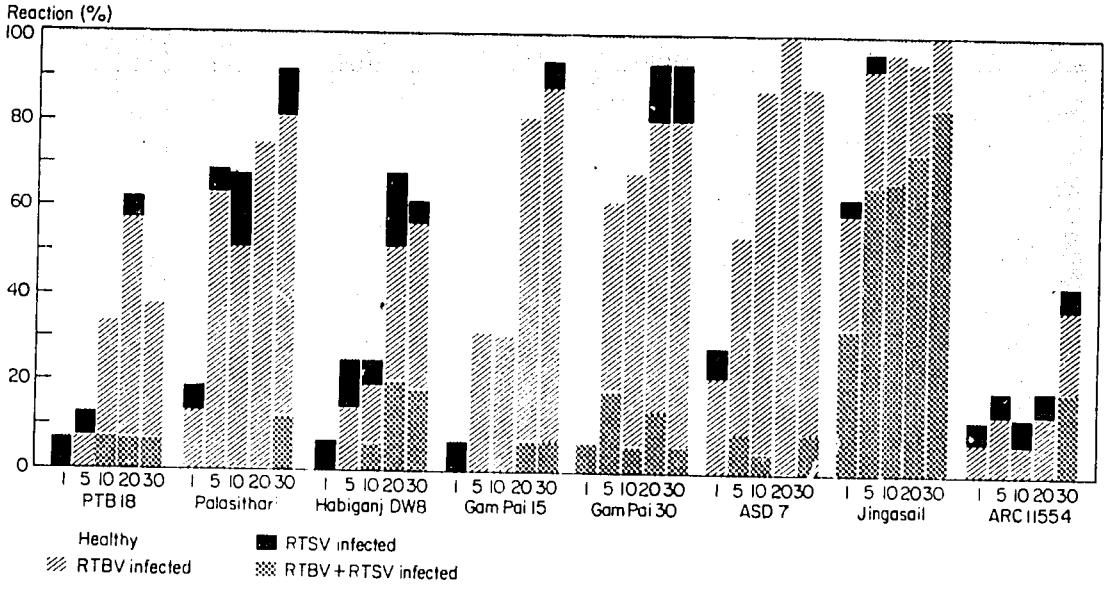
Results revealed two types of resistance to RTV:

- high resistance to complex RTSV + RTBV and to RTBV alone, even with high insect pressure as in Ptb 18, Habiganj DW8, and ARC11554, and
- increased RTBV infection with increased insect pressure as in Palasithari, Gam Pai 15, Gam Pai 30, and ASD7. When the latter varieties are infected, they do not serve as a virus source for the disease, because RTBV is not transmitted without RTSV.

Resistance to tungro and green leafhopper. Resistance of 8 rice varieties to RTV infection was

Table 6. Percentage infection of IR varieties when inoculated with RTSV at 1 insect per seedling. IRRI, 1983.

Variety	Inoculated seedlings (no.)	Infected seedlings	
		No.	%
IR36	36	21	58.3
IR42	38	15	39.4
IR50	38	6	15.7
IR54	38	8	21.0
IR56	39	32	82.0
TN1	102	85	83.3



2. Reaction of GLH-resistant varieties to RTV complex when inoculated with 1, 5, 10, 20, or 30 viruliferous insects per plant. IRRI, 1983.

determined by mass and test tube inoculation with 1, 3, and 5 GLH per seedling. Percentage seedling infection in test tube inoculation was higher than in mass inoculation. The percentage increased as the number of insects increased from 1 to 5 regardless of variety (Table 7). ARC11554, Basmati, Ptb 18, and IR28 showed resistance at one insect per seedling; however, IR28 and Ptb 18 changed from resistant to susceptible at 3 and 5 insects per seedling. ARC11554 and Basmati showed stable resistance in both methods of inoculation.

Studies of GLH feeding behavior, mortality, and population growth on the selected varieties showed that they did not prefer the four varieties with lower seedling infection. Although GLH fed on the xylem, no population growth occurred. IR28 and Ptb 18 resist RTV infection because they resist the vector insect.

The latex test determined the presence of RTBV and RTSV in RTV-infected plants of the eight varieties. A low percentage of ARC11554 and Ptb 18 plants reacted to both RTBV and RTSV (Table 8), and virus retention was shorter and GLH infective capacity was lower on ARC11554 and IR28. ARC11554 should be a good source for RTV resistance.

Table 7. Reaction of 8 selected varieties to RTV when inoculated with 1, 3, or 5 GLH per seedling using the mass and test tube methods of inoculation. IRRI, 1983.

Variety	Seedling reaction					
	Mass inoculation			Test tube		
	1	3	5	1	3	5
ARC11554	R	R	R	R	R	R
Basmati	R	R	R	R	I	I
Latisail	I	S	S	S	S	S
Peta	I	I	S	S	S	S
Ptb 18	R	I	I	R	S	S
TKM6	S	S	S	S	S	S
IR28	R	R	I	R	R	S
TN1	S	S	S	S	S	S

Table 8. Presence of RTBV and RTSV in 8 varieties infected with RTV as detected by the latex test. IRRI, 1983.

Variety	Plants tested (no.)	Plants (no.) reacting to presence of			Plants with no infection (no.)
		RTBV + RTSV	RTBV	RTSV	
ARC11554	25	1	12	0	12
Basmati	6	0	5	0	1
Latisail	31	18	10	1	2
Peta	31	15	11	2	3
Ptb 18	17	2	3	0	12
TKM6	33	4	25	0	4
IR28	30	5	21	0	4
TN1	29	19	9	0	1

RICE YELLOW DWARF DISEASE

IR varieties were tested for their response to YD disease by artificial inoculation of 7-d-old plants in test tubes for 24 h with viruliferous GLH at 2 insects per seedling. They were transplanted into clay pots, and kept in screened metal trays for symptom development. Diseased plants were counted 40 d later.

Results showed that IR5, IR8, IR24, IR26, IR29, IR30, IR43, and IR58 had low infection percentages and were rated resistant (Table 9).

Table 9. Reaction of IR varieties to rice YD in the test tube inoculation using 2 viruliferous GLH per seedling. IRRI, 1983.

Variety	Infection (%)	Rating[a]
IR5	20	R
IR8	17	R
IR20	76	S
IR22	55	I
IR24	20	R
IR26	13	R
IR28	49	I
IR29	19	R
IR30	18	R
IR32	42	I
IR34	74	S
IR36	67	S
IR38	60	I
IR40	45	I
IR42	54	I
IR43	16	R
IR44	45	I
IR45	38	I
IR46	73	S
IR48	57	I
IR50	43	I
IR52	34	I
IR54	46	I
IR56	66	S
IR58	19	R
IR60	43	I
TN1 (check)	95	S

[a]R = 0-30%, 1 = 31-60%, and S = 61-100%.

RESISTANCE TO RAGGED STUNT VIRUS AND ITS VECTOR

The resistance of eight rice varieties to RSV and its BPH vector was studied (Table 10). Varieties showing resistance in the mass screening test were less preferred by BPH. The insects probed more per day, had shorter lifespans, produced fewer nymphs, and had lower nymphal survival rates on the resistant varieties.

Reactions of eight varieties to RSV infection with three BPH biotypes were tested. Some correlation exists between a variety's resistance to BPH biotypes and its resistance to RSV.

Both resistant and susceptible varieties infected with RSV showed no recognizable difference in symptom severity and no significant difference in amount of virus in the tissues. The results indicate that resistant varieties were resistant to RSV infection but not to virus multiplication.

PATHOGEN VARIATION

Rice blast pathogen. In the 1983 Korea-IRRI collaborative project, parallel experiments were conducted on the pathogenic variability of *Pyricularia oryzae* in both locations. In Korea, single

Table 10. Reaction of 8 selected varieties to 3 BPH biotypes and RSV transmitted by 3 biotypes. IRRI, 1983.

Variety	Reaction to BPH biotypes[a]			Reaction to RSV transmitted by biotypes[b]		
	1	2	3	1	2	3
Ptb 21	S	S	S	I	S	S
Murungakayan	R	R	S	R	R	I
Mawee	R	R	R	R	R	R
Balaratawee	R	MR	S	R	I	S
Hathili	R	R	MR	R	I	I
IR22	S	S	S	I	I	S
IR50	R	R	MR	R	I	I
TN1	S	S	S	S	S	S

[a]Data from Entomology Department, IRRI. [b]Results of mass inoculation based on 0-20% infection = R, 31-60% infection = 1, 61-100% infection = S.

Table 11. Reaction of Philippine differential varieties to SSI of *Pyricularia oryzae* in Korea and IRRI, 1983.

Differential variety	Varietal reaction[a]						
	Korea lesions[b]		IRRI lesions[c]				
	M23-3	M23-2	IR-1	IR-2	IR-3	IM23-2	IM23-3
Kataktara DA-2	R	S S	R R	R	R	R R R	R
CI 5309	R	R S	R R	S	R	R R R	R
Chokoto	R	R R	R R	S	R	R R R	R
CO 25	R	R R	S S	S	S	S S R	S
Wagwag	R	R R	R R	R	R	R R R	R
Pai-kan-tao	R	R R	R R	R	R	R R R	R
Peta	S	S S	S S	S	S	S S S	S
Raminad Str. 3	R	R R	R R	R	R	R S R	R
Taichung T. C. W. C.	S	S S	S S	S	S	S S S	S
Lacrosse	S	S S	S S	S	S	S S S	S
Sha-tiao-tsao (S)	R	S S	R R	R	R	R R R	R
Khao-tah-haeng 17	R	S S	S R	R	R	R R R	R
No. of SSI	19	17 1	22 3	25	24	23 1 1	25

[a]Reaction was considered susceptible if more than 20% of the plants exhibited type 4 lesions (SES scale). [b]The experiment was conducted at Suweon, Korea, with isolates from Milyang 23, replicated 3 times. [c]The experiment was conducted at IRRI with isolates from Milyang 23 (M23) and IR442-2-58 (IR), replicated three times. Variant isolates were retested.

Table 12. Race frequency of *Xanthomonas campestris* pv. *oryzae* population in the Philippines with specific virulence to a set of differential varieties. IRRI, 1980-83.

Race group[a]	Reaction to differential varieties[b]	Frequency[c] (%)			
		1980 (55)	1981 (33)	1982 (123)	1983[d] (66)
1	SRRSR	1.8	0	0.8	0
2	SSRRR	75.9	84.8	85.4	92.4
3	SSRSR	14.9	6.1	9.8	7.6
4	SRSSR	0	3.0	0.8	0
A	SRRRR	0	6.1	1.6	0
B	SSSSR	1.8	0	1.6	0
C	SSSSMS	5.6	0	0	0

[a]Letters represent one or more isolates causing reaction combination different from that to the known races. [b]Differential varieties corresponding to the reaction pattern of each race: IR8, IR20, IR1545-339, CAS209, DV85. [c]Number of isolates tested each year are in parentheses. [d]Collection from one locality only.

spore isolates (SSI) from two single lesions on Milyang 23 (M23-3 and M23-2) were tested against the Philippine differential variety set. Based on pathogenicity patterns, all 19 SSI from lesion M23-3 were identical and only 1 of the 18 SSI from lesion M23-2 produced a different reaction (Table 11). Moreover, the variant SSI from lesion M23-3 was identical to the other isolates except for a more pathogenic reaction on CI 5309.

Experiments at IRRI showed similar results (Table 11). Since there were no variant isolates among the SSI from lesions IR2, IR3, and IM23-3, they were all classified as one race. Although more than one race was found among SSI from lesions IR1 and IM23-3, the variant SSI were few.

Bacterial blight pathogen races. A 1980-83 survey of the natural BB population determined frequency of race occurrence and distribution in the

Philippines. A total of 276 isolates were collected from naturally infected native or IR varieties carrying the *Xa 4* gene for BB resistance and tested for their reactions to BB differential varieties. Race 2, virulent to rices with *Xa 4* gene for resistance, was the most predominant group in the population, probably because of continuous commercial planting with the same genetic background since mid-1970s (Table 12). The large difference in race 2 could come from selection pressure on the pathogen population by the resistant varieties. Previously undescribed races also had a low frequency rate.

Further study compared variability of the BB population pathogen for 3 yr. Variability was measured by the pathogen's virulence: variance of lesions induced on IR8, IR20, IR1545-339, and DV85. On IR8 and IR20, variance values were higher and increased each year, indicating the tendency of the bacterial population to become more heterogeneous. Variance values of IR1545-339 and DV85 were low but increased proportionally with mean lesion length.

Genetic evaluation and utilization (GEU) program

Insect resistance

Entomology, Plant Breeding, and Chemistry Departments

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SOURCES OF RESISTANCE

Entomology and Plant Breeding Departments

Greenhouse screening for resistance to rice thrips. To evaluate rice varieties for resistance to thrips *Stenchaetothrips biformis*, a greenhouse technique providing sufficient insects for screening was developed (Fig. 1). A work schedule of 2 h/d produced 400 adult thrips daily.

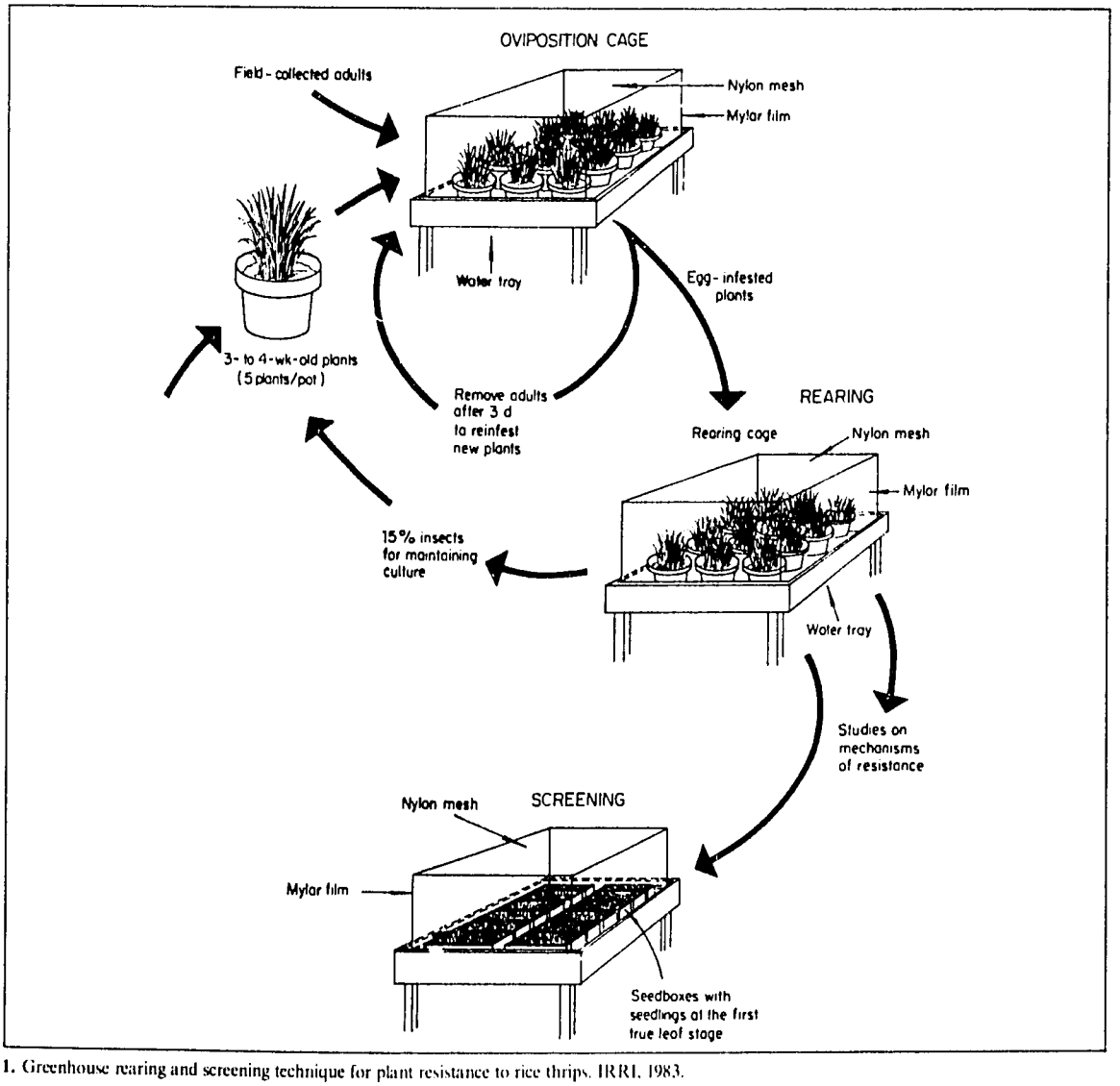
Rice varieties were evaluated by a new rating scale (Table 1). Eleven of 79 traditional varieties and 12 of 85 wild rices were selected for resistance (Table 2).

Leaffolder. With a new LF rearing and screening method for identifying resistant varieties (Fig. 2), 5 of 5,908 germplasm accessions were selected as moderately resistant to LF and 1 as resistant (Table 3). Of 17,914 accessions screened through 1983, 116 were resistant or moderately resistant to LF.

NATURE OF RESISTANCE

Entomology Department

Thrips. Studies of resistance mechanisms show that thrips usually did not prefer resistant varieties for feeding and oviposition (Fig. 3). Fewer larvae survived (Table 4) and adult life-spans were shorter on resistant than on susceptible varieties (Table 5).



1. Greenhouse rearing and screening technique for plant resistance to rice thrips. IRRI, 1983.

Table 1. Rating scale used in evaluating rice cultivars and species against thrips. IRRI greenhouse, 1983.

Scale	Reaction[a]	Damage
1	HR	Rolling of terminal 1/3 area of 1st leaf only.
3	R	Rolling of terminal 1/3 to 1/2 area of 1st and 2d leaves.
5	MR	Rolling of terminal 1/2 of 1st and 2d leaves. Scorching of less than 30% of the leaf surface.
7	S	Rolling of entire length of all leaves. Scorching of 30-60% of the leaf area. Wilting not pronounced.
9	HS	Rolling of entire length of all leaves. Scorching of more than 60% of the leaf area. Wilting of leaf tips.

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

Resistant varieties also had an adverse effect on fecundity and oviposition rate, resulting in low population growth (Table 6). Plant injury on susceptible varieties resulted in low plant height and weight.

Whorl maggot resistance in wild rices. About 300 wild rice accessions were screened in the field for RWM resistance. Those selected were retested, and succeeding selections were evaluated in the greenhouse to determine their resistance mechanisms. IR40 was used as the moderately resistant check and IR36 and TN1 as susceptible checks. No resistant check has been identified in *Oryza sativa*.

The tests indicated very high levels of resistance to the RWM in wild rices, which were not preferred for oviposition (Table 7). Only 2 eggs were laid on *O. brachyantha* accession 101232 while more than 300 were laid on the checks. Damage was low on most of the wild rices, and larval survival was 0% on several.

Resistance of Indonesian radiated mutant lines to the brown planthopper. Seven mutant rice lines from the National Atomic Energy Agency, Jakarta, Indonesia, were tested at IRRI for resistance to BPH. The lines, which had been derived from a BPH-susceptible variety Pelita I/1, were Atomita 1, 627/10-3/PsJ, Atomita 2, and 627/4-E/Psj derived from a Pelita I/1, irradiated with 0.2 k Gy of gamma rays; and A227/2/PsJ, A227/3/Psj, and A227/5/PsJ, derived from an early-maturing mutant of Pelita I/1 and irradiated with 0.1 k Gy of gamma rays. Seedbox screening for plant damage and population growth tests measured BPH resistance levels.

The Indonesian mutant lines were resistant to moderately resistant to biotypes 1 and 3 but susceptible to biotype 2. The mutant lines had moderate resistance to GLH and WBPH compared to the susceptible check TN1.

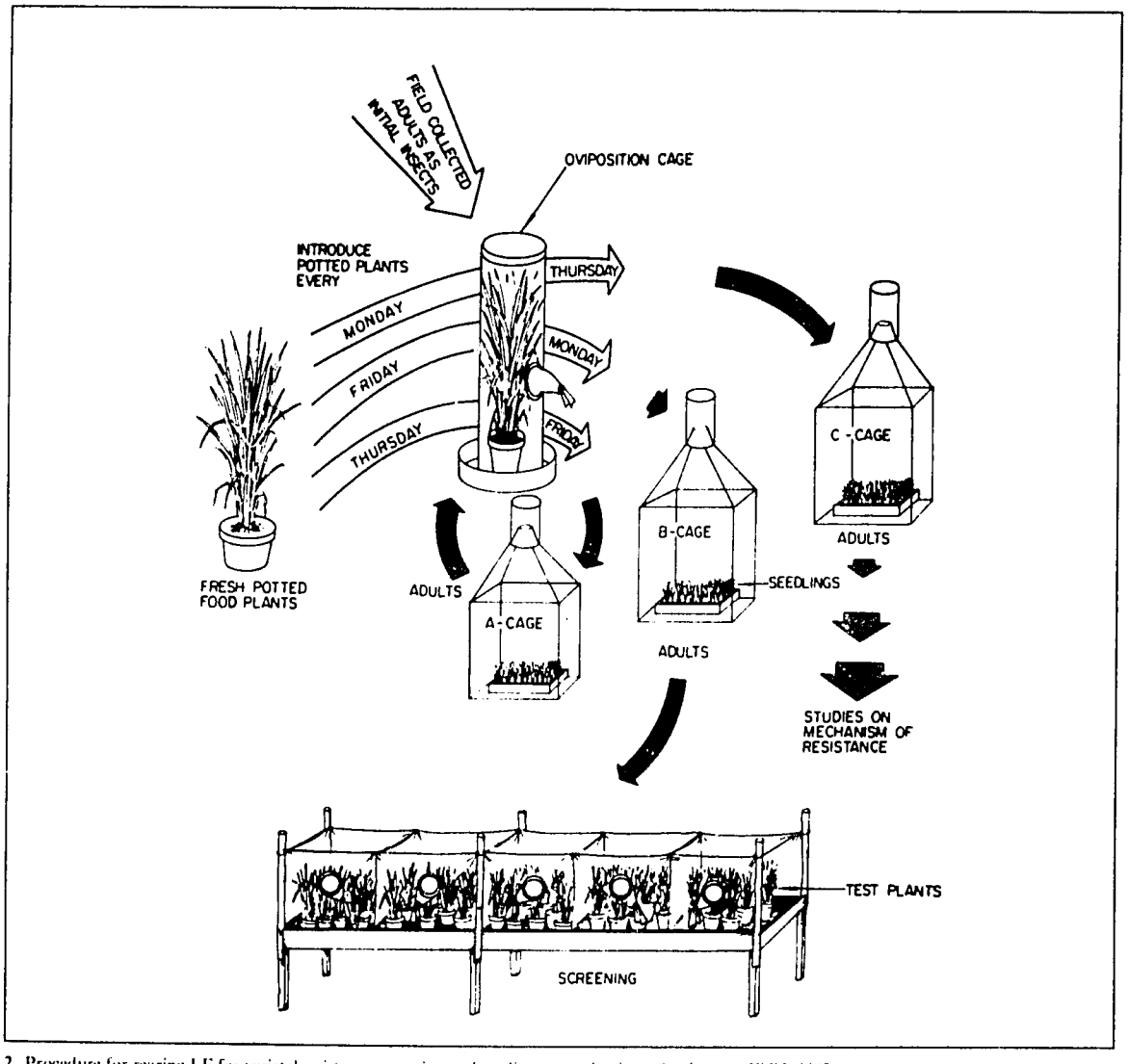
Atomita 2 has been released for commercial cultivation in Indonesia. In addition to its resistance to BPH biotypes 1 and 3, it has high yield potential, salt tolerance, and good eating quality.

Green leafhopper feeding and rice tungro virus infection. The feeding activity of GLH on susceptible, moderately resistant, and resistant IR varieties was compared with RTV infection (Table 8). The percentage of basic honeydew spots, an indication of phloem feeding, was most closely related to percentage of RTV infection. In susceptible IR22, 100% phloem feeding resulted in 99% RTV infection. The low percentage of phloem feeding in IR29 (10%) resulted in low (14%) RTV infection. Even though total feeding, as indicated by area of honeydew spots, was high on IR29,

Table 2. Rice cultivars and wild species found resistant to thrips based on their performance at IRRI and in other countries. 1983.

Species, cultivars	IRRI accession no.	Resistance rating[a]	Origin
O. sativa			
ASD 7	06303	3	India
BJ1	00256	3	Bangladesh
BJ1	03711	3	Bangladesh
Dahanala 682	50729	3	Sri Lanka
Dahanala 2220	50730	1	Sri Lanka
Gonabaru	07809	3	Sri Lanka
Heenati	08964	3	Sri Lanka
Heenati	08921	3	Sri Lanka
Kalubalawee	07702	3	Sri Lanka
Kaluheenati	15568	3	Sri Lanka
Wanni Dahanala	11726	3	Sri Lanka
O. officinalis	100181	3	Burma
	100973	3	Philippines
	101073	3	Philippines
	101117	1	Philippines
	101155	1	Malaysia
O. eichingeri	101418	3	Uganda
	101422	3	Uganda
	101424	3	Uganda
O. minuta	101079	3	Philippines
	101083	3	Philippines
	101097	3	Philippines
O. nivara	100897	3	India

[a]On a scale of 0-9 in order of ascending susceptibility.



2. Procedure for rearing LF for varietal resistance screening and studies on mechanism of resistance. IRRI, 1983.

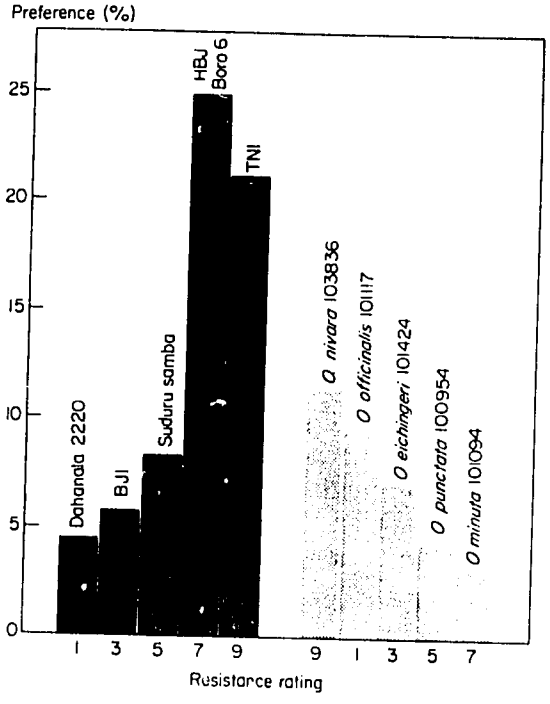
RTV was low. This indicates that feeding must occur in the phloem, not the xylem, for RTV to occur. Feeding is restricted to the xylem on resistant varieties.

Table 3. Data on germplasm collection varieties R or MR to LF. IRRI, 1983.

IRRI accession no.	Name	Origin	Rating
54369	Acheh 62	Malaysia	5
54440	Hema	Malaysia	3
54645	CH5	India	5
55059	ADT8	India	5
55111	Kighuwela	India	5
54444	Itan Empati	Malaysia	5

Leaffolder. Varieties with different levels of resistance to LF, based on damage ratings in greenhouse screening, were studied to determine their resistance mechanisms. Females did not prefer resistant varieties for oviposition, and larvae had antibiosis as indicated by pupal weight (Table 9).

Yield losses to striped stem borer compared to resistance level. SSB resistance level is based on percent deadhearts in screenhouse tests when plants are infested at 30 DT. On a 0-9 scale varieties with ratings 0-3 are considered resistant; 5, moderately resistant; and 7-9, susceptible. The value of resistance levels in preventing yield loss had not



3. Preference, based on the percentage of insects that settled on each entry at 48 HAI, of adult thrips for varieties and wild species with different resistance (damage) ratings. IRRI, 1983.

been previously tested. In 1983, varieties with different resistance levels to SSB were evaluated for yield loss at various populations 30 DT.

Resistant varieties IR36 and IR40, moderately resistant IR52 and IR54, and susceptible IR29 and IR46 were infested with three levels of SSB larvae. Percent deadhearts was highest in the susceptible varieties (Table 10). Yield loss increased as number of larvae per hill increased (Table 11). Yield losses were highest in susceptible varieties followed by the moderately resistant. At the high rate of 20 larvae/hill, yield decreased only 34% in resistant IR36, but 87% in susceptible IR46. Yield loss was related to screenhouse ratings for SSB resistance.

Table 4. Survival of thrips larvae on R and S varieties and wild species.[a] IRRI insectary, 1983.

Species, cultivars	IRRI accession no.	Damage rating	Larval survival (%)
O. sativa			
Dahanala 2220	50730	HR	9.33 c
BJ1	00256	R	7.33 c
Suduru Samba	11671	MR	20.70 b
HBJ Boro 6	06439	S	27.30 b
TN1	–	HS	32.00 a
O. officinalis	101117	HR	6.67 c
O. eichingeri	101424	R	4.67 c
O. punctata	100954	MR	4.67 c
O. minuta	101094	S	11.30 c
O. nivara	103836	HS	19.30 b

[a]Av of 5 replications with 6 subsamples each and 150 larvae/treatment.

SSB resistance in traditional and modern varieties. Resistant varieties IR20, IR36, and IR50 were compared with traditional varieties Peta and Intan for level of SSB resistance. Deadhearts on IR varieties were one-half that on Peta and Intan (Table 12). Insect survival, pupal and larval weight, and egg production were lowest on IR varieties, indicating that as food they were less suitable than traditional varieties. More males than females were produced on IR varieties, which greatly influences population size over several generations.

Table 5. Longevity, fecundity, oviposition, and hatchability of thrips on R and S *Oryza* spp. IRRI insectary, 1983.

Species, cultivar	IRRI accession no.	Longevity (d)		Fecundity[a] (eggs/female)	Oviposition (eggs/5 females per 3 d)	Hatchability[b] (%)
		Male	Female			
O. sativa						
Dahanala 2220	50730 (HR)	2.4 c	4.2 c	2.6 c	6.0 cd	84.9 a
BJ1	00256 (R)	4.0 b	6.6 b	3.1 c	9.8 abcd	85.5 a
Suduru Samba	11671 (MR)	3.8 b	7.4 a	7.1 b	11.8 abc	94.0 a
HBJ Boro 6	06439 (S)	5.6 a	7.2 a	9.1 ab	13.8 ab	87.4 a
TN1	– (HS)	5.6 a	7.8 a	11.4 a	15.4 a	94.1 a
O. officinalis	101117 (HR)	4.0 b	3.8 c	0.6 d	7.8 cd	93.3 a
O. eichingeri	101424 (R)	4.2 b	6.0 b	1.5 cd	6.8 cd	91.8 a
O. punctata	100954 (MR)	4.0 b	6.4 b	2.6 c	5.4 d	92.7 a
O. minuta	101094 (S)	3.8 b	6.4 b	4.0 c	8.4 bcd	82.1 a
O. nivara	103836 (HS)	5.0 ab	6.8 ab	3.8 c	7.6 cd	86.0 a

Av of 10 replications and 10 adult pairs/treatment. [b]Av of 5 replications and 25 adult pairs/treatment.

Table 6. Population growth of thrips on R and S *Oryza* spp. and its effect on plant weight and height at 14 DAI.[a] IRRI insectary, 1983.

Species, cultivar	IRRI accession no.	Population growth (no./female)	Plant wt (g)			Plant ht (cm)		
			Noninfested	Infested	Difference	Noninfested	Infested	Difference
O. sativa								
Dahanala 2220	50730 (HR)	3.4 a	2.35	2.23	0.12 ns	27.5	27.3	0.2 ns
BJ1	00256 (R)	9.6 ab	3.19	2.96	0.23 ns	22.5	23.1	−0.6 ns
Sudu:u Samba	11671 (MR)	15.4 c	4.03	3.93	0.11 ns	29.3	27.2	2.1*
HBJ Boro 6	06439 (S)	27.2 d	4.12	3.61	0.51*	26.3	23.2	3.1**
TN1	– (HS)	25.0 d	3.27	2.51	1.76**	19.7	15.2	4.5**
O. officinalis	101117 (HR)	6.0 ab	2.13	2.32	−0.19 ns	17.2	18.5	1.3 ns
O. eichingeri	101424 (R)	5.2 ab	1.93	2.01	−0.08 ns	19.2	17.3	1.9 ns
O. punctata	100954 (MR)	6.2 ab	1.54	1.81	−0.27 ns	21.3	22.1	−0.8 ns
O. minuta	101094 (S)	4 6 a	2.41	2.08	0.33 ns	15.3	13.5	1.8 ns
O. nivara	103836 (HS)	14.6 c	2.72	2.08	0.64*	21.3	19.2	2.1*

[a]Av of 5 replications.

Table 7. Resistance of wild rices to RWM *Hydrellia philippina*.[a] IRRI greenhouse, 1983.

IRRI accession no.	Species, variety	Eggs[b] (no./pot)	Damage rating[c] (visual)	Plant damage[d] (%)	Larval survival[d] (%)
101232	*O. brachyantha*	2.3 s	1.0 e	0 t	0 i
101235	*O. brachyantha*	2.5 s	1.0 e	5 st	0 i
101084	*O. minuta*	3.5 q--s	5.5 b	90 ab	90 ab
100125	*O. punctata*	3.5 q--s	3.0 c--e	20 k--t	10 g--i
100161	*O. alta*	3.8 p--s	1.0 e	55 d--h	0 i
101234	*O. brachyantha*	4.3 rs	1.0 e	5 st	0 i
101392	*O. latifolia*	4.5 n--r	1.0 e	31 f--n	5 hi
100884	*O. punctata*	5.3 l--r	3.0 c--e	25 g--p	15 f--h
101395	*O. alta*	5.8 j--r	1.0 e	13 n--t	0 i
101236	*O. brachyantha*	6.0 k--r	1.0 e	5 st	0 i
100181	*O. officinalis*	6.0 k--r	4.5 b--d	66 c--g	20 e--g
100964	*O. latifolia*	6.8 j--q	3.0 c--e	26 g--p	10 g--i
101233	*O. brachyantha*	7.0 j--q	1.0 e	5 st	0 i
100126	*O. punctata*	7.3 j--q	2.0 de	20 k--t	5 hi
101439	*O. punctata*	7.8 i--p	2.0 de	25 g--q	20 e--g
100885	*O. latifolia*	8.3 h--n	1.0 e	24 j--t	10 g--i
100172	*O. latifolia*	9.3 g--n	1.0 e	38 f--n	20 e--g
101234	*O. brachyantha*	9.8 f--n	1.0 e	5 st	0 i
100965	*O. latifolia*	11.3 e--l	3.0 c--e	70 b--e	45 d
100891	*O. latifolia*	11.8 e--l	2.5 c--e	60 c--h	25 d--f
100962	*O. latifolia*	11.8 e--l	2.5 c--e	30 f--n	15 f--h
100890	*O. latifolia*	11.8 e--l	1.0 e	50 f--j	40 de
100887	*O. minuta*	12.8 e--m	2.5 c--e	54 e--h	30 d--f
101417	*O. punctata*	12.8 e--m	1.5 e	45 f--i	30 d--f
100168	*O. latifolia*	13.8 e--l	1.0 e	45 f--i	20 e--g
101231	*O. brachyantha*	14.5 d--i	1.0 e	5 st	0 i
101434	*O. punctata*	14.8 d--i	1.0 e	85 a--d	20 e--g
101378	*Oryza* spp.	14.8 d--i	1.0 e	10 l--t	0 i
100966	*O. latifolia*	16.0 d--h	5.0 bc	70 b--e	20 e--g
100963	*O. latifolia*	17.8 c--g	2.5 c--e	20 k--t	10 g--i
100169	*O. latifolia*	18.0 c--f	1.0 e	65 e--g	25 d--f
100895	*O. latifolia*	21.8 c--e	3.0 c--e	40 f--l	20 e--g
101167	*O. ridleyi*	28.8 cd	3.5 b--e	70 b--f	30 d--f
101397	*O. australiensis*	29.0 cd	1.0 e	35 f--n	10 g--i
101443	*O. latifolia*	35.5 c	5.0 bc	80 ab	75 c
100882	*O. australiensis*	79.8 b	1.0 e	20 k--t	0 i
101410	*O. australiensis*	95.8 b	1.0 e	5 st	0 i
36958	IR40, *O. sativa* (MR check)	302.5 a	5.0 bc	100 a	85 bc
30416	IR36, *O. sativa* (S check)	360.8 a	9.0 a	100 a	100 a
105	TN1, *O. sativa* (S check)	335.5 a	9.0 a	100 a	100 a

[a]Av of 4 replications. [b]Population density of 25 RWM adults/pot infested inside a cage. Eggs were counted 48 HAI. [c]At 20 DAI with 25 adults/pot. Rating was based on a 0-9 scale: 0 = no damage, 9 = more than 1/2 of the leaves damaged with some leaves broken. [d]At 15 DAI, percent damaged plants was determined by counting damaged tillers and larval survival (infested with 1 egg/plant) by dissecting the plants.

Table 8. GLH feeding activity and RTV infection on S, MR, and R rice varieties. IRRI, 1983.

Variety	Feeding punctures (no.)	Area of honeydew spots (mm^2)	Basic honeydew spots (%)	Tungro infection (%)
IR8 (MR)	82 c	188 b	49 b	75.7 b
IR22 (S)	45 d	228 a	100 a	99.0 a
IR24 (MR)	125 a	179 b	52 b	71.0 b
IR29 (R)	88 bc	197 ab	10 c	14.4 d
IR40 (MR)	110 ab	172 b	43 b	42.9 c

Table 9. Varietal resistance to LF. IRRI, 1983.

Variety	Damage rating	Eggs (no./pot)	Preference (larvae/plant)	Pupal wt (mg)
ARC10560	7.4 a	350 bcd	2.8 a	20.05 a
ARC6650	7.4 a	341 bcd	2.5 ab	18.84 ab
ASD5	3.4 b	218 d	1.4 cd	17.13 bc
ASD11	3.4 b	480 abc	1.0 d	19.05 ab
BKNBR-1008-21	4.6 b	427 bcd	2.9 a	16.57 c
TKM6	3.4 b	277 cd	1.4 bcd	15.22 c
IR36	9.0 a	539 ab	1.5 bcd	19.79 a
Ptb 33	3.4 b	211 d	2.0 abc	17.13 bc
TN1 (susceptible check)	9.0 a	876 a	2.9 a	20.06 a

Table 10. Percent deadhearts in rice varieties with different resistance levels and various populations of SSB at 30 DT. IRRI greenhouse, 1983.

Larvae/ hill	Deadhearts[a] (%)					
	IR36 (R)	IR40 (R)	IR52 (MR)	IR54 (MR)	IR29 (S)	IR46 (S)
0	0.0 c (a)	0.0 d (a)	0.0 c (a)	0.0 c (a)	0.0 c (a)	0.0 d (a)
5	27.5 b (b)	25.1 c (b)	28.4 c (b)	28.8 b (b)	45.4 b (a)	43.7 c (a)
10	29.6 b (c)	29.9 b (c)	39.2 b (b)	34.1 b (bc)	48.4 b (a)	50.5 b (a)
20	38.0 a (c)	35.3 a (c)	47.9 a (b)	45.0 a (b)	67.4 a (a)	63.2 a (a)

[a]Letters in parentheses indicate separation of means in a row.

Table 11. Grain weight loss of rice varieties with different resistance levels when infested with various populations of SSB. IRRI screenhouse, 1983.

Variety	Grain wt loss (%)			
	5 larvae/ hill	10 larvae/ hill	20 larvae/ hill	Mean
IR36 (R)	8.0	24.5	33.5	22.0 c
IR40 (R)	17.7	28.6	31.9	26.1 c
IR52 (MR)	54.5	65.8	67.0	62.5 b
IR54 (MR)	46.2	57.3	63.5	55.7 b
IR29 (S)	69.1	84.7	90.2	81.3 a
IR46 (S)	63.7	72.8	87.4	74.6 a

Plant age effect on yellow stem borer resistance. IR46 is considered susceptible based on screenhouse evaluation where plants are infested with YSB larvae at 30 DT. When plants were infested with 5 YSB larvae at 39, 54, 69, and 84 DT, most significant yield losses occurred at 39 and 84 DT (Fig. 4). There was no yield loss at 54 DT, even at 800 YSB larvae/36 hills. Yield losses at 69 DT were low. Yield loss at 39 and 84 DT was partially due to the high percentage of unfilled grains.

Technique for demonstrating phloem or xylem feeding by leafhoppers. To monitor the feeding

Table 12. Percent deadhearts and response of SSB reared on IR varieties and traditional varieties. IRRI screenhouse, 1983.

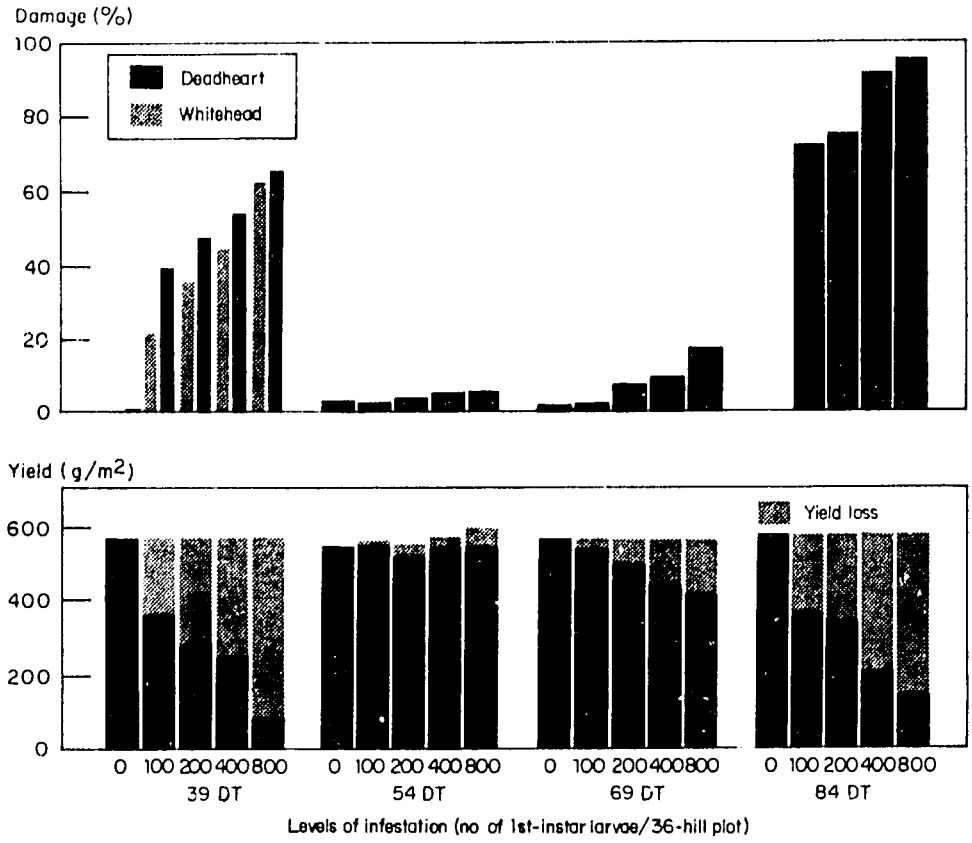
Variety	Deadhearts (%)	Survival (%)	Pupal wt (mg)	Larval wt (mg)	Egg masses (no./female)	Eggs (no./egg mass)	Males[a] (%)
IR20	30.6 c	74 a	52.8 bc	45.0 c	2.9 b	40.2 b	60.6** a
IR36	33.3 c	78 a	53.5 b	47.9 b	3.4 a	41.3 b	60.3** a
IR50	31.4 c	70 b	50.2 c	43.3 c	2.7 b	30.1 c	62.9** a
Peta	62.8 b	87 a	63.7 a	50.2 a	3.9 a	49.6 a	49.1ns b
Intan	66.9 a	88 a	64.6 a	50.5 a	3.8 a	49.4 a	45.5ns b

[a]** = significantly different from 50% at 1% level, ns = not significantly different from 50% at 5% level.

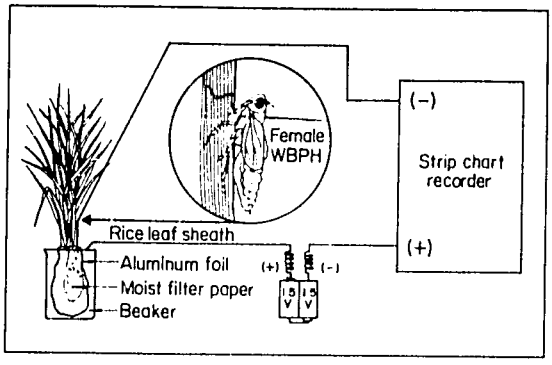
behavior of GLH, BPH, and WBPH in susceptible and resistant rice varieties, a simple technique using a lignin-specific dye that selectively translocates in xylem vessels was tested.

Roots of TN1, a variety susceptible to all three hopper species; ASD7, resistant to GLH and BPH; and IR2035-117-3, resistant to WBPH, were immersed in an aqueous solution of 0.2% safranine "O" for about 6 h. The translocated dye colored the seedling xylem vessels red. Ten hoppers of each species were then released in mylar cages on the seedlings. The honeydew they excreted dropped onto filter paper discs and was readily absorbed. Red honeydew spots indicated xylem feeding by hoppers on the safranine-treated seedlings. When filter paper discs from untreated seedlings were treated with a 0.1% ninhydrin-acetone solution, bluish amino acid spots indicated phloem feeding.

GLH proved to be primarily a phloem feeder on susceptible TN1, although occasionally it sucked



4. Reaction of IR46 at different growth stages when exposed to different YSB populations. IRRI, 1983 WS.



5. Diagram of circuit and equipment for recording WBPH feeding. IRRI, 1983.

small amounts of xylem sap. On resistant ASD7, the hopper switched to xylem feeding but also did some phloem feeding, evidenced by amino acid traces in the honeydew.

BPH and WBPH were only phloem feeders on both susceptible and resistant varieties and consumed less on resistant than on susceptible plants.

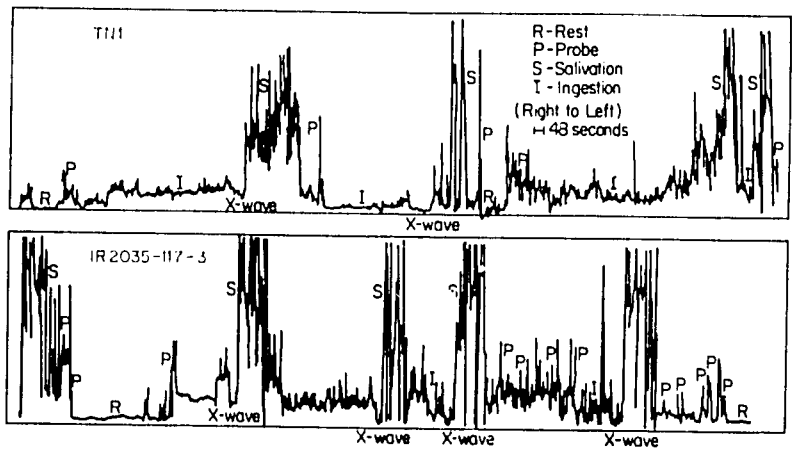
Electronically recorded waveforms associated with feeding behavior of whitebacked planthopper. To determine WBPH feeding activity on susceptible and resistant varieties, a 10-cm, fine (20μ) copper wire was attached to the dorsum of an 8- to 10-h-old brachypterous female by Duco cement and a small quantity of EKG electrolyte paste. The insect was starved for 2 h and then placed on the leaf sheath of 45-d-old plants of susceptible TN1 or resistant IR2035-117-3. The copper wire was connected to the negative input terminal of a transistorized, automatic, and null-balancing DC chart recorder. The voltage source consisted of two 1.5 penlight batteries connected in a series. The positive terminal of the battery was connected with the leaf sheath substrate through aluminum foil and moistened filter paper (Fig. 5). The recorder pen was adjusted to the base line of the chart and the insect's feeding activity was monitored for 60 min. Probing, salivation, and ingestion registered distinct sequences of waveforms during feeding on the two varieties (Fig. 6). Feeding patterns suggest that WBPH ingests mainly phloem sap of both susceptible and resistant varieties.

The waveforms showed that insects probed readily and fed longer on the susceptible variety but made brief repeated probes on the resistant variety, reducing effective feeding time.

CHEMICAL BASES OF RESISTANCE

Entomology and Chemistry Departments

Brown planthopper. The seedling dip bioassay technique was used to monitor factors for BPH resistance in extracts of rice seedlings at maximum tillering. Extraction and solubility fractionation of fresh or frozen rice plants and their steam distillates confirmed the presence of resistance factors in all susceptible and resistant rice samples in the relatively nonpolar fractions eluted by hexane and diethyl ether. Crude oils obtained by steam distillating leaf sheaths from plants 45-60 DT of 3 susceptible and 7 resistant rices showed the same trend.



6. Waveforms recorded with an electronic monitoring device during WBPH feeding on susceptible TN1 and resistant IR2035-117-3. IRRI, 1983.

Striped stem borer. Gas chromatography of plant extracts can estimate the oviposition deterrent Compound A in TKM6 plants. Variable levels have been observed on TKM6 and Rexoro plants of the same age but sown at various dates. To find out what influences the Compound A level, four rices differing in SSB resistance were grown in pots in the phytotron. At 50 DT, only resistant TKM6 showed significantly higher Compound A level at 12 h daylength and 50 klux light intensity than at 10- and 14-h daylength and 25 klux light intensity. TKM6 and, to a limited extent, IR20 had a higher Compound A level 60 DT at 26° C day/ 18° C night temperatures than at 29°/21°C and 35°/27°C. This was not true of Rexoro and IR1514A-E666.

Compound A contents of whole TKM6 and Taitung 16 plants were estimated at 10-d intervals from 10 DT to maturity at 90 DT. Compound A level decreased sharply up to 40 DT, coinciding with maximum tillering. TKM6 had a higher level of Compound A than Taitung 16, but both varieties showed identical trends.

COLLABORATIVE PROJECTS

Entomology and Plant Breeding Departments

Green leafhopper. GLH-resistant varieties were evaluated against local GLH populations at IRRI, and in India, Indonesia, Malaysia, and Thailand. Population virulence was based on damage ratings in the seedbox screening test and on percentage of insect survival. Most varieties responded similarly in the seedbox test in different locations (Table 13). However, Pankhari 203 having the *Glh 1* gene was susceptible in India and Malaysia but resistant or moderately resistant at other locations. IR8 was susceptible in Malaysia and moderately resistant at other sites. Moddai Karuppan was moderately

Table 13. Damage ratings of seedlings in seedbox screening for GLH resistance. GLH Collaborative Project, 1983.

Variety	Gene	Reaction at					
		IRRI	India	Indonesia	Malaysia	Thailand[a]	
						1	2
Pankhari 203	*Glh 1*	R	S	R	S	MR	MR
ASD7	*Glh 2*	R	MR	R	R	R	R
IR8	*Glb 3*	MR	MR	MR	S	MR	MR
Ptb 8	*glh 4*	MR	R	MR	R	R	R
ASD8	*Glh 5*	R	MR	R	R	MR	MR
TAPL #796	*Glh 6*	MR	MR	MR	R	R	MR
Moddai Karuppan	*Glh 7*	MR	R	R	R	R	R
IR29 (resistant check)	–	R	R	R	MR	MR	R
TN1 (susceptible check)	–	S	S	S	S	S	S

[a]1 = Rice Division, 2 = Entomology and Zoology Division.

Table 14. Survival of GLH at different locations. GLH Collaborative Project, 1983.

Variety	Gene	Survival[a] (%)			
		IRRI	Indonesia	Malaysia	Thailand[b]
Pankhari 203	*Glh 1*	2 c	0 c	4 c	66 bc
ASD7	*Glh 2*	8 bc	32 b	6 bc	40 cd
IR8	*Glh 3*	24 b	42 b	28 a	78 ab
Ptb 8	*glh 4*	76 a	40 b	2 c	58 bcd
ASD8	*Glh 5*	14 bc	2 c	2 c	72 b
TAPL #796	*Glh 6*	28 b	32 b	12 abc	38 cd
Moddai Karuppan	*Glh 7*	74 a	34 b	6 bc	32 d
IR29 (resistant check)	–	0 c	0 c	4 c	80 ab
TN1 (susceptible check)	–	80 a	74 a	28 a	94 a

[a]Av of 5 replications. [b]Rice Division.

Table 15. Damage ratings of varieties in seedling screening for WBPH resistance. WBPH Collaborative Project, 1983.

Variety	Gene	Reaction at					
		IRRI	India	Indonesia	Korea	Thailand	Vietnam
N22	*Wbph 1*	R	R	R	R	R	MR
ARC10239	*Wbph 2*	R	R	R	R	R	S
WC1240	*Wbph 1* + 1 recessive	R	R	R	R	R	MR
Colombo	*Wbph 2* + 1 recessive	R	R	R	R	R	MR
IR2035-117-3	*Wbph 1* + *Wbph 2*	R	R	R	MR	R	MR
TN1	None	S	S	S	S	S	S

resistant at IRRI and resistant at other locations. In the insect survival test, Pankhari 203 appeared resistant in Malaysia (Table 14). Survival was high on Moddai Karuppan at IRRI and low at the other locations. Survival on the resistant check IR29 was high in Thailand and low at other locations. GLH populations differ in virulence on resistant varieties depending on the country.

Whitebacked planthopper. Seedbox reactions of varieties with genes for WBPH resistance were similar at all locations in South and Southeast Asia. However, ARC10239 was resistant in all locations except Vietnam although insect survival there was low (Table 15).

INHERITANCE OF RESISTANCE

Plant Breeding and Entomology Departments

A new gene for resistance to whitebacked planthopper. The ongoing program studying inheritance of resistance to WBPH investigated 15 additional resistant varieties. Susceptibility to WBPH was studied in F_1 and F_2 populations and F_3 progenies from their crosses with susceptible TN1. Results showed that single dominant genes confer resistance in Boegi Boera, DD4, PI 184675-7, Siam Garden, Rening, N'Diang Marie, Manggar, Oha, Gokhue Saier, Tjempo Tolo, and Nemai. Two independent dominant genes govern resistance in ARC5752, Chaia Anaser, Katuyhar Dhan, and Dhera Dun Basmati.

Tests for allelism with known WBPH resistance genes revealed that the single dominant genes in Boegi Boera, DD4, PI 184675-6, Siam Garden, Rening, Oha, Gokhue Saier, Tjempo Tolo, and Nemai, and one of the two independent dominant genes in ARC5752, Chaia Anaser, Katuyhar Dhan, and Dhera Dun Basmati are allelic to *Wbph 1*. The second gene in ARC5752 is allelic to *Wbph 2*. The second gene of Chaia Anaser, Katuyhar Dhan, and Dhera Dun Basmati is allelic to *Wbph 3*. The dominant genes of N'Diang Marie and Manggar segregated independently of *Wbph 1*, *Wbph 2*, and *Wbph 3*. The dominant gene of N'Diang Marie was designated *Wbph 5*. The allelic relationships of the dominant gene of Manggar to *Wbph 5* are not known.

CYTOLOGICAL VARIATIONS AMONG BPH BIOTYPES 1, 2, AND 3, AND A GRASS-INFESTING BIOTYPE

Entomology Department

Studies were made of the cytological-cytogenetic aspect of BPH biotypes 1, 2, and 3 that are specific to rice and another biotype specific to *L. hexandra* grass. Specificity of populations to their host variety or species is strong, and individuals die soon when caged on nonhosts.

The cytology of the rice and the grass biotypes showed that they shared a prereductional meiosis. The first and second meiotic divisions were reductional and equational for all components of the species' genome. The male diploid number was constant among the four biotypes, 2n = 30, consisting of 14 bivalent autosomal pairs and XY sex chromosomes. Thus, BPH has an XY sex-determining mechanism. Males are heterogametic (14 II A + XY), producing two types of secondary spermatocytes, 14 I A + X and 14 I A + Y. Females are homogametic (14 II A +XX), producing a single type of secondary oocyte, 14 I A + X. Likewise, chromosomal behavior (orientation, broad spindle attachment, parallel anaphasic disjunction, and normal segregation of X and Y chromosomes) indicates that BPH chromosomes

Table 16. Variation[a] in nuclear and chromosome measurements of BPH biotype 1, biotype 2, biotype 3, and a grass-infesting biotype during prophase I. IRRI, 1981-83.

Prophase I (substages)	Biotype 1	Biotype 2	Biotype 3	Grass-infesting biotype
Leptonema (Nuclei:aml and amw) ns	31.75μ and 26.50μ intermediate	29.90μ and 24.00μ lowest	30.50μ and 24.75μ intermediate	38.20μ and 30.60μ highest
Zygonema (Autosomes) (Sex chromosomes)	No difference	No difference	No difference	No difference
Pachynema (Autosomes rml) (Sex chromosomes rml) ns	11.11 mm, lowest 6.50 mm, lowest	12.43 mm, intermediate 9.00 mm, highest	13.17 mm, intermediate 7.00 mm, intermediate	15.50 mm, highest 7.00 mm, intermediate
Diplonema (Autosomes aml)[b] (Sex chromosomes aml)	5.92μ, lowest 7.50μ	8.08μ, highest 5.00μ	7.08μ, intermediate, 5.00μ	Negatively pycnotic
Diakinesis (Chromosomes aml)[c]	4.35μ, highest	3.77μ, intermediate	3.39μ, intermediate	3.25μ, lowest

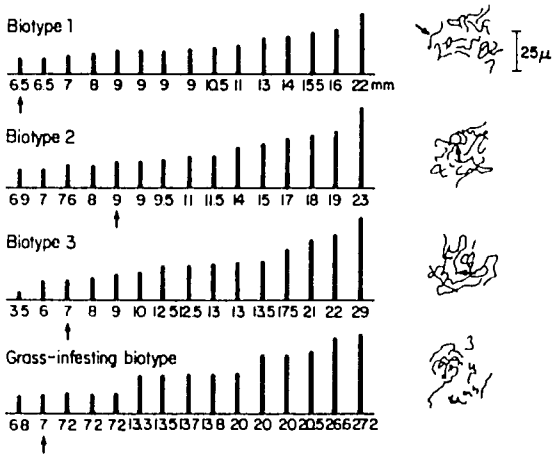
[a]Differences in absolute mean length (aml), absolute mean width (amw) and relative mean length (rml). [b]Biotype 1 was significantly different from biotypes 2 and 3; biotypes 2 and 3 did not significantly differ from each other at the 5% level by analysis of variance and Duncan's multiple range test. [c]Biotype 1 significantly differed from biotype 3 and the grass-infesting biotype but not from biotype 2; biotype 2 did not significantly differ from biotype 3 and the grass-infesting biotype at the 5% level. ns = not significant at the 5% level.

during gonial meiosis are holokinetic or possess the typical diffuse centromeres.

Salient variations were detected in nuclear chromosome measurements during different stages of prophase I (Table 16). Despite numerical variations among populations, statistically significant differences were observed only during diplonema and diakinesis. During pachynema, which provides the most favorable material for characterizing chromosome lengths, the karyotypes and idiograms of 15 bivalent chromosomes varied in length (Table 16, Fig. 7).

The following observations were noteworthy in the four biotypes:

1. The most metaphase I cells were detected in biotype 1, followed by biotype 3 and biotype 2; the grass-specific biotype had the fewest.
2. Biotype 1, biotype 3, and the grass-specific biotype revealed two types of metaphase I cells: those with sex chromosomes isolated from autosomes and cells with both chromosome types together. Biotype 2 showed only the first type of cells.
3. The average distance of the sex chromosomes from autosomal grouping was highest in biotype 2, almost twice that of biotype 1. Biotype 3 and the grass-specific biotype ranked next.
4. Biotype 1 had more cells with combined autosomes and sex chromosomes than biotype 3 or the grass-infesting biotype did. Intra- and interchiasmatic connections were higher in homologues of biotype 1 than of biotype 3 or the grass-infesting biotype.
5. The sex chromosomes of the four biotypes varied in length and width with biotype 2 having the longest chromosomes followed by biotype 3 and the grass-infesting biotype. Biotype 1 and biotype 3 had almost equal



7. Karyotypes and idiograms of the bivalent pachytene chromosomes of BPH biotypes. Arrows indicate sex chromosomes. IRRI, 1981-83.

girth, and the grass-specific biotype had the narrowest X and Y chromosomes.

The four biotypes can be ranked in genetic versatility: biotype 1 > biotype 3 > biotype 2 > grass-specific biotype. In genetic stability they would be grass-specific biotype > biotype 2 > biotype 3 > biotype 1.

Considerable genetic variation exists in BPH biotypes which are apparently morphologically alike. The cytological variations among the biotypes indicate that they are generating de novo genetic isolating mechanisms. Those variations further support the observed subtle differences in BPH behavior, physiology, and morphology.

Comparative cytology of field populations of brown planthopper infesting grass and rice. BPH were observed thriving on grass weed *L. hexandra* along irrigation canals at IRRI. The population was unique in its strong preference for the weed host and individuals died when caged on rice plants. It was considered a primitive, nonvirulent BPH biotype. To ascertain its taxonomic status, its cytology was studied and compared with that of the rice-infesting field population. Testicular cells of brachypters from grass and rice hosts were examined using the standard cytological techniques.

Table 17. Variations in relative mean length of pachytene chromosomes of BPH biotypes infesting field rice and grass hosts. IRRI, 1982-83.

Autosome no.	Relative chromosome length (mm)				Difference[a]
	BPH (grass)		BPH (rice)		
	$\bar{x}$	SEM	$\bar{x}$	SEM	
1	10.0	0.00	18.0	1.61	- 8.0**
2	10.3	0.21	22.3	1.26	-12.0**
3	10.4	0.27	25.3	1.17	-14.9**
4	10.4	0.27	28.2	1.89	-17.8**
5	11.0	0.36	29.5	1.56	-18.5**
6	20.0	0.00	30.7	1.43	-10.7**
7	20.3	0.21	32.7	1.84	-12.4**
8	20.5	0.22	35.3	0.80	-14.8**
9	21.0	0.06	38.4	1.87	-17.4**
10	30.0	0.00	40.3	1.82	-10.3**
11	30.0	0.00	42.7	1.71	-12.7**
12	30.2	0.17	47.5	2.20	-17.3**
13	30.8	0.17	51.2	2.33	-20.4**
14	40.0	0.00	54.5	2.79	-14.5**
15	40.7	0.21	64.2	2.31	-23.5**

[a]** = significant at the 1% level, av of 6 samples.

The two populations varied substantially during the pachytene stage (Table 17). Karyotypes and idiograms of the two populations show clear individual chromosomes of different relative mean lengths (rml). For instance, the chromosome with the nucleolus organizing region (site of ribosomal RNA synthesis) measured 47.20 mm for the rice BPH and 20.75 mm for the grass BPH. The rice insects had longer chromosomes than the grass insects. The nucleolar organelle in rice BPH was either a darkly stained body or two fused nucleoli, but in the grass BPH, it was a densely stained ovoid body.

Chromosomal behavior was similar for both populations, except that the intensive coiling of chromosomes during diakinesis resulted in shorter and more heterochromatic chromosomes in rice BPH than in the grass BPH.

These cytological criteria may help characterize and differentiate the grass BPH from the rice BPH. The study also confirms that the grass BPH is unique and justifies its categorization as an additional BPH biotype.

INTRASPECIFIC HYBRIDIZATION BETWEEN RICE AND GRASS-INFESTING BROWN PLANTHOPPER BIOTYPES

Entomology Department

Hybridization trials were conducted between grass and rice BPH to determine biological and evolutionary relationships of the parental biotypes and to understand how host specificity could be transmitted to their progenies.

Genetic crosses between grass and rice BPH populations were made on the grass host and the respective rice plants (TN1 for biotype 1, Mudgo for biotype 2, and ASD7 for biotype 3) enclosed together in mylar cages. The cross between biotype 1 (Bl) and the grass-specific (BL) produced three generations of offspring and backcross progenies. The cross of a BL female and a Bl male had low successful mating frequency and low percentage of egg hatchability (Table 18). The reciprocal cross of a Bl female and a BL male had a high mating frequency and egg hatchability, but the survival of F_1 hybrids remained low. Some premating and postmating barriers exist between the two populations.

Host specificity was controlled by a single major

Table 18. Successful matings and oviposition and egg hatchability in crosses between and within biotype 1 (B1) and the grass-infesting biotype (BL).[a] IRRI, 1983.

Cross		Mating frequency (no.)		Eggs laid (no.)	Nymphs that emerged (no.)	Hatchability (%)
		Successful	Unsuccessful			
Female	*Male*					
B1	B1	10	0	588 a	520 a	94 a
BL	BL	10	0	160 b	154 a	95 a
B1	BL	9	1	506 a	436 a	81 a
BL	B1	4	6	108 b	56 b	27 b

[a]Av of 10 replications.

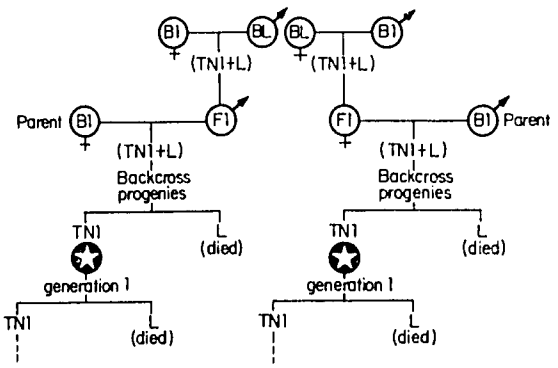
autosomal gene. Tests showed that the ability of the F_1 progenies to feed and survive on rice was dominant over that on grass. This dominance was observed up to generation 3 of the genetic cross and generation 1 of the backcross progenies (Fig. 8).

ENZYME POLYMORPHISM AMONG BROWN PLANTHOPPER BIOTYPES IN THE PHILIPPINES

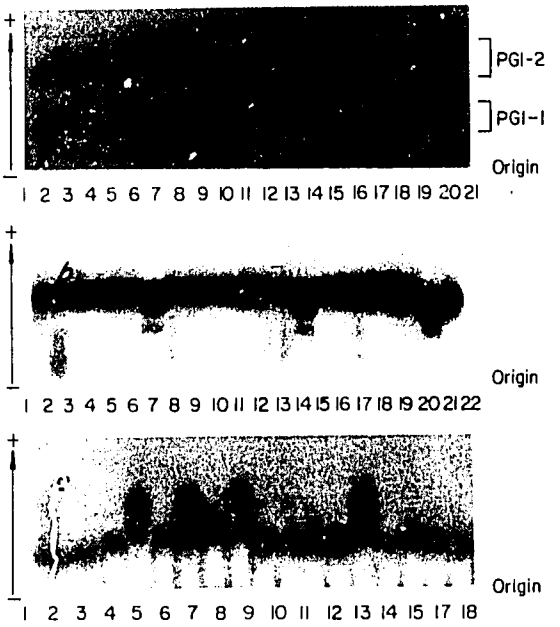
Entomology Department

Among the three BPH biotype populations, 18 enzymes were surveyed. Polymorphism was noted in 6 of 11 enzymes for which activity was detected. For all three biotypes, the variant enzymes indicated a high proportion of polymorphic loci (P), equal to 0.54. An enzyme was considered polymorphic when the most common allele had a frequency not greater than 0.99. The polymorphic enzymes were catalase, esterase, isocitrate dehydrogenase, malate dehydrogenase, malic enzyme, and phosphoglucose isomerase. Acid phosphatase, glucose kinase, glucose-6-phosphate dehydrogenase, leucine aminopeptidase, and phosphogluconate dehydrogenase were all monomorphic.

Phosphoglucose isomerase (PGI). Based on the zymogram pattern, PGI appears to be coded by two gene loci: Pgi-1 and Pgi-2 (Fig. 9). Both were polymorphic, but the analysis was restricted to the more anodal Pgi-2 because of the poor banding pattern of Pgi-1. Pgi-2 had three alleles designated as Pgi^{95}, Pgi^{100}, and Pgi^{105}, designated as 1, 2, and 3, respectively (Table 19). The banding pattern indicated that PGI is a dimer and heterozygotes formed a hybrid band in addition to the homozygote bands.



8. Scheme of direct, reciprocal, and backcrosses involving BPH biotype 1 (B1) and the grass-infesting biotype (BL). BPH were maintained on rice variety TN1, *Leersia hexandra* (L.), or a mixture of TN1 and *L. hexandra* (TN1 + L).



9. Electrophoretic phenotypes (left to right) of a) PGI-2: 1-6, 9, 15, 16, 18, 19 (100 105); 7, 12, 13, 17, 21 (100 100); 8, 10 (95 100); 11, 14, 20 (105 105); b) IDH: 1-6, 8-14, 16-21 (100 100); 7, 15, 22, (93 100); c) MDH: 1-4, 6, 8, 10-13, 15-17 (100 100); 5, 7, 9, 14 (100 109). IRRI, 1983.

Table 19. Allele frequencies in 3 protein loci of BPH biotype 1 and biotype 3. IRRI, 1983.

Locus	Biotype	Allele frequency			Heterozygosity[a] (H)
		1	2	3	
Pgi-2	1	0.018	0.583	0.398	0.38
	3	0.005	0.868	0.128	0.17
Idh	1	0.037	0.963	–	0.07
	3	0.003	0.997	–	0.006
Mdh	1	–	0.957	0.043	0.09
	3	–	0.997	0.003	0.006
					$\bar{H}1 = 0.068$
					$\bar{H}3 = 0.023$

[a]The 5 other invariant loci were included in the calculation of $\bar{H}$.

Isocitrate dehydrogenase (IDH). The IDH locus contained two alternative alleles, Idh^{93} designated as 1 and Idh^{100} designated as 2. The banding pattern indicated that IDH is a dimer and heterozygotes formed a hybrid band in addition to the homodimer bands (Fig. 9b).

Malate dehydrogenase (MDH). MDH had alternative allele 2, Mdh^{100}, and allele 3, Mdh^{109}. This hybrid was noted in heterozygotes, indicating that MDH is a dimer (Fig. 9c).

The allelic frequencies and heterozygosity of each of the three protein loci are presented in Table 19. Biotype 1 had a slightly higher mean heterozygosity of 0.068 than biotype 3 (0.023). This was due to the higher number of heterozygotes in Pgi than in Idh and Mdh. The last two were almost monomorphic in biotype 3. Biotype 1 exhibits more genetic variation than biotype 3.

CYTOGENETICS OF THE WHITEBACKED PLANTHOPPER

Entomology Department

WBPH chromosomes were holocentric: the kinetochores were diffused along the entire length of both autosomes and sex chromosomes. The diploid number in males was 2n = 29 while females had 2n = 30. The sex chromosome in each testicular cell was a univalent X body, 2μ long and 1 to 1.5μ wide. The oogonial cells had XX bivalents each measuring about 3μ long. The sex-determining mechanism was XX-XO type with males being heterogametic and females homogametic. The complete genome in males comprised 14 bivalent autosomes plus an X chromosome (Fig. 10), but females had 14 bivalent autosomes plus XX sex chromosomes.

10. Complete genome in male WBPH (2n = 14 II A+X). Sex chromosome is indicated by an arrow. IRRI, 1983.

INTEGRATION OF VARIETAL RESISTANCE AND INSECTICIDES FOR GREEN LEAFHOPPER CONTROL

Entomology Department

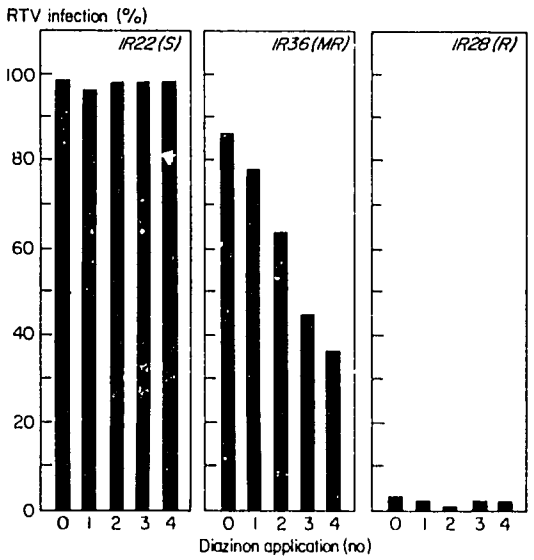
Two WS experiments in a farmer's field in Victoria, Laguna, and at IRRI tested GLH-susceptible IR22, moderately resistant IR36, and resistant IR28.

In the Victoria test, 3 rates of carbofuran (1.0, 1.5, and 2.0 kg ai/ha) were soil incorporated before transplanting. Even with high insecticide rates, GLH populations were high in the susceptible variety, intermediate in the moderately resistant, and low in the resistant. As a result, RTV infection was high on both untreated and treated plots of IR22. Gross profit was highest on IR28 and IR36. At the GLH population level in the study, there was no benefit from applying insecticide on the moderately resistant and resistant varieties. Net

Table 20. Rice yield and economics[a] of diazinon applications on rices with different levels of resistance to GLH. IRRI, WS 1983.

Diazinon applications[b] (no.)	Yield (t/ha)	Gross profit[c] ($)	Cost of insecticide application[d]	Net gain[e] ($)	Gain from insecticide[f] (%)	Benefit/ cost[g]
			IR22 (S)			
0	0.06 a	9	0	9	–	–
1	0.09 a	14	20	– 6	0	<1
2	0.22 a	35	40	– 5	0	<1
3	0.27 a	42	60	–18	0	<1
4	0.16 a	25	80	–55	0	<1
			IR36 (MR)			
0	0.69 bc	108	0	108	–	–
1	0.55 c	86	20	66	–42	<1
2	0.91 b	143	40	103	– 5	<1
3	1.27 a	199	60	139	31	<1
4	1.34 a	210	80	130	22	<1
			IR28 (R)			
0	2.64 b	415	0	415	–	–
1	2.88 ab	452	20	432	17	<1
2	3.00 a	471	40	431	16	<1
3	2.94 ab	462	60	402	–13	<1
4	2.88 ab	452	80	372	–43	<1

[a]Based on an exchange rate of 1 US$ = ₱14 in December 1983. [b]Granules broadcast at 1.5 kg ai/ha. One application was made at 1 DT, two applications at 1 and 11 DT, three at 1, 11, and 21 DT, and four at 1, 11, 21, and 31 DT. [c]Based on a rough rice price of US$ 157/t. [d]Cost of insecticide application = cost of insecticide + labor. [e]Net gain = gross from insecticide application. [f]Gain from insecticide = net gain of treatment minus net gain of control. [g]Gain from insecticide ÷ cost of insecticide application.



11. Percent RTV infection at 60 DT of varieties S, MR, and R to GLH when treated with diazinon applications broadcast at 1.5 kg ai/ha, at 1, 11, 21, and 31 DT. IRRI, 1983 WS.

gain increased when insecticide was applied on IR22.

RTV infection was higher on the IRRI farm (Fig. 11). None of the treatments controlled RTV on IR22. RTV decreased on IR36 as the number of insecticide applications increased. Insecticide was not needed on IR28 as RTV was only 3% in the untreated check due to the high level of GLH resistance.

Gross profit and net gain were highest in IR28 and intermediate in IR36.

When RTV pressure was low (Victoria test), there was some benefit from applying carbofuran on susceptible varieties. However, when RTV pressure was high (IRRI farm test), there was no benefit in applying diazinon on resistant, moderately resistant, or susceptible varieties (Table 20). More effective insecticides and application methods are needed to increase their profitability for controlling GLH and RTV.

Genetic evaluation and utilization (GEU) program

Nutritional value

Cereal Chemistry, Plant Breeding, and Statistics Departments

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EVALUATION TRIALS

Cereal Chemistry, Plant Breeding, and Statistics Departments

Since rice is the major protein source (30-80%) in the Asian diet, all promising lines have been monitored for brown rice protein (BRP) content to maintain their nutritional value.

Protein screening of replicated yield trials (*Cereal Chemistry, Plant Breeding, and Statistics*). Continued screening of the replicated yield trials for BRP monitored nutritional value of the promising lines. The correlation coefficient between rough rice yield and BRP was -0.44** ($n = 456$) for the 1982 WS crop and -0.33** ($n = 462$) for the 1983 DS crop. BRP and yield values for check varieties in WS were 8.9% and 4.6 t/ha for IR42, and 9.8% and 3.6 t/ha for IR36. In DS, BRP and yield values were 7.7% and 6.4 t/ha for IR42 and 8.4% and 6.2 t/ha for IR36. IR58 had 10.2% BRP and 3.4 t yield/ha in WS and 7.8% and 5.9 t/ha in DS.

Only IR18350-229-3 had yield (4.64 t/ha) and BRP (9.3%) comparable to those of IR42 in WS. The yield and protein content of many lines were comparable to those of the check varieties and IR58 in the 1983 DS. IR18350-229-3 yielded 7.11 t/ha and 9.2% BRP in DS, comparable to IR36 and better than IR42 in the same trial plot. IR32819-37-3-2 also had 7.17 t yield/ha and 9.1% BRP in the DS crop, comparable to IR36. However, it had more BRP than IR42 in the same trial plot.

Protein loss during milling (*Cereal Chemistry*). Studies on protein loss during milling using different varieties and a McGill miller showed less protein loss from brown rice as protein content increased (1971 annual report). These studies were verified using IR36 and IR42 brown rice with BRP of 8-13% and a Satake TM-05 abrasive mill. The fraction of BRP retained in milled rice with 10 ± 1% bran-polish removal also tended to decrease linearly with increasing BRP. Staining milled rice with May-Grünwald reagent for bran-polish showed that, at the same degree of milling, more bran streaks were present in milled rice with the Satake abrasive mill than with the McGill friction mill. Protein loss during milling was higher for IR42 than for IR36 particularly at the lower BRP levels. This was verified by low protein content of IR36 bran layers compared to that of IR42.

PROTEIN AND ENERGY UTILIZATION

Cereal Chemistry Department

Studies were made on the effect of traditional heat processing on the protein quality of rice based on the decomposition of its heat-sensitive amino acid, lysine. The cause of poor energy digestibility in children with high mungbean intake was also studied. Cooperative studies with the Nutritional Evaluation Laboratory (NEL) led to valuable data on protein requirements for typical rice-based weaning foods and the interrelationship between protein and energy requirements in preschool children.

Effect of heat treatment on lysine content. Earlier studies on rice yellowing and on mungbean toasting suggested that lysine was the amino acid most sensitive to heat decomposition. Since traditional processes expose rice to dry and wet heat, their effect on lysine content of protein was surveyed. Accelerated rice aging and toasting without charring had minor effect on protein quality (Table 1). To induce yellowing, high moisture milled rice was heated at 60° C for 4 d. The induced yellowing affected lysine content the same way natural yellowing did in high moisture rice. Even lower-moisture grain which did not change color decreased in lysine content. Popping also decreased lysine content, but this could be partly caused by loss of high-lysine germ. Puffing dry cooked milled rice decreased lysine content of protein as previously reported.

Energy and nitrogen balance in rats. A confirmatory study at the National Institute of Animal Science, Copenhagen, Denmark, on high protein IR58 milled rice for human feeding studies showed satisfactory net protein utilization (NPU = true digestibility × biological value) for its protein level (Table 2). In addition, yellow milled rice representing two of the three worst samples from the National Food Authority (Manila) were analyzed again to verify 1982 data. The analysis using rats confirmed that yellow rice has lower lysine content and reduced digestibility and biological value (Table 2). These samples had lower NPU than the 62.3 and 62.7% of 1982 samples, probably because

Table 1. Effect of heat treatment on the lysine content of rice grain protein. IRRI, 1983.

Treatment[a]	Lysine content[b] (g/16.8 g N)	
	Check	Treated
Accelerated aging (100°C, 3 h, sealed container)	3.5	3.4
Toasted	4.00 ± 0.08	3.83 ± 0.07
Induced yellowing (60°C, 4 d, sealed)		
IR42, 25% moisture	4.00 ± 0.08	3.40 ± 0.02
IR36, 14% moisture	3.46 ± 0.02	3.16 ± 0.02
IR36, 26% moisture	3.46 ± 0.02	2.99 ± 0.01
Yellow rice[c] (high moisture, <100°C)		
White	3.8	3.08 ± 0.02
Yellow	3.8	2.99 ± 0.04
Popped (207°C, 45 s)	3.6	3.08 ± 0.04
	3.6	3.0
Cooked and puffed (commercial)		
Cooked	3.8	3.30 ± 0.10
Puffed	3.8	2.45 ± 0.21

[a]All were milled rice samples except popped rice, which was brown rice. [b]Mean ± standard error. [c]Mean of two samples.

Table 2. Energy and N balance in growing rats fed IR58 milled rice and two yellow milled rices from the Philippine National Food Authority. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1983.[a]

Property	IR58	Yellow rices	
		1	2
Protein (% N × 6.25)	11.9 ± 0.0	7.0 ± 0.0	7.5 ± 0.0
Lysine (g/16 g N)	3.48 ± 0.04	3.04 ± 0.02	2.96 ± 0.07
Energy content (kJ/g)	15.9	15.4	15.3
Balance data in 5 rats			
Digestible energy (% of intake)	97.0 ± 0.3	96.0 ± 0.3	95.9 ± 0.2
True digestibility (% of N intake)	99.1 ± 0.4	92.1 ± 0.5	93.1 ± 0.5
Biological value (% of absorbed N)	68.8 ± 0.2	63.7 ± 0.2	64.8 ± 0.3
NPU (% N intake)	68.3 ± 0.1	58.7 ± 0.3	60.4 ± 0.4

[a]Mean ± standard error.

Table 3. Energy and N balance in growing rats fed boiled mungbean preparations. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1983.

Property	Whole mungbean	Dehulled toasted mungbean	Mechanically dehulled mungbean
Boiling time (min)	30	20	10
Protein (% N × 6.25)	23.7	26.0	24.0
Lysine[a] (g/16 g N)	6.87 ± 0.02	6.03 ± 0.00	6.95 ± 0.09
Cystine + methionine[a] (g/16 g N)	2.10 ± 0.01	2.16 ± 0.10	2.01 ± 0.06
Energy content (kJ/g)	15.8	15.9	15.8
Balance data in 5 rats			
Digestible energy (% of intake)	79.4 b	79.6 b	93.6 a
True digestibility (% of N intake)	83.7 b	81.6 c	97.1 a
Biological value (% of absorbed N)	60.0 a	49.3 b	60.1 a
NPU (% of N intake)	50.2 b	40.2 c	58.3 a
	(53.0 a)[b]	(44.4 c)[b]	(50.5 b)[b]

[a]Mean ± standard error. [b]NPU of raw mungbean in 1982 annual report.

of more yellow grains, lower lysine content, and lower biological value.

Rats were fed three kinds of boiled mungbean — whole, toasted dehulled; mechanically dehulled green; and raw — to test their effect on the nitrogen balance (1982 annual report). Results showed that only the mechanically dehulled green bean improved in NPU from increased biological value (Table 3). The poor NPU for toasted bean is probably due to lower biological value from protein decomposition shown by lysine content. The rat data suggest that mungbean's poor nutritional value is not from trypsin inhibitor but the low content of sulfur-containing amino acids, cystine, and methionine.

Protein requirements for rice-based weaning foods. AID funding which established the NEL at the Food and Nutrition Research Institute (FNRI), National Science and Technology Authority (Manila), has now terminated. NEL studies on protein requirements for rice-based weaning foods in preschool children began as part of the United Nations University World Hunger Programme. Since the protein content of rice was too low for the slope ratio multilevel technique, IRRI grew the high-protein (>11%) IR58 rice in 1982 and applied fertilizer close to the flowering stage for higher protein content.

Using market rice, rice-fish and rice-milk diets (1/3 of nitrogen from fish or milk) had better protein quality than rice-mungbean diets as reflected by lower protein requirements (Table 4). Based on the reported safe level of daily protein intake of 0.89 g milk protein/kg body wt, rice-milk approached milk in protein quality. The rice-whole mungbean diet had poorer quality despite its better amino acid balance than high-protein IR58 rice. Toasting and dehulling the mungbean improved the quality of the diet somewhat, but it was still inferior to rice-fish. The short-term nitrogen balance index for IR58 rice estimated on the same children showed relative protein quality of 69% of rice-milk or 66% of milk. These rice diet values are similar to the amino acid score based on dietary lysine of 65% and to the 68% NPU of IR58 rice in rats (Table 2). Thus, addition of lysine-rich animal protein to lysine-deficient milled rice improved the protein quality of rice-based weaning diets to nearly that of milk.

Table 4. Mean protein requirements and safe level (97.5% of population) of protein (N × 6.25) intake by male Filipino toddlers (18-30 mo old) consuming local weaning diets[a]. NEL and IRRI, 1979-83.

	Rice-fish	Rice-milk	Rice-whole mungbean	Rice-toasted mungbean	IR58 rice
Lysine content[b] (g/16 g N)	6.23 ± 0.60	5.40 ± 0.08	5.27 ± 0.13	5.26 ± 0.11	3.62 ± 0.22
Children (no.)	7	8	6	8	3
Mean daily protein requirement[b,c] (g/kg body wt)	0.62 ± 0.16	0.62 ± 0.10	0.99 ± 0.20	0.84 ± 0.11	0.85 ± 0.16
Adequate daily protein intake (g/kg body wt)	1.00	0.93	1.48	1.19	1.33
Relative protein quality[d] (% of milk)	89	96	60	75	67

[a]Energy intake of 418 kJ/kg body weight daily. [b]Mean ± S. D. [c]Allowing 0.06 g protein/kg a day for miscellaneous losses. Rice-fish and rice-milk data were significantly different from those of the three other diets. [d]Based on reported safe level of daily protein intake of 0.89 g cow's milk protein/kg body weight as 100%.

In nutrition trials with rice-mungbean diets, preschool children continued to improve in nitrogen balance above 1.25 g protein/kg body wt, but energy digestibility decreased as fecal weight and volume increased. Antinutrition factors such as tannin adversely affect both protein and energy digestibility. Investigations show both whole and dehulled toasted beans had about 4% free sugars, mainly galactose-rich. Humans cannot digest them and they can cause flatulence from microbial fermentation in the large intestine. Soaking beans in water before mechanical dehulling leached out the sugars, leaving 0.7% residual free sugar.

Nitrogen balance studies at 1.50-1.56 g protein and 418 kJ/kg body wt intake showed that Energro weaning food is similar to the milk diets in protein quality (Table 5). Energro is an extrusion cooked blend of 60% rice flour, 35% full fat Association of Southeast Asian Nations soybean flour, and 5% nonfat dry milk developed by FNRI.

Protein-energy interrelationship in preschool children. Preliminary studies were undertaken at NEL on protein-energy interrelationship using rice-fish diet (1/3 of protein from Spanish mackerel *Scomberomorus commerson*) at the safe intake level of 1.6 g/kg body wt daily. The energy intake varied from the recommended level of 418 kJ/kg body wt for preschool children to 95, 90, and 85% of recommended value. Energy absorption (91-94%) and apparent N absorption (72-77%) were similar at all levels of energy intake, but apparent N retention was lower at 90% of recommended level. At 85% of recommended energy intake, all three test children lost weight. At 90%, 4 out of 5 children progressively lost weight. Even at 418 kJ/kg body wt energy intake, after 2 wk normal growth, the rate slowed in 3 out of 6 test children. Results suggest that the optimum daily energy intake for a rice-fish diet providing 1.6 g protein/kg body wt may be higher than the current recommendation of 418 kJ/kg body wt. This energy level has been adequate for 9-day balance periods with 1.56 g milk or casein protein/kg body wt daily, but it has not been tried for longer periods.

BY-PRODUCTS STUDIES

Cereal Chemistry

To investigate possible income-generating processes involving rice by-products, IRRI began screening studies to determine varietal differences in oil content of bran-polish, nutritional value of straw, and silicon content of rice hull.

Oil content of bran-polish of IR lines. Preliminary studies showed significant differences in oil content of bran-polish of IR lines using a McGill mill at 10% weight removal from brown rice. Crude fat ranged from 16.7 to 20.2% wet basis (mean 18.7%, 10.6-11.8% moisture) for 3 varieties and 13 lines in the 1982 WS. For 23 lines and 3 varieties in the 1983 DS, differences in oil content were again significant and ranged from 17.4 to 25.1% wet basis (mean 22.1%, 9.8-11.3% moisture). For six samples represented in both crops, oil content also was lower in WS than in DS. This suggests that oil content of bran-polish is higher during DS (Table 6). Japanese workers have reported a positive correlation between crude oil content of brown rice and ripening temperature.

Fat deterioration in rice bran. The biggest drawback to the use of rice bran as a source of edible oil is its potent lipase, the enzyme involved in

Table 5. N balance data in preschool children consuming Energro weaning food[a], NEL and IRRI, 1983.

Property of diet	Milk diet I	Energro diet	Milk diet II
Protein content (% N X 6.25)	5.1	7.09 ± 0.03	4.9
Lysine (g/16 g N)	7.2	5.16 ± 0.01	6.7
Nitrogen intake (mg/kg body wt)	240 ± 10	248 ± 9	241 ± 6
Urinary nitrogen (mg/kg body wt)	89 ± 18	89 ± 12	94 ± 19
Fecal nitrogen (mg/kg body wt)	59 ± 13	68 ± 11	62 ± 14
Nitrogen balance (mg/kg body wt)	92 ± 18	90 ± 12	85 ± 16
Apparent nitrogen absorption (% of intake)	75 ± 5	73 ± 4	74 ± 6
Apparent nitrogen retention (% of intake)	39 ± 8	36 ± 4	35 ± 6

[a]Daily energy intake of 418 kJ/kg body wt. Mean ± S. D.

Table 6. Effect of season on oil content of bran-polish of aged rice. IRRI, 1983.

Variety or line	Oil content (% wet basis)	
	1982 WS	1983 DS
Peta	17.8	18.4
IR19672-140-2	20.0	24.2
IR21015-80-3	16.7	22.5
IR21848-65-3	19.8	23.4
IR22082-41-2	20.2	20.4
IR28128-45-2	18.6	20.8
Mean	18.9	21.6

the rapid hydrolysis of its fat to fatty acids. Fat deterioration also could reduce palatability of the bran as feed. The importance of bran lipase and microbial lipase to bran deterioration was studied on IR58 bran (4% free fatty acids). Ultraviolet (UV) treatment for 6 h to disinfect and heat treatment at 94-96° C under partial vacuum for 5 h was used to completely inactivate lipase. The dry heat treatment reduced moisture content to 10% and lipase activity per gram of bran from 0.30 mg 4-methyl umbelliferone/min to <0.1. It also kept free fatty acid level at 6% for 4 wk after which acid formation increased linearly during storage at 60-75% RH at 27-30° C. In contrast, UV-treated and control bran samples maintained high lipase activity, and free fatty acids increased to 60% in 4 wk and were 100% hydrolyzed by 16 wk. Results verified observations of others that bran lipase is the principal cause of fat hydrolysis in stored rice bran. The increase in fat acidity of heat-treated bran may be from residual lipase or microbial lipase.

Straw and hull properties. Possible factors which reduce nutritional value of rice straw for ruminants include high oxalate, silica, lignin, and cellulose (fiber) content. Farmers also worry that pesticides applied during crop growth may still be present in toxic levels in the straw. However, pesticide residue analysis of selected rice straw samples with different growth duration, studied for nutritive value by UPLB animal nutritionists, verified minimal pesticide levels.

Animal nutritionists assessed the effect of variety on nutritional value of IRRI-grown rice straw. H4 straw had lower mean protein content (5.6%) and in vitro DM digestibility (36%) than IR8, IR36, and IR42 straws (5.9-7.3% protein and 38-43% DM digestibility). Nitrogen fertilizer increased protein content and reduced neutral detergent fiber content of the straw.

Hull feed value is much lower than that of straw due to higher silica, lignin, and cellulose levels. Rice hull may be a source of solar grade silicon for solar batteries. The rice hull silicon content of 18 IR varieties from the 1982 WS crop replicated yield trial ranged from 5.4 to 10.3% wet basis or 5.9-11.3% dry basis. For 16 IR varieties from both 1982 crops, mean silicon content was 7.6% wet basis (8.3% dry basis) for DS crop and 9.6% wet basis (10.5% dry basis) for WS crop. Analysis of variance showed highly significant differences in silicon content within each crop. But interaction between season and sample was also significant, resulting in inconsistency in sample ranking in the two crops.

Genetic evaluation and utilization (GEU) program

Drought resistance

Agronomy and Plant Breeding Departments and International Rice Testing Program

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VARIETAL SCREENING

Agronomy and Plant Breeding Departments

Field screening, 1983 dry season (*Agronomy*). Soil moisture tension (SMT) values were 3 bars at 21 d from start of soil moisture stress, 10 bars at 28 d, and 15 bars at 35 d. For the first time in 9 yr, scoring was up to 15 bars SMT. Scoring in the past 8 yr had been up to 10 bars, except in 1979 when early rains allowed scoring only at 2 and 5 bars.

Of 3,842 tested breeding lines, varieties, and accessions, 37 scored better than the tolerant checks (Table 1).

KDML65 GIU-45 from Thailand and Rikuto Norin Moshi 1 from Japan showed only slight leaf tip drying at 15 bars SMT. At this time, KDML65

Table 1. Outstanding selections for vegetative growth drought tolerance in field screening at IRRI, 1983 DS.

Designation	Origin	Drought score[a] at SMT of			Recovery score[b]
		3 bars	10 bars	15 bars	
IR52		1	3	4	3
IR3646-13-3		1	1	4	1
IR5178-1-1-4		1	1	3	1
IR6115-1-1-1		1	3	4	3
IR7801-1-2-1		1	1	3	1
IR9782-111-2-1-2		1	1	3	1
IR11438-1		0	1	4	1
IR12721-4-1-1		1	1	4	1
IR12721-24-3-1		1	1	4	1
IR15413-4		1	1	3	1
IR19728-9-3-2-3-3		1	1	4	1
IR19774-23-2-2-1-3		1	1	3	1
IR21015-196-3-1-3		1	1	4	3
IR24761-35-3		1	1	3	1
IR24761-156-3		1	1	3	1
IR33153-5		1	2	3	1
Agsam	Philippines	1	1	3	1
ARC10372	India	1	1	3	1
Arpa	Italy	1	1	4	1
Balibod	Philippines	1	1	4	1
IITA117	Nigeria	1	1	3	1
IRAT104	Ivory Coast	0	1	4	1
IRAT113	Ivory Coast	0	1	3	1
IRAT133	Ivory Coast	1	2	4	1
IRAT144	Ivory Coast	0	1	3	1
Kabodit	Philippines	0	1	4	1
KDML65 G1U-45	Thailand	0	1	1	1
KU86	Thailand	1	3	4	1
Magaya	Philippines	1	1	3	1
Mestesa	Philippines	0	1	3	1
Moroberekan	Guinea	0	1	4	3
NCS130	India	1	1	3	1
NCS166	India	1	1	3	1
RD19	Thailand	1	2	4	1
Rikuto Norin Moshi 1	Japan	0	1	1	1
Thangone	Laos	1	2	4	3
TOX504-13-NK33-N1B	Nigeria	1	1	4	1
IR20 (susceptible check)		3	5	7	5
IRAT9 (susceptible check)	Ivory Coast	4	7	8	7
IR442-2-58 (tolerant check)		1	3	6	3
Salumpikit (tolerant check)	Philippines	1	3	5	1

[a]1980 SES scale 0-9: 0 = no symptoms, 9 = all plants apparently dead. [b]1980 SES scale 1-9: 1 = 90-100% plants recovered, 9 = 0-19% plants recovered.

Table 2. Drought resistance[a] of entries at the vegetative growth phase, 1983 DS.

Entries	Entries (no.)	Frequency of indicated drought score								
		1	2	3	4	5	6	7	8	9
IRGC accessions	2924	13	197	637	1037	682	382	29	1	0
Thai hill rices	35	0	8	20	3	4	0	0	0	0
Oryza glaberrima	102	8	12	29	22	19	12	0	0	0
Advanced breeding lines from dryland nurseries	949	73	95	235	232	204	75	34	1	0
F_4 lines from dryland nurseries	845	66	44	307	233	155	36	3	1	0
Advanced lines from rainfed-wetland nurseries	205	0	8	62	37	57	19	22	0	0
GEU elite lines	57	0	0	0	0	10	21	26	0	0
Hybridization block entries	245	13	8	42	46	108	19	6	3	0
Introduced lines and varieties (TOX, IRAT, ITA, and Indonesian lines)	173	24	55	53	25	11	2	3	0	0
Total	5535	197	427	1385	1635	1250	512	123	6	0

[a] 1 = resistant, 9 = susceptible.

GIU-45 was already headed and showed no visible symptoms of moisture stress.

The tolerant checks Salumpikit (a Philippine traditional variety) and IR442-2-58 had only one-fourth leaf tip drying 28 d from start of soil moisture stress (10 bars SMT), and about one-half the leaves still green 1 wk later (15 bars SMT). The susceptible checks IR20 and IRAT9 had severe leaf desiccation. The recovery scores of the selected test rices were excellent, as were those of the tolerant checks.

Field screening under dryland culture (*Plant Breeding*). A total of 5,535 test entries and check varieties from IRGC, breeding lines from upland and lowland nurseries, *Oryza glaberrima* strains, and introduced lines from outside sources were screened for field drought resistance (Table 2). Of the 2,924 test varieties from the IRGC, 64.3% were resistant to moderately resistant (drought score of 1-4 where 1 = resistant and 9 = susceptible), 23.3% were intermediate, and 12.2% were moderately susceptible to drought at the vegetative phase. Most IRGC accessions were traditional upland varieties from Asia, Latin America, and Africa. A high percentage of drought-resistant varieties came from Thai hill rices and African *O. glaberrima*.

Upland nursery breeding lines also had a large percentage of progenies with high levels of drought resistance. Of the F_4 lines selected earlier for deep and thick root systems, 77% gave drought scores between 1 and 4. Most IRRI hybridization block entries had intermediate resistance while the GEU elite lines scored from 5 to 7.

Introduced lines from IITA, IRAT, and Brazil also showed high levels of drought resistance at the vegetative phase.

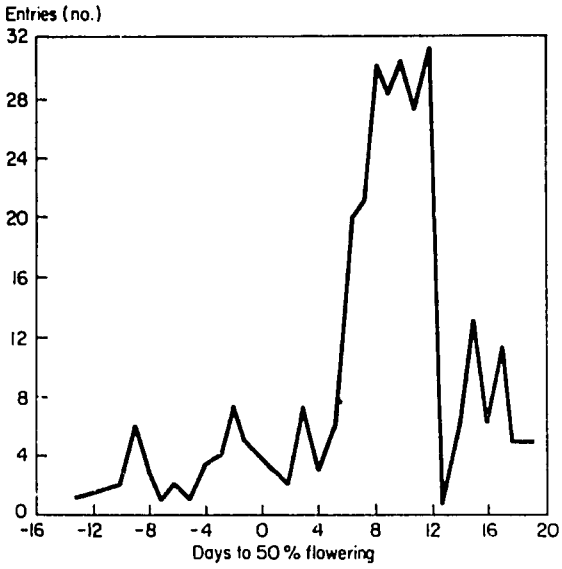
Screening at the reproductive phase (*Agronomy*). A screening method to detect genetic variability in drought resistance at the reproductive phase was developed in 1981, refined in 1982, and used in 1983 DS for a mass screening. The trial included 345 entries from Agronomy, Plant Breeding, and IRTP plus some genotypes with outstanding performance in the previous 2-yr trials.

Entries were seeded on five different dates based on their maturity class for simultaneous flowering. Two replications of the control (well watered) and three of the stress treatment were in the randomized complete block.

Water applied by the whole plot sprinkler irrigation system was 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 began on 8 Apr (day 0) with application of the last full irrigation.

Some entries flowered too early (before day 6) or too late (after day 12). Only 187 entries that experienced 50% flowering on stress days 6 to 12 were considered for sampling and observations (Fig. 1).

Of the 345 entries, a few genotypes with mean



1. Number of entries at 50% flowering stage in relation to the start of the stress period (0 on X axis). IRRI, 1983.

Table 3. Entries[a] with the highest and lowest grain yield during stress treatment. IRRI, 1983.

Genotype	Grain yield (g/m²)
Highest yielding	
IR9669 Sel.	112
IRAT140	102
RAU4020-10	97
IRAT144	89
IR12702-10-1-1	83
IRAT101	78
IR10147-113-5-1	77
B201-193-1	71
B3007b-Tb-22-2-3-3-1	71
IR5873-9-1	67
IR11383-20	67
IR3880-10	66
ITA139	64
IR10029-26-3	61
M18	61
Lowest yielding	
Rata 74-5	3
IR25863-8-2-3	3
IR25898-57-2-3	3
B3016b-Tb-64-3-4-2-3	2
RP1931-14-2-1-1	2
C894-21	2
IR17494-32-1-1-3-2	2
IR3839-1	2
IR19670-263-3-2-2-1	1
IR19058-107-1	1
IR25882-32-1-3	1
RP1442-4-3-1-1	1
IR28	0
IR2987-13-1	0

[a]Of 187 entries that flowered synchronously in the control, only the 172 with good stand in the stress treatment were considered.

Table 4. Entries[a] with high and low estimated spikelet fertility percentage in the stress treatment. IRRI, 1983.

Genotype	Mean spikelet fertility (%)
High	
IRAT140	71.2
M55	61.0
IRAT110	45.0
IR113	39.2
M18	37.2
Sokoni	36.5
IR10025-16-2	34.8
B3007b-Tb-22-2-3-3-1	34.0
IR9669 Sel.	30.8
C991-5	29.0
Low	
IR25588-7-3-1	1.2
IR7950-31-4-1	1.2
IR17494-32-1-1-3-2	1.2
IR10133-30-1-2	1.0
IR22082-41-2	1.0
RP1442-4-3-1-1	0.8
BPI Ri-6 (MRC 438)	0.7
IR2987-13-1	0.7
IR25863-8-2-3	0.5
IR25882-32-1-3	0.5
IR25621-94-3-2	0.3

[a]Only 115 entries out of 172 were available for estimation of spikelet fertility.

drought tolerance scores of less than 5.0 were selected. IR9669 Sel. plus several IRAT and IR lines were among the best entries. Other genotypes that performed well were the tall entries such as M18, M55, Azucena, and Carolina sp. 407. IR9669 Sel. was consistently outstanding in this category in the past years' tests.

In the previous year, grain yield, relative yield, and percent spikelet fertility were highly correlated with flowering date. This year, the relationships were not significant, an expected response because of the improvement in synchronizing flowering. Most entries flowered within a 7-d period; flowering in previous years was at 21 and 28 d. Since the flowering date effect is removed, entries can be compared directly without computing drought indices. Tables 3, 4, and 5 show entries that ranked high or low in grain yield, spikelet fertility percentage, and relative grain yield. Among the entries that flowered on stress days 6 to 12, IR9669 Sel. and IRAT140 were consistently outstanding in grain yield, relative yield, and spikelet fertility percentage.

Table 5. Entries with high and low relative grain yield. IRRI, 1983.

Genotype	Relative grain yield[a] (%)
High	
IRAT140	66
ITA139	60
IR52	54
B201-193-1	53
IR3880-10	49
RAU 4020-10	49
IR1138-3-20	47
Rata 35	45
IR9669 Sel.	43
IR5873-9-1	35
Low	
IRAT109	2
IR25898-57-2-3	2
IR25863-8-2-3	2
IR25774-3-1 (A)	2
RP1931-14-2-1-1	1
C894-21	1
B3016b-Tb-64-3-4-2-3	1
IR17494-32-1-1-3-2	1
IR3839-1	1
RP1442-4-3-1-1	1
IR19058-107-1	0.7
IR19670-263-3-2-2-1	0.6
IR25882-32-1-2	0.6
IR28	0
IR2987-13-1	0

[a]Yield in the stress treatment in relation to the control.

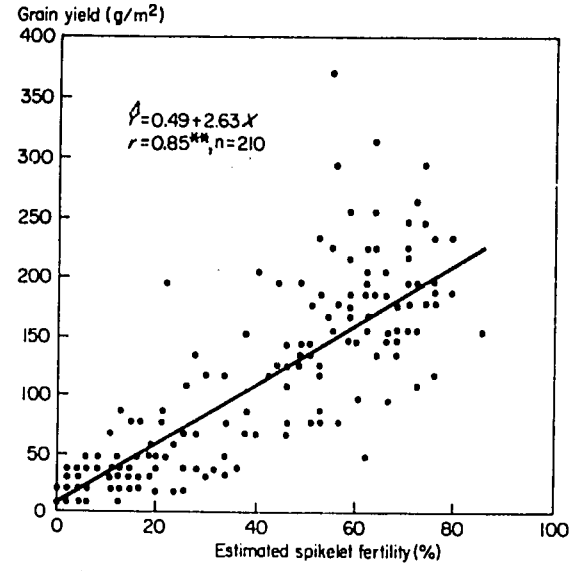
A positive linear relationship (r = 0.85**) resulted when grain yield was regressed against estimated percentage of spikelet fertility (Fig. 2). This confirms that grain yield and spikelet fertility are important parameters in drought studies at the reproductive phase.

Actual spikelet fertility percentage regressed against estimated spikelet fertility showed a correlation coefficient value of 0.93** (Fig. 3). Therefore, visual estimates of spikelet fertility can be important in predicting grain yield in drought studies involving a large number of test materials at the reproductive phase.

FIELD EVALUATION OF RAINFED RICES

Agronomy and Plant Breeding Departments and IRTP

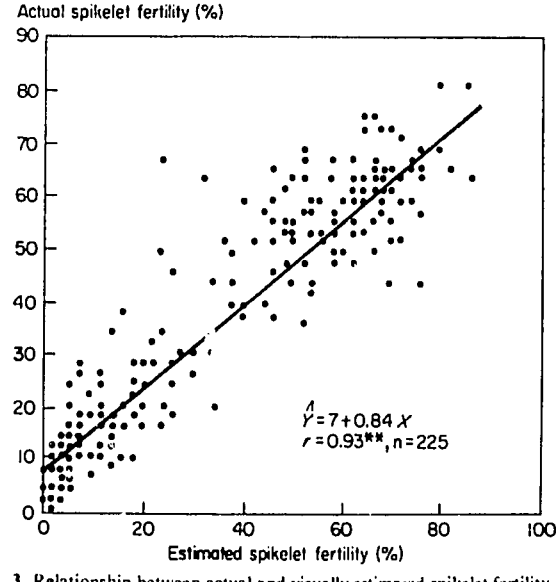
Upland rice yield trial, 1983 wet season (*Agronomy*). Twelve varieties and lines from the 21-entry



2. Relationship between grain yield and visually estimated spikelet fertility of entries from both control and stress treatments. IRRI, 1983 DS.

International Upland Rice Yield Nursery (IURYN) and 49-entry special group of upland rice yield trials produced higher than or similar grain yield averages as the check IR43 during 1983 WS tests at IRRI and in 2 farmers' fields in Cuenca and Santo Tomas, Batangas Province (Table 6, 7).

Of the six selected IURYN entries, three were Philippine upland varieties, two of which were



3. Relationship between actual and visually estimated spikelet fertility. IRRI, 1983 DS.

Table 6. Grain yield of selected rices seeded at different dates in IURYN at 3 Philippine sites, 1983 WS.

Designation	Grain yield (t/ha)				
	IRRI	Cuenca	Santo Tomas		Mean
	14 Jun	29 Jun	31 May	4 Jul	
IR5931-110-1	1.4	4.1	3.5	2.8	3.0
BR319-1	2.1	3.6	3.8	2.3	3.0
UPL Ri-7	2.4	3.9	3.6	1.6	2.9
UPL Ri-5	2.0	3.3	3.3	2.4	2.8
BPI Ri-6	2.0	3.2	3.4	2.5	2.8
C894-21	1.7	3.7	2.8	2.7	2.7
IR43 (check)	1.5	3.1	3.7	2.6	2.7
Kinandang Patong (local check)	1.5	2.6	2.4	1.4	2.0
Mean of 21 entries	1.5	3.0	2.7	2.1	

Table 7. Grain yield of selected rices seeded at different dates in upland rice yield tests at 3 Philippine sites, 1983 WS.

Designation	Grain yield (t/ha)					
	IRRI		Cuenca	Santo Tomas		Mean
	14 Jun	12 Aug	29 Jun	31 May	4 Jul	
IR9560-2-6-3-1	2.7	1.0	4.2	2.3	4.0	2.8
UPL Ri-5	2.3	2.0	3.7	3.1	2.9	2.8
IR9101-37-1	2.3	2.0	3.1	3.8	2.0	2.6
IR9814-11-3	2.4	1.6	3.9	2.8	2.4	2.6
IR43 (check)	2.0	2.0	3.7	2.2	3.1	2.6
UPL Ri-3	2.0	2.0	3.4	3.0	2.5	2.6
IR21015-196-3-1-3	2.1	1.5	3.6	2.8	2.9	2.6
Mean of 49 entries	1.5	1.2	2.6	2.1	2.0	

Table 8. Grain yield and agronomic characteristics of selected rices in IURYN at 3 Philippine sites and drought tolerance score in Ilagan, Isabela, 1983 WS.

Designation	Grain yield average (t/ha)	Heading (DE)	Plant height (cm)	Panicles (no./m^2)	Drought tolerance[a]	Important diseases
IR5931-110-1	3.0	86	101	210	3	ShB
BR319-1	3.0	82	101	214	5	–
UPL Ri-7	2.9	80	102	202	0	NBI, ShB
BPI Ri-6	2.8	90	99	209	3	BI, NBI
UPL Ri-5	2.8	90	105	192	3	–
C894-21	2.7	91	106	215	5	ShB
IR43 (check)	2.7	95	80	224	1	NB1, ShB
Kinandang Patong (local check)	2.0	80	135	160	0	ShB

[a]1980 SES scale 0-9: 0 = no visible effects of soil moisture stress, 9 = all plants apparently dead.

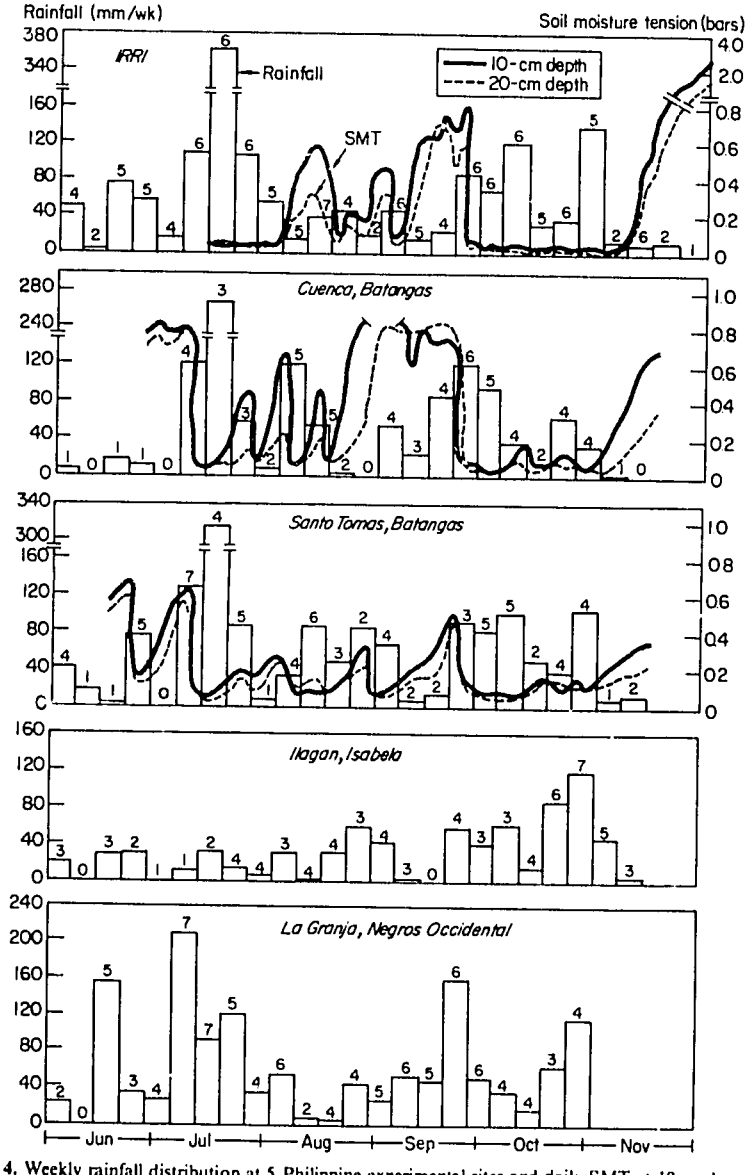
developed by UPLB and one by the Philippine Bureau of Plant Industry; one (BR319-1) was from Bangladesh; and the other two were IRRI and UPLB breeding lines. All 6 headed earlier than IR43 by 2 to 13 d and were taller than IR43 by 19 to 26 cm (Table 8).

Five of the six selected entries in the special group were earlier maturing than IR43 (Table 9). The earliest entry, IR9101-37-1, headed 19 d earlier. UPL Ri-3 and UPL Ri-5 had intermediate

Table 9. Grain yield and agronomic characteristics of selected rices in upland rice yield test at 3 Philippine sites and drought tolerance score in Ilagan, Isabela, 1983 WS.

Designation	Grain yield average (t/ha)	Heading (DE)	Plant height (cm)	Panicles (no./m²)	Drought tolerance[a]	Important diseases
IR9560-2-6-3-1	2.8	96	78	252	3	BS, ShB, SR
UPL Ri-5	2.8	90	109	176	5	BS, FSm, NBI
IR9101-37-1	2.6	74	83	280	1	NBI
IR9814-11-3	2.6	80	83	244	1	NBI, ShB
IR43 (check)	2.6	93	80	214	3	ShB
UPL Ri-3	2.6	90	110	181	1	NB1, ShB
IR21015-196-3-1-3	2.6	84	80	271	3	BS, ShB

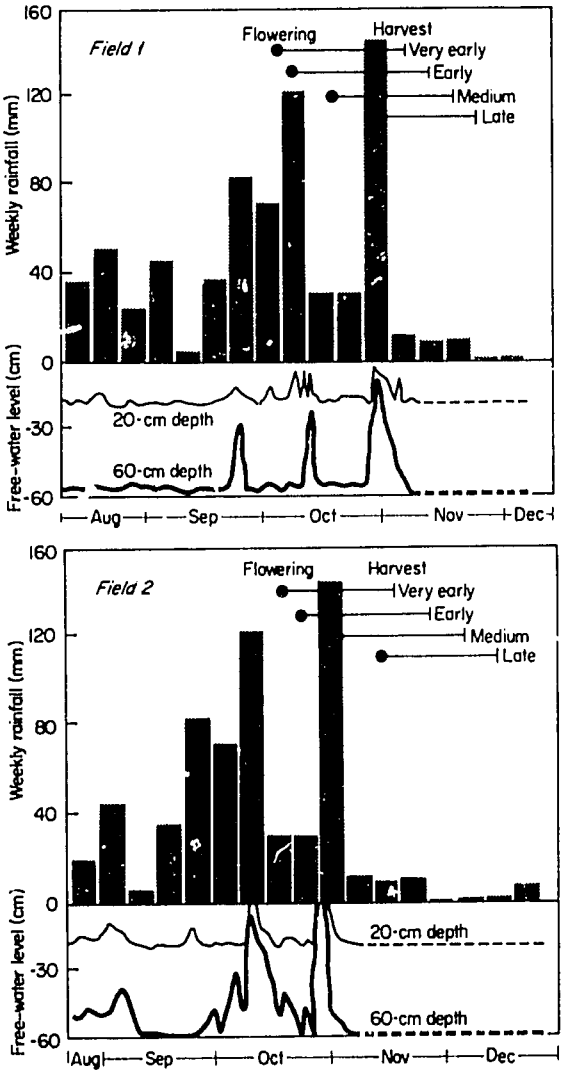
[a]1980 SES scale 0-9: 0 = no visible effects of soil moisture stress, 9 = all plants apparently dead.



4. Weekly rainfall distribution at 5 Philippine experimental sites and daily SMT at 10- and 20-cm soil depth in IRRI and Batangas sites, 1983 WS. Values on the bars indicate number of rainy days per week.

Table 10. Solar radiation in IRRI and 2 Batangas upland rice test sites from August to October 1983.

Decade	Decade mean of solar radiation (g cal/cm² per d)		
	IRRI	Cuenca	Santo Tomas
Aug 1-10	318	346	312
11-20	271	317	296
21-31	370	405	401
Sep 1-10	404	366	354
11-20	443	383	395
21-30	275	281	234
Oct 1-10	301	318	276
11-20	297	318	322
21-31	327	334	305



5. Water level (piezometer at 20 and at 60 cm), field water depth, and rainfall in 2 IRRI fields, 1983 WS.

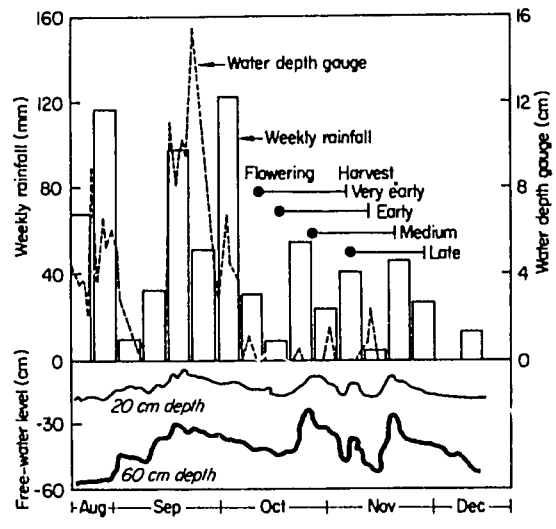
height, while four other IRRI entries were similar to semidwarf IR43. Short growth duration and intermediate height are desirable agronomic characteristics for upland rice.

Rainfall was low in August and September and caused root zone SMT to rise above 0.3 bar for up to 4 wk in Cuenca (Fig. 4). A typhoon passed through southern Luzon on 15 Jul and gave 2-d rainfalls of 356 mm at IRRI, 264 mm at Cuenca, and 296 mm at Santo Tomas.

The lower June to October rainfall in Ilagan, Isabela, prolonged the growth duration of all Ilagan test rices by an average of 30 d. Uneven maturity prevented accurate harvest data. A 2-wk dry spell in September caused leaf desiccation on most entries but did not visibly affect UPL Ri-7 and Kinandang Patong, the local check (Table 8).

Bl and NBl infected many entries in all sites, but was most serious in Santo Tomas. ShB was observed in Cuenca and Santo Tomas. In La Granja, Negros Occidental, an unidentified grain disease caused high sterility and highly variable grain yield. BR319-1 was disease free (Table 8). So was UPL Ri-5 in IURYN (Table 8), but in the special group it was infected with BS, FSm, and NBl.

The season's highest grain yield was 4.2 t/ha from the 31 May seeding of IR9782-111-2-1-2 at Santo Tomas, and IR9560-2-6-3-1 at Cuenca, and IR19728-9-3-2 at La Granja. The record high grain



6. Water level (piezometer at 20 and at 60 cm), field water depth, and rainfall at Liloan, Cebu, 1983 WS.

s 6.6 t/ha with IR3260-91-100 at Santo nd 6.3 t/ha with IR937-76-2 at Cuenca in

isease pressure and higher solar radiation) during the reproductive phase produced st grain averages in Cuenca (Table 6, 7).

Integrated performance trials for rainfed-shallow drought-prone environments (*Agronomy, Plant Breeding, and IRTP*). Three replicated trials during the 1983 WS assessed the yield performance of the International Rainfed Rice Shallow Water Yield Nursery (IRRSWYN). They also were used to

Table 11. Summary of grain yields and plant characters for the top 13 entries[a] in each group of the integrated performance trial for rainfed shallow drought-prone environments. IRRI, 1983.

Rank	Designation	Yield (t/ha) Cebu	IRRI	IRRI	Mean	Plant height (cm)	Days to flowering
			Group A (IRTP entries)				
3	IR46**	5.43 ab	2.05 bcde	1.87 abcd	3.12	87	92
10	IR15853-89-7E-P3	5.38 ab	1.21 ef	1.34 d	2.65	87	92
5	C1158-8	5.04 abc	1.64 bcdef	1.86 abcd	2.85	71	81
2	IR19431-72-2	5.01 abc	2.31 b	2.17 abc	3.17	97	94
9	IR14875-98-5	4.91 abc	1.37 cdef	1.86 abcd	2.72	86	94
11	IR18599-68-1	4.85 abc	1.64 bcdef	1.35 d	2.62	85	92
16	IR3880-10	4.70 abc	2.24 b	1.57 bc	2.84	101	92
1	IR13146-45-2-3*	4.68 abc	3.05 a	2.26 ab	3.33	105	95
7	IR2307-247-2-2-3	4.52 abc	2.28 b	1.57 bc	2.79	75	84
8	IR14632-2-3	4.26 abc	1.77 bcde	2.22 abc	2.75	95	98
12	IR14753-49-2*	4.16 bc	1.34 cdef	2.10 abc	2.54	99	94
13	IR4829-89-2	4.13 bc	1.36 cdef	1.64 bcd	2.38	96	88
4	BR10 (BR51-46-5)	4.00 bc	2.26 b	2.38 a	2.88	93	92
			Group B				
6	IR10025-8-1	5.7 a	1.28 de	1.44 def	2.81	101	86
6	IR36**	5.3 ab	1.72 cde	1.39 def	2.81	81	82
7	B4242-30-2-1	5.19 ab	1.53 de	1.62 cdef	2.78	95	92
1	IR19274-26-2-3-1**	5.17 abc	2.78 a	2.52 ab	3.49	88	84
5	IR21015-80-3-3-1-2*	5.13 abc	1.66 cde	1.83 cde	2.88	82	85
3	IR22082-41-2**	5.07 abc	2.03 bcd	2.2 abc	3.10	85	90
4	IR21188-87-3-3-2-2	4.95 abc	2.04 bcd	2.2 abc	3.07	90	95
10	IR5931-110-1*	4.73 abc	1.51 de	1.35 def	2.53	93	89
2	IR26933-16-2-3	4.72 abc	2.38 abc	2.65 a	3.25	86	87
13	IR10147-113-5-1	4.65 abc	1.36 de	0.95 f	2.32	101	97
8	IR21015-196-3-1-3	4.56 abcd	1.43 de	1.95 bcd	2.65	83	86
9	IR3179-25-3-2	4.36 abcde	1.48 de	1.78 cde	2.54	93	89
12	IR13759-16	4.03 bcdef	1.48 de	1.67 cdef	2.40	100	89
11	IR19058-107-1*	3.97 bcdef	1.72 cde	1.66 cdef	2.45	81	80
			Group C				
10	BPI-76 N.S.*	4.83 a	1.03 de	1.22 de	2.36	108	93
2	IR19672-140-2-3-2-2*	4.71 ab	2.3 ab	1.82 bcde	2.95	94	96
11	IR13754-5**	4.70 ab	1.13 cde	1.21 e	2.35	102	97
3	IR5853-198-1-2**	4.54 ab	1.44 cde	2.79 a	2.93	92	93
1	IR13146-13-3-3**	4.37 abc	2.63 a	1.95 bc	2.99	98	96
7	IR8997-4-18-1*	4.36 abc	1.57 cd	1.59 bcde	2.51	106	96
9	IR9852-22-3*	4.3 abc	1.55 cd	1.47 cde	2.44	86	92
11	IR25774-3-1-1	4.1 abc	1.27 cde	1.68 bcde	2.35	99	94
4	KKN7205-39-3-KN-1-1-1*	3.99 abc	1.96 bc	1.89 bcde	2.62	95	89
6	IR21363-13-2-2-1-1	3.96 abc	1.69 bcd	1.91 bcde	2.52	94	98
5	IR54***	3.92 abc	1.14 cde	2.63 ab	2.57	86	92
8	IR10044-24-1-1**	3.9 abc	1.37 cde	2.2 ab	2.49	96	92
12	IR12665-8-3-5	3.54 abcd	1.83 bcd	1.5 e	2.29	122	94
13	IR21313-36-2-2-3	3.15 bcd	1.58 bcd	1.59 bcde	2.11	99	104

[a] * = entries performed well for 2 yr, ** = entries performed well for 3 yr, *** = entries performed well for 4 yr.

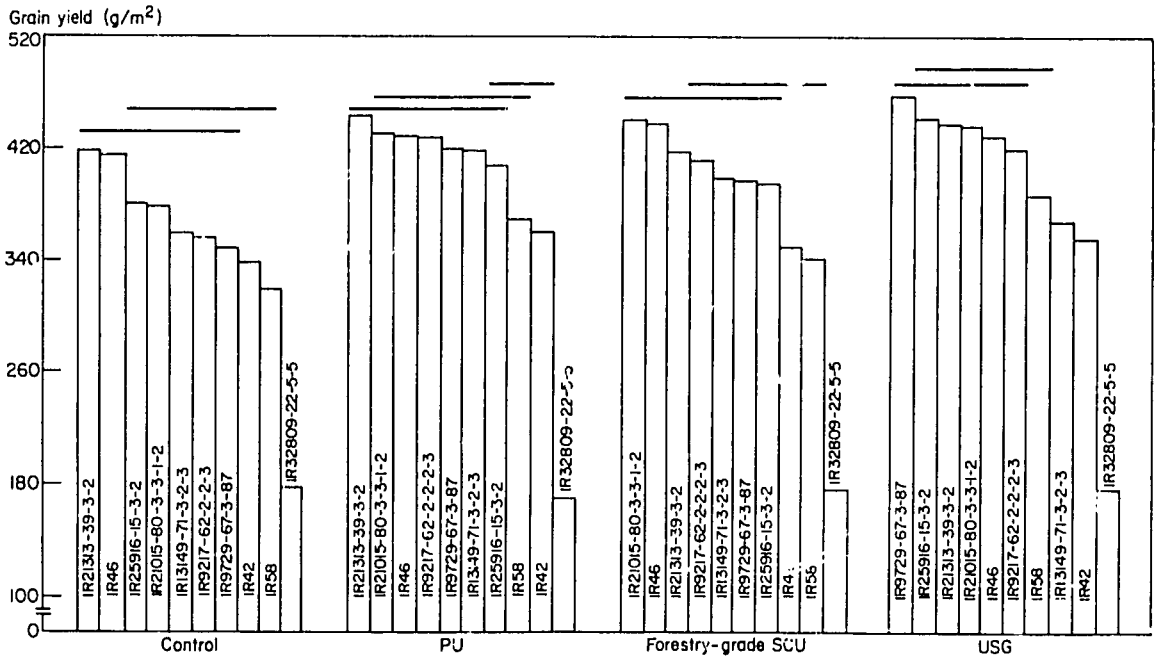
select advanced lines from IRRI's breeding program for drought-prone environments. Two trials were planted on a well-drained field at IRRI, and the other on a farmer's field in Liloan, Cebu, using a group balanced block design with four replications. A dry spell at IRRI (Fig. 5) during the vegetative phase, which caused the soil to crack, produced little apparent crop stress. During the growing season the IRRI field did not retain standing water except during rainfall. Low grain yields (0.2-3.0 t/ha) at IRRI were attributed to water stress, high weed density, and severe RTV. Among the heavily infected entries in the second planting at IRRI were BR4, Cisadane, IR13419-113-1, IR24, UPL Ri-2, IR10120-5-1-1, IR11438-13, IR13761-16, IR13763-5, and IR9669 Sel.

The Cebu field produced yields of up to 5.7 t/ha with adequate rainfall throughout the growing season. The field retained impounded water until the flowering stage of the medium-maturing lines except for brief periods (Fig. 6). The water table stayed near the soil surface until harvest was completed.

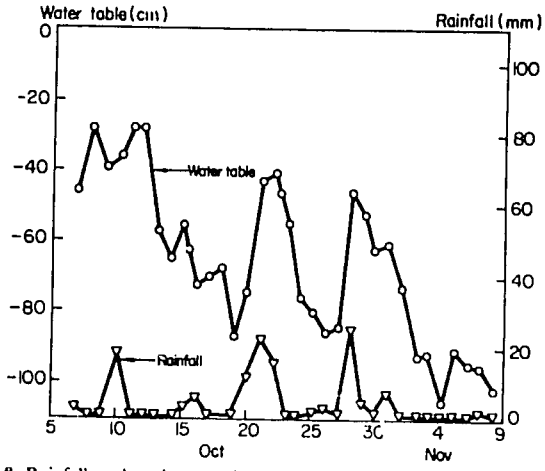
Table 11 shows the top 13 entries in each group of the integrated performance trials for rainfed shallow water drought-prone environments. Some entries produced high grain yields for 2 or more yr. Many lines produced high average yields in Cebu but only low yields at the two IRRI fields. The IRRI site yields illustrate the entries' response to stress while the Cebu yield shows the potential without water limitations.

Highest yielding genotypes in the trial in all three environments included IR46, IR19431-72-2, IR13146-45-2-3, IR19274-26-2-3-1, IR22082-41-2, IR26933-16-2-3, and IR13146-13-3-3.

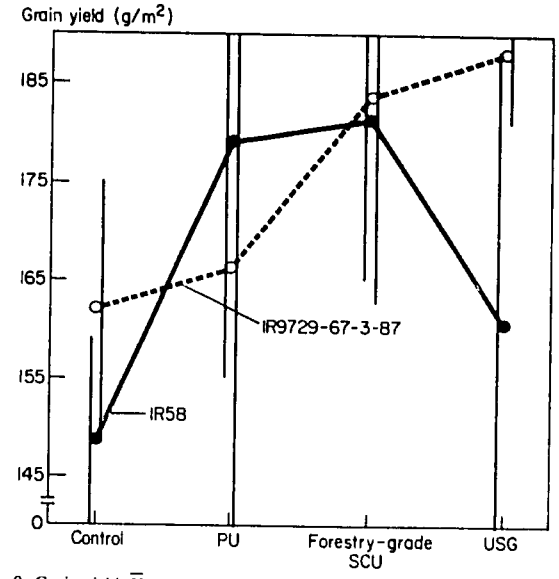
Yield potential of rainfed wetland breeding lines with improved nitrogen management (*Agronomy*). The yield potential of 10 breeding lines was evaluated in Cebu and Santa Rosa, Laguna, in 1983 DS. The improved N management practices were PU (2/3 basal incorporated, 1/3 topdressed 5 DBPI), forestry-grade SCU (B&I), and USG (point placement). Fertilizer rate was 60 kg N/ha. The rainfall was adequate in Cebu during the growing season and 9 of 10 varieties produced high grain yields (Fig. 7). Very early-maturing varieties IR9729-67-3-87 and IR58 also produced high yields, but IR9729-67-3-87 was more responsive to fertilizer. Bird damage caused IR32809-22-5-5 to produce the lowest yield, which was, however, consistently low even when amended with PU, forestry-grade SCU, or USG. Yields increased with all N sources.



7. Grain yield of rice varieties as affected by N sources. Means connected by the same line are not significantly different at 5% level. Cebu, 1983 WS.



8. Rainfall and underground water table in Santa Rosa, Laguna, 1983 WS.



9. Grain yield ($\bar{X} \pm$ S.E.) of IR58 and IR9729-67-3-87 from different N sources. Santa Rosa, Laguna, 1983 WS.

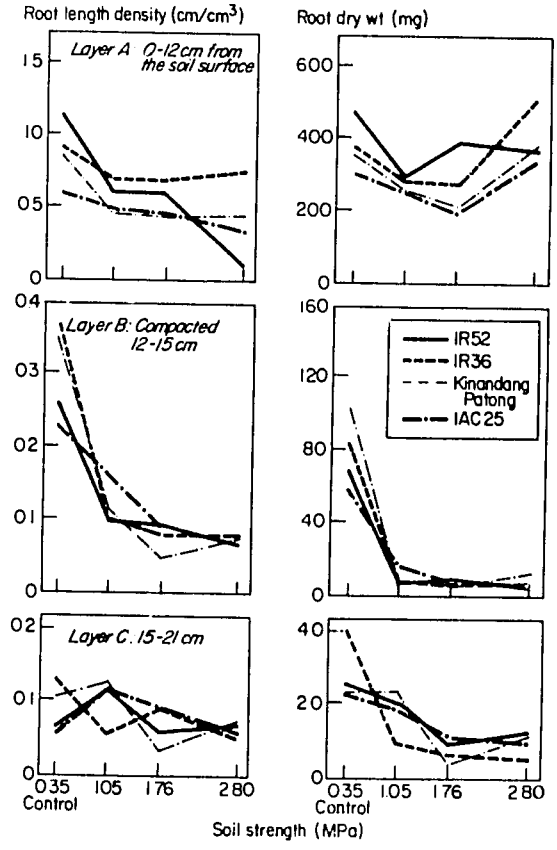
Low rainfall caused severe water stress in most of the test cultivars in Santa Rosa, Laguna (Fig. 8). Although the early maturity of IR9729-67-3-87 and IR58 helped them escape water stress (Fig. 9), their yields were still low. During early stress, varieties fertilized with USG appeared greener than those with PU and forestry-grade SCU. As stress became severe especially in the reproductive phase, the remaining varieties could not produce panicles.

ROOT STUDIES

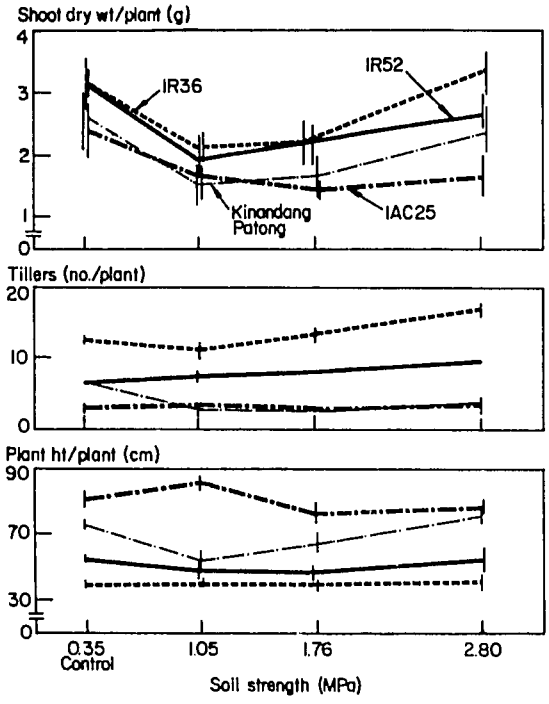
Agronomy and Plant Breeding Departments

Root and shoot responses to soil mechanical impedance (*Agronomy*). An impeding soil layer (high soil strength) which affects root penetration may be a constraint to rainfed rice production. A greenhouse study using clay loam soil determined the root and shoot responses of four rice varieties to four soil strengths during the vegetative phase. A 15- × 24- × 21-cm container grew one plant with soil moisture at about field capacity (≅0.03 MPa) and a compacted subsoil layer at 12 to 15 cm.

All varieties declined in root length density and root weight at 1.05 MPa in the compacted zone (layer B) and in the layers above (layer A) and below (layer C) that zone (Fig. 10). Total root length density decreased by 62% as soil strength increased from 0.35 MPa (uncompacted) to 1.05 MPa. As soil strength increased to 2.80 MPa, varieties did not differ significantly in root length density or in their response to the soil strength



10. Effect of soil strength (layer B) on root length density and root weight in clay loam soil maintained at about field capacity (≅0.03 MPa) for 35 d. Soil strength was measured with a penetrometer before adding 12-cm surface soil. IRRI, 1983.

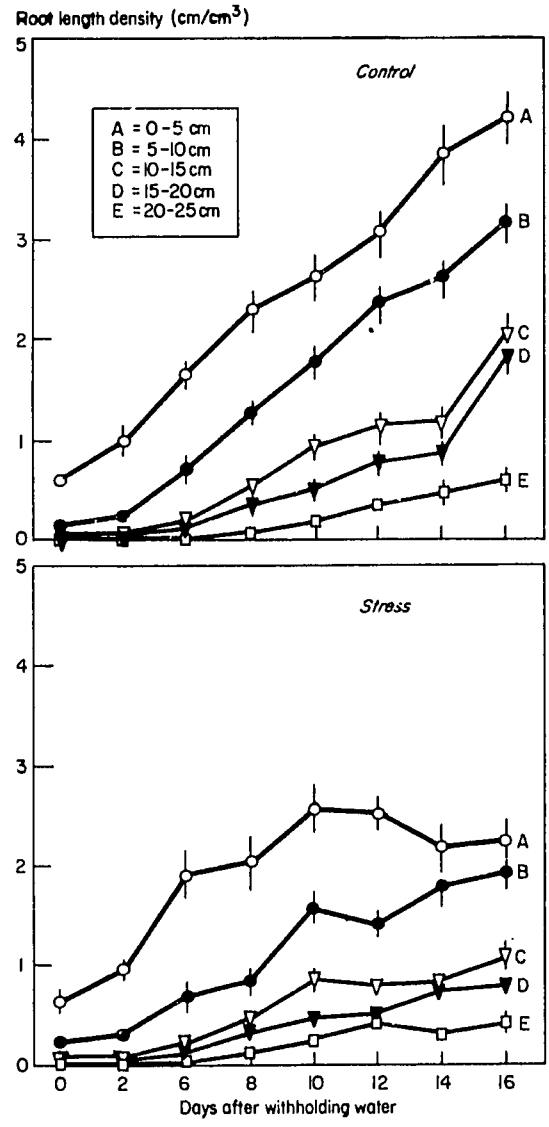


11. Effect of soil strength on shoot dry weight, tiller count, and height of rice. All mean points ± S.E. IRRI, 1983.

treatment levels in layers A, B, and C. Variation in root length density at 0.35 MPa could relate to difference in tiller count (Fig. 11).

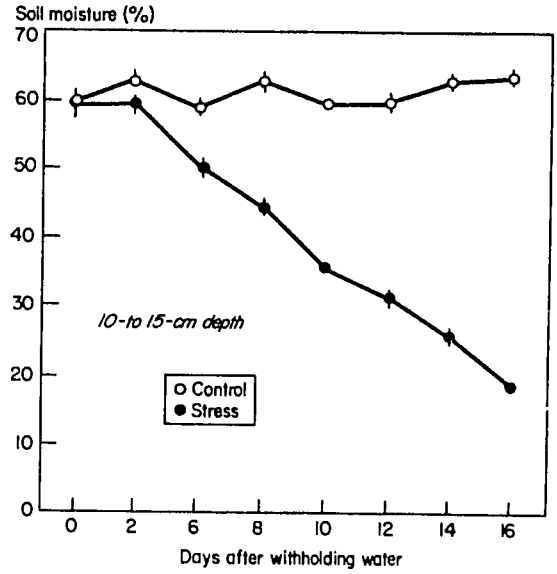
The same trend occurred in root weight except at 2.80 MPa in layer A (Fig. 10) where root dry weights of most cultivars increased significantly and equalled or exceeded values at 0.35 MPa. An impeding layer of greater soil strength in the subsoil strongly influenced response in layer A where 73% of the total root length density occurred. IR36 had significantly higher root dry weight than the 3 other varieties in layer A at 2.80 MPa which indicated a corresponding increase in root diameter. Shoot dry weight of most varieties (Fig. 11) paralleled root dry weight in layer A at increased soil strength. High soil strength increased tiller development especially in wetland varieties IR36 and IR52 by 10% at 1.76 MPa and by 40% at 2.80 MPa (Fig. 11). There was no clear trend in plant height but upland varieties Kinandang Patong and IAC25 were consistently taller than the semidwarf IR varieties.

Response of rice root system to water stress in puddled soil (*Agronomy*). A greenhouse experiment with IR36 was conducted to understand the

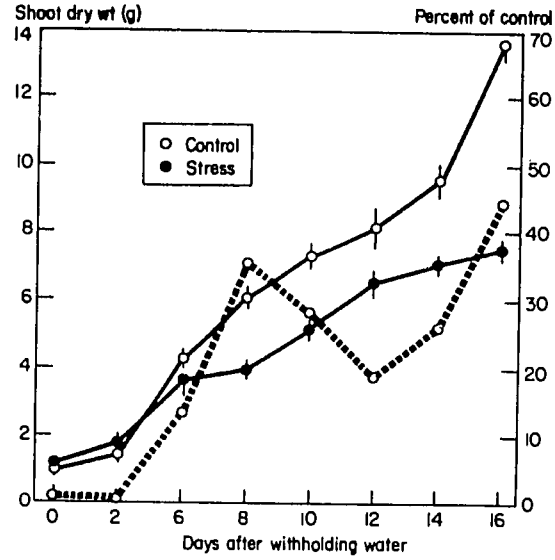


12. Effect of water management on root length density over time and depth. IRRI greenhouse, 1983.

response of the rice root system to water stress in puddled soil. The randomized complete block design experiment with 4 replications involved 2 systems of water management: continuously flooded (2 cm of standing water) and stress. Nine kilograms of ground, air-dried, and sieved Maahas clay soil was placed 25 cm deep in 27-cm-deep plastic containers with an internal diameter of 23 cm at the top and 19 cm at the bottom. Each container received fertilizer according to recommendations before transplanting. Two 21-d-old uniform-sized seedlings were transplanted into



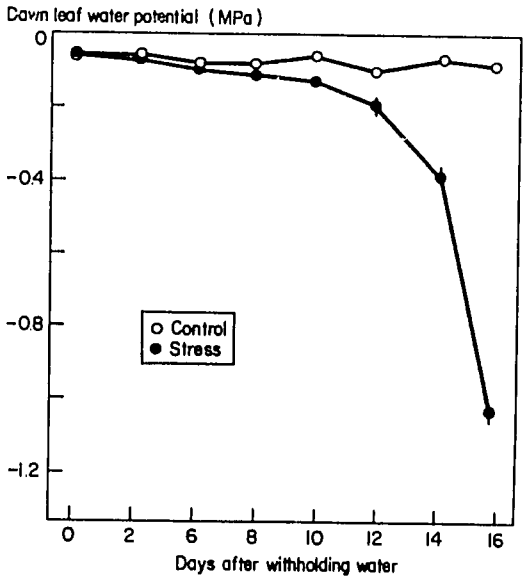
13. Soil moisture content of flooded and stress treatments. IRRI greenhouse, 1983.



15. Effect of water management on shoot dry weight accumulation. IRRI greenhouse, 1983.

each container and thinned to 1 plant 7 d later. Watering for the stress treatment stopped 17 DT. The wet soil was frozen and later sectioned into 5-cm depths.

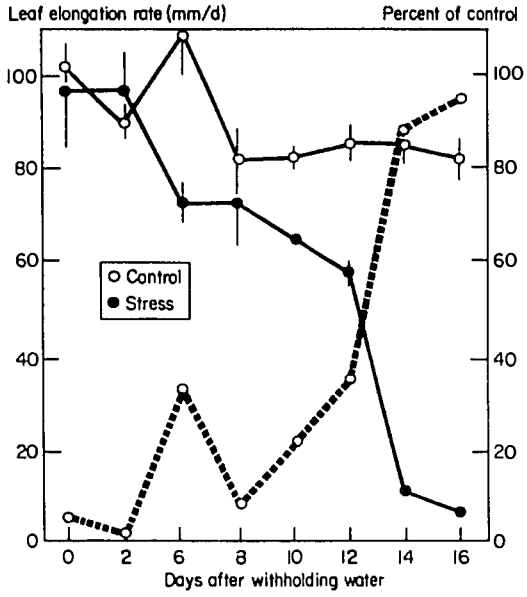
A Root Length Scanner estimated root length density (RLD) from 0-25 cm at every 5-cm-depth increment through a 16-d drying cycle. Figure 12 shows that differences in RLD between stressed and flooded plants were negligible from day 1 to day 10. On day 12, stressed plants averaged 31% less RLD than flooded plants, and on day 16, 45% less. Slow root growth, old root death, reduced soil moisture (SM) (Fig. 13) and low dawn leaf water potential (DLWP) (Fig. 14) probably reduced RLD significantly after day 12.



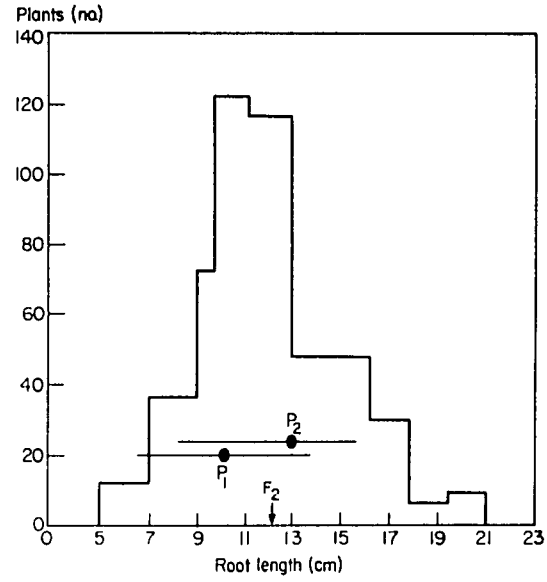
14. Dawn leaf water potential of flooded and stress treatments. IRRI greenhouse, 1983.

The effects of stress on plant dry weight were observable on day 6 but the decline was not dramatic (Fig. 15). By day 8, the dry weight of stressed plants was 36.5% less than that of the flooded plants and by day 16, 45.3% less. Leaf elongation rate (LER) was also reduced with moisture stress (Fig. 16). On day 6, LER was 33% reduced with 49% SM and -0.09 MPa DLWP. The greatest reduction (94.0%) in LER was on day 16 at 19% SM and -1.02 MPa DLWP.

Genetic studies on root systems (*Plant Breeding*). Genetic studies on root systems in the field were conducted to improve the selection method for deep-and-thick root characters. Seeds of two F_2 bulk populations, IR20/Kinandang Patong and IR20/Moroberekan, and the parent lines were grown in a dry seedbed for 25-30 d. Root data on 500 F_2 seedlings showed that in the cross IR20/Kinandang Patong, the F_2 distribution was continuous with transgressive segregation beyond parental limits (Fig. 17). Root length of the F_2 seedlings varied from 5 to 21.5 cm with mean root



16. Effect of water management on LER. IRRI greenhouse, 1983.



17. Distribution and means of parent and F_2 plants by root length classes in the cross IR20 (P1)/ Kinandang Patong (P2) in the field. IRRI, 1983. Solid horizontal lines show ranges of the parents about the mean (circles); the arrow shows the mean of the F_2 population.

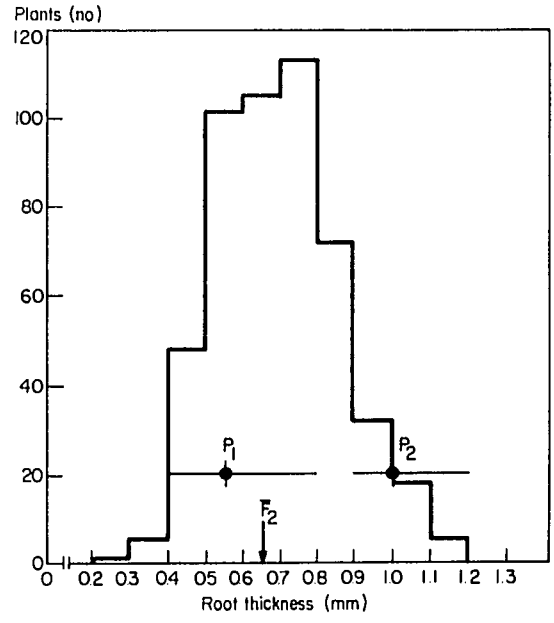
thickness of 0.65 mm ranging from 0.2 to 1.2 mm. Only 1.2% F_2 plants transgressed the lower limit of the thin-rooted parent IR20 (Fig. 18).

Root number also showed a continuous F_2 distribution with slight positive skewedness (Fig. 19). The number ranged from 1 to 76, having a mean of 30.

An F_2 population of the same cross was grown in an aeroponic culture system. In both cultures, results indicated that root length, root thickness, and root number were controlled by multiple genes. IR20 had more dominant alleles for thin roots, while Kinandang Patong showed more dominant alleles for low root number and root length. In the IR20/Moroberekan cross, the longer Moroberekan roots appeared to be governed by dominant alleles.

Correlation analysis showed that root length is significantly related with root thickness (0.27**), plant height (0.96**), and tiller number (0.87**). Although there was a positive significant correlation between root length and root thickness, the value is rather low. However, it still indicates the possibility of selecting intermediate height plants with deep-and-thick root systems.

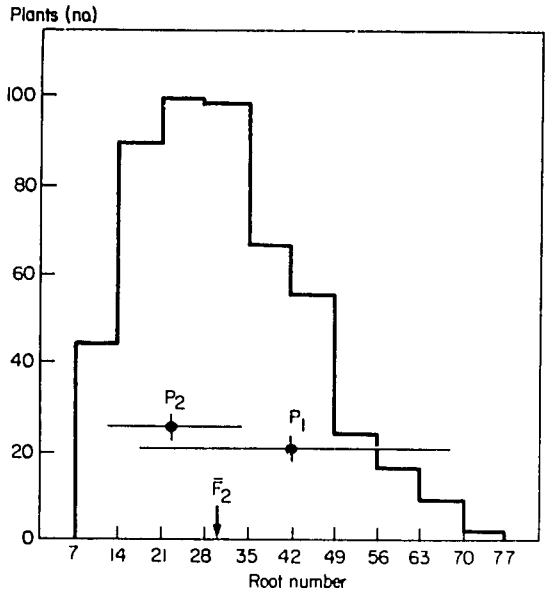
This study demonstrated that it is possible to study the rice root system under field conditions when physical facilities and financial inputs of an experiment station are limited. The results also



18. Distribution and means of parent and F_2 plants by root thickness classes in the cross IR20 (P1)/ Kinandang Patong (P2) in the field. IRRI, 1983. Solid horizontal lines show the range of the parents about the mean (circles); the arrow shows the mean of the F_2 population.

provide useful information on selecting progenies with deep and thick roots.

Root characters of 25-day-old seedlings grown in a dry seedbed (*Plant Breeding*). A deep-and-



19. Distribution and means of parent and F_2 plants by root number classes in the cross IR20 (P1) Kinandang Patong (P2) in the field. IRRI, 1983. Solid horizontal lines show the range of the parents about the mean (circles); the arrow shows the mean of the F_2 population.

thick-root system is useful in selecting for drought resistance. Fifteen rice varieties, including upland, aus, bulu, and semidwarf, were grown in a dry seedbed for 25 d during WS. Seedlings were gently pulled and roots were washed thoroughly before data were recorded. Kalakeri had the greatest mean root length (15.4 cm) and IR20 the shortest (9.4 cm) (Table 12). The root length of traditional upland varieties ranged from 12.9 to 15.4 cm. Improved upland varieties had root lengths from 12.0 to 15.0 cm. Aus 61 had a mean root length of 13.4 cm and the bulu variety Hawara Batu, 14.1 cm.

IACs of Brazil and ITAs of Nigeria had thick roots. Traditional upland varieties have thicker roots — 0.91 mm to 1.02 mm. IR20 had the thinnest root, but the highest root number. Moroberekan and IAC25 had the lowest.

Analysis of variances showed that the varieties had highly significant differences in root length, root thickness, and root number.

Root systems of aus, bulu, and upland rices (*Plant Breeding*). Traditional upland rices commonly have an avoidance mechanism to resist drought. Deep roots exploit the lower soil horizons for nutrients and water to meet the evaporative demand. Thick roots are important to water uptake and translocation; they allow easy flow through conducting vessels and thus prevent moisture stress.

A comparative study of 6 parental varieties and 15 F_1 hybrids investigated root system, water uptake, and similarities among the aus, bulu, and upland groups. An aeroponic culture of the root systems showed that upland varieties generally have deep and thick roots, higher root-to-shoot ratios, lowest root numbers, and lowest root dry weight among the three varietal groups.

Correlation analysis showed positive associa-

Table 12. Mean values of 3 root characters of 15 rice varieties grown in the field. IRRI, 1983 WS.

Variety	Type of culture	Root length (cm)	Root thickness (mm)	Root no.
IR20	Lowland	9.4	0.52	32.8
IR43	Lowland	11.0	0.69	24.9
IR45	Lowland	10.8	0.76	17.1
IR6115-1-1-1	Improved upland	12.0	0.67	21.3
UPL Ri-7	Improved upland	14.0	0.95	21.8
ITA235	Improved upland	14.4	1.03	18.7
IAC25	Improved upland	15.0	1.08	14.1
IAC165	Improved upland	14.5	1.09	15.9
Black Gora	Traditional upland	15.0	0.98	23.1
Kalakeri	Traditional upland	15.4	1.02	23.8
Kinandang Patong	Traditional upland	13.0	0.92	15.3
Moroberekan	Traditional upland	12.9	0.91	12.3
OS4	Traditional upland	13.0	0.94	12.9
Aus 61	Aus	13.4	0.82	16.1
Hawara Batu	Bulu	14.1	0.93	17.7

Table 13. Matrix of correlations among 8 traits in 6 parents and 15 F_1 hybrids. IRRI, 1983.

	Tiller number	Plant height	Root length	Root number	Root thickness	Root dry weight	Shoot dry weight	Root-to-shoot
Tiller	1.0000							
Plant height	−0.74719	1.0000						
Root length	0.42993ns	0.66198	1.0000					
Root number	0.88373	0.85843	−0.49329	1.0000				
Root thickness	−0.53115	−0.17258ns	0.43303	−0.42911ns	1.0000			
Root dry weight	0.65258	0.75582	0.91635	0.70976	0.22769ns	1.0000		
Shoot dry weight	0.87586	0.91340	0.68512	0.91417	−0.19709ns	0.83225	1.0000	
Root-to-shoot	−0.60878	−0.54887	0.07022ns	−0.63967	0.71087	−0.07231ns	−0.57016	1.0000

tions among eight root characters (Table 13). Root length was significantly and positively correlated with root thickness, root dry weight, shoot dry weight, and plant height but not with the root-to-shoot ratio. The correlation between root thickness and root-to-shoot ratio was positive and highly significant, but that between root thickness and tiller number was negative and significant. Root number was positively and highly significantly correlated with root dry weight, shoot dry weight, and tiller number. The unusual correlation between plant height and root number was likely contributed by the bulu parents as they are both tall and high in root number. However, there was a negative and highly significant correlation between root number and root-to-shoot ratio. The interrelationship of different root characters indicates that selection for one desirable root character could lead to improvement of others.

A study on water uptake of three varietal groups in hydroponic culture was conducted in DS. The upland group had significantly lower water uptake than the drought-susceptible check IR20 (Table 14). Water uptake estimates for the aus and bulu groups were higher than for IR20. The aus and bulu groups have higher drought resistance than IR20 and also gave higher water uptake values. Therefore, the uptake data alone cannot be a criterion for drought resistance screening in hydroponic culture.

Correlation coefficient values among varieties showed that the aus group is similar to upland and bulu groups in root length, root thickness, and root number.

Root development of varieties grown in aeroponic culture (*Plant Breeding*). A preliminary study on root development of 10 rice varieties in aeroponic culture included upland, aus, bulu, and two semidwarf varieties. Measurements at 14, 21, and 28 DAS showed that most deep-rooted upland varieties have a slower root elongation rate up to 21 DAS (Table 15). From 21 to 28 DAS, however, the rate increased, with Kalakeri increasing most (13.4 cm) followed by Kinandang Patong (11.9 cm). The shallow-rooted IR20 rapidly increased 5.4 cm at 21 DAS, but further increase to

Table 14. Root characteristics and water uptake of 7 rice varieties measured on the 30th day from sowing.[a] IRRI, 1983 DS.

Variety	Root thickness (mm)	Root length (cm)	Root number	Root dry weight (g)	Root-to-shoot ratio	Water uptake/ plant (cc)
Moroberekan	1.20	27.5	38	0.59	0.340	29.7
Kinandang Patong	1.01	21.0	51	0.60	0.306	33.4
Aus 61	0.89	26.1	39	0.83	0.323	46.6
Dular	0.90	24.4	47	0.86	0.326	34.8
Hawarabatu	0.68	22.3	74	0.85	0.299	39.4
Rodjolele	0.56	25.1	81	0.89	0.287	53.1
IR20	0.35	19.0	87	0.45	0.286	33.6

[a]Average of 3 replications.

Table 15. Root length of 10 cultivars grown in aeroponic culture. IRRI, 1983 WS.

Variety	Root length (cm)		
	14 DAS	21 DAS	28 DAS
IR20	6.6	12.0	18.6
IR43	7.5	13.8	23.7
Black Gora	12.3	16.6	25.5
Kalakeri	12.6	17.1	30.5
Kinandang Patong	11.8	17.3	29.2
Macuspana A75	8.3	11.9	20.9
Moroberekan	11.6	16.6	27.5
OS4	12.5	16.5	27.2
Aus 61	10.1	14.5	24.2
Hawara Batu	16.3	18.0	26.4

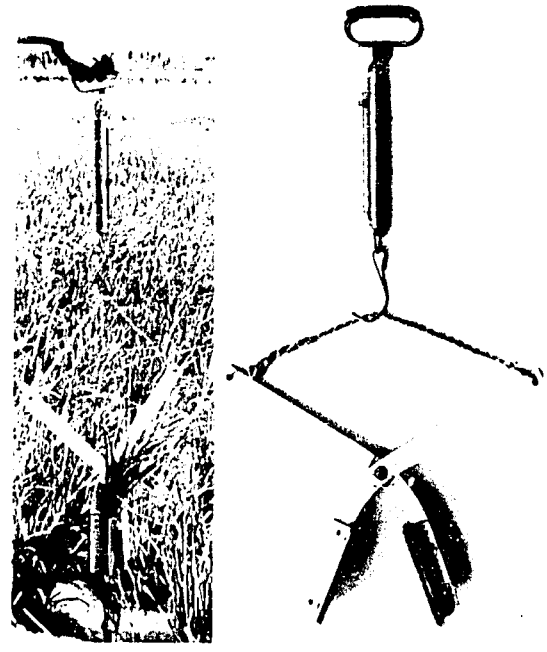
Table 16. Root thickness of 10 cultivars grown in aeroponic culture. IRRI, 1983 WS.

Variety	Root thickness (mm)		
	14 DAS	21 DAS	28 DAS
IR20	0.53	0.55	0.61
IR43	0.57	0.59	0.84
Black Gora	0.63	0.68	0.96
Kalakeri	0.62	0.69	0.91
Kinandang Patong	0.77	0.72	1.02
Macuspana A75	0.58	0.57	0.71
Moroberekan	0.65	0.73	0.92
OS4	0.62	0.66	0.87
Aus 61	0.61	0.66	0.97
Hawara Batu	0.56	0.56	0.90

28 DAS was almost the same (6.7 cm).

Upland varieties also showed the thick root characteristic early. At 14 DAS, root diameter among the 10 varieties ranged from 0.53 mm of IR20 to 0.77 mm of Kinandang Patong (Table 16). The thick-rooted varieties like OS4, Moroberekan, and Kinandang Patong grew 0.04 mm to 0.08 mm from 14 to 21 DAS, and 0.21 mm to 0.30 mm from 21 to 28 DAS. The thin-rooted IR20 and IR43 both grew 0.02 mm from 14 to 21 DAS. IR20 grew 0.06 mm and IR43 0.25 mm from 21 to 28 DAS.

Root pulling force as a means of evaluating drought resistance in rainfed lowland rice (*Agronomy*). Earlier studies show a positive correlation between greater root pulling force and tolerance for drought possibly because deeper root systems can acquire more moisture. Since 1980 GEU elite breeding lines and the replicated yield trials (RYT) have been screened for root pulling force. A randomized complete block design with four replications was used to measure the force required to pull the seedling. Two check varieties or lines (IR20 and MGL 2 for GEU, IR36 and IR42 for RYT) were used each season. The root pulling force was measured by attaching a spring balance with maximum reading indicator to each seedling with a clamping device (Fig. 20) and raising the seedling out of the soil at a uniform rate. Ten hills per entry were pulled alternately in the center of the 2 inside rows in each 10-row plot. Varieties with insect pests and diseases were discarded and the maximum kg reading was recorded for each seedling at 25-30 DT. The test showed that IR9729-67-3 and IR19735-5-2-3-2-1 performed well for 3 or more years (Table 17). The test used transplanted seedlings and is most relevant to shallow wetland areas where water deficits decrease yield.



20. Instrument scale with heavy duty handle and clamp device used to measure force in kilograms required to pull rice plants from the soil. IRRI, 1983.

SOIL-PLANT-WATER RELATIONSHIPS

Agronomy Department

Drought tolerance under limited rooting depth. A total of 105 GEU elite lines and selected varieties were evaluated in 2 seasons for drought tolerance and ability to recover from drought stress with rooting depth limited to 45 cm. All entries were

Table 17. Varieties or lines with high root pulling force for 2 or more years.

Variety	1980	1981	1982	1983
IR52	√	√		
IET1444	√	√		
IR9729-67-3	√	√		√
IR9763-11-2-2	√	√		
IR13443-53-2-2-1-1-1		√	√	
IR19735-5-2-3-2-1	√	√	√	√
IR21188-87-1		√	√	
IR25572-87-3-3			√	√
IR25621-68-2-3			√	√
IR25840-38-3-2			√	√
IR25861-64-3-2			√	√
IR25863-8-2-3			√	√
IR25890-82-5-3			√	√

seeded in dry soil in steel drums and watered regularly to 30 DAS when evapotranspiration dried the soil. When indicator plant Leb Mue Nahng was apparently dead, the plants were scored for drought tolerance and then rewatered.

Promising entries recovered after relief from stress (Table 18). Some have outstanding drought tolerance as compared to Leb Mue Nahng, but recovery was poor and slow compared to previous tests. Despite the poor rating of IR17525-7-19-1-3-3-2, it recovered; Leb Mue Nahng did not. Results indicate that the ability to tolerate drought does not necessarily mean good drought recovery.

Table 18. Drought tolerance ratings of promising entries during the vegetative phase and their recovery after relief from stress. IRRI greenhouse, 1983.

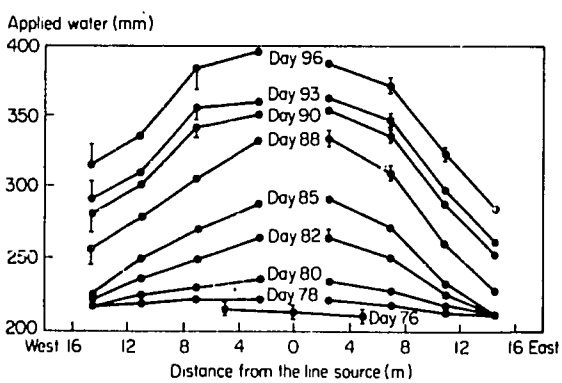
Variety or line	Drought tolerance rating[a]	Tillers (%) that recovered 2 wk after relief from stress
Dry season		
IR10110-24-1	6	17.9
IR25861-64-3-2	7	15.5
IR28143-51-3-3-1	6	15.4
IR25924-92-1-3	7	14.9
IR17525-7-19-1-3-3-2	9	14.1
IR3639-1	6	6.9
IR25863-8-2-3	6	6.3
IR6115-1-1-1	7	4.8
Leb Mue Nahng	9	0
Wet season		
B44b-50-2-2-5-1-1	7	17.9
IR10011-16-3	6	9.1
IR19735-5-2-3-2-1	6	7.5
IR29725-3-1-3-2	7	7.5
IR5931-110-1	7	5.0
Leb Mue Nahng	9	0

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

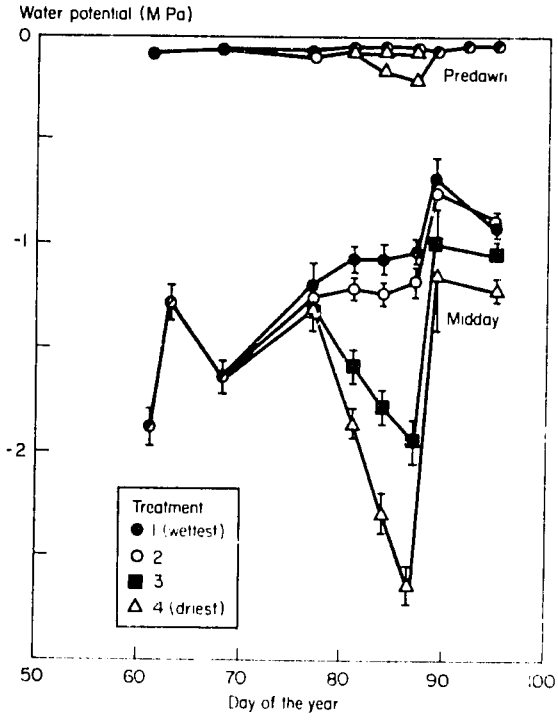
Response of divergent rice ecotypes at vegetative phase to a line source sprinkler irrigation gradient. Previously line source sprinkler irrigation was used to assess reproductive phase drought tolerance of several varieties. In the 1983 DS, the sprinkler was used to determine response of lowland and upland varieties at the vegetative phase.

Line source treatment and evaporative demand. Irrigation was imposed from 44 to 55 DAS. Figure 21 illustrates the linearly decreasing amount of water applied by a centrally located single line of sprinklers. During the treatment period, average total radiation was 20 MJ/m^2 daily, maximum vapor pressure deficit 3.1 kPa, rainfall 0 mm, and pan evaporation 7 mm/d.

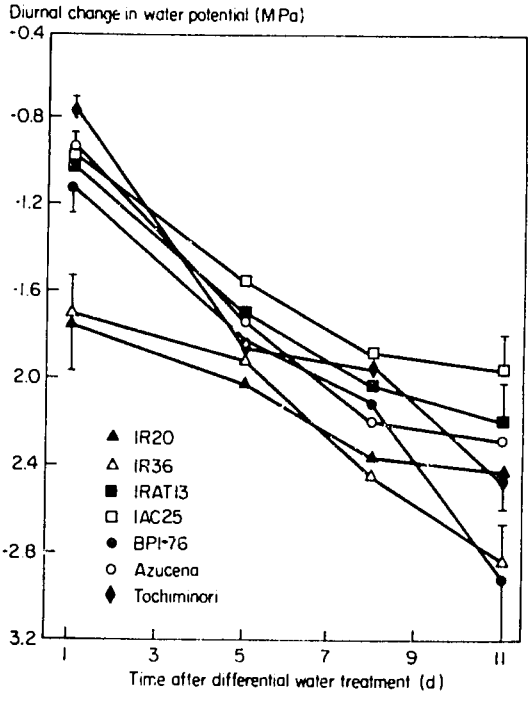
Leaf water potential. Figure 22 shows the development of plant water stress from treatment 1 (wettest) to 4 (driest). Immediately after differential irrigation treatment, average midday LWP of varieties in treatments 3 and 4 decreased progressively until rewatering. The predawn LWP in treatment 4 decreased 8 d after differential irrigation treatment. Since predawn LWP did not differ significantly among the varieties (Fig. 22), the diurnal change in LWP (difference between midday and predawn values) in the well-watered plants was significantly greater in the two lowland varieties than in the five upland varieties (Fig. 23). However, the diurnal change in the upland cultivars became greater as water deficits developed.



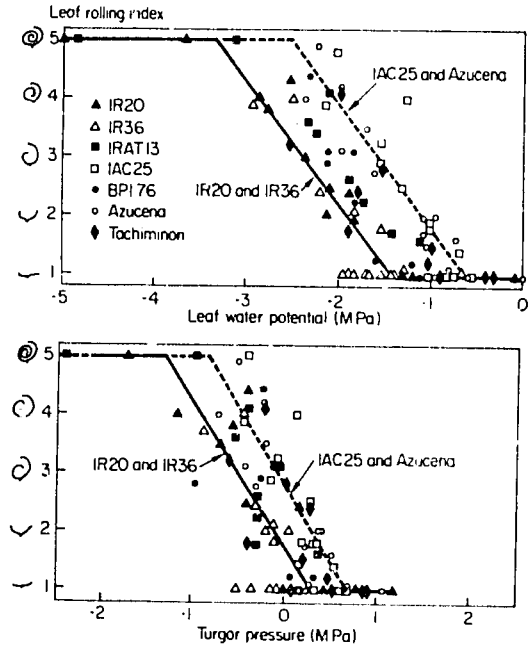
21. Amount of water applied before, during, and after the differential irrigation treatment. IRRI, 1983. East and west halves of the plot represent 2 replications. Distance from the line source is represented by treatment 1 at 4 m, 2 at 8 m, 3 at 12 m, and 4 at 16 m. All mean points ± S.E.



22. Changes with time in the predawn (0400 to 0600 h) and midday (1200 to 1500 h) rice leaf water potential in the 4 water treatments. IRRI, 1983. Standard errors less than ±0.2 MPa are omitted for clarity.

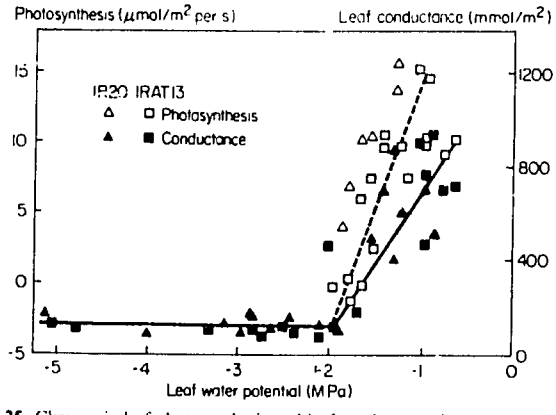


23. Diurnal change in LWP (midday values minus predawn values) over time after differential irrigation for treatment 4. IRRI, 1983. All mean points ± S.E.



24. Relationship between leaf rolling index and midday LWP and midday leaf turgor pressure in 7 rice varieties. IRRI, 1983.

Leaf rolling. The leaf rolling score, a visual stress indicator used in field screening, was related to total LWP and its component, turgor pressure (Fig. 24). This score showed that Azucena and IAC25 were the first to roll during the day and first to remain rolled overnight while IR36 was last to roll. Although IR36 and IR20 had the lowest midday LWP, they also had the lowest water potential and turgor pressure at which leaf rolling began. They had the same leaf rolling score, but at

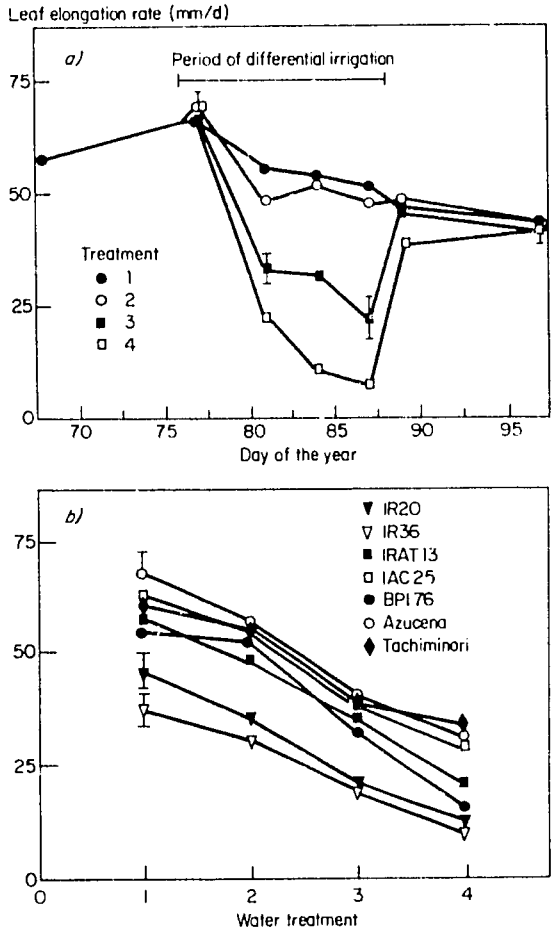


25. Changes in leaf photosynthesis and leaf conductance in response to changes in LWP. IRRI, 1983. The solid line is the fitted linear regression to conductance values below and above -2 MPa and the broken line is the fitted linear regression to the photosynthetic values.

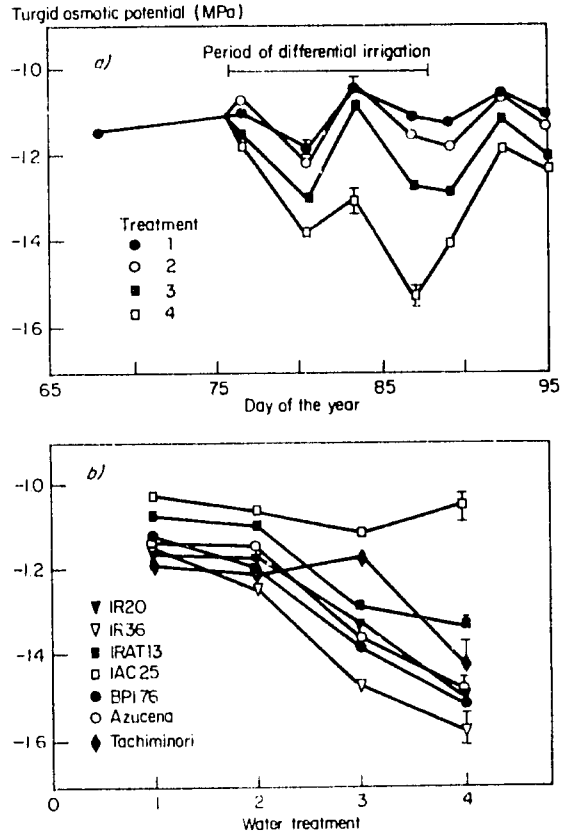
a -0.8 MPa lower LWP than IAC25 and Azucena. Results show that the leaf rolling index does not indicate LWP or leaf turgor since it is higher at higher MPa in upland than in lowland varieties.

Photosynthesis and stomatal conductance. Water stress decreased stomatal conductance and photosynthesis rates in IR20 and IRAT13 (Fig. 25). Leaf conductance decreased from 800 mmol at -0.8 MPa to 100 mmol at -1.8 MPa; photosynthesis rates decreased from 15 μmol at -1.0 MPa to 0 at -1.9 MPa. Leaf conductance values were constant at about 100 mmol m^2 per second to below -5.0 MPa. There was no difference in the relationship between stomatal conductance and midday LWP in the two varieties.

Growth. There was no significant difference among varieties in growth rates, but average growth rate in treatment 1 was 0.22 ± 0.02 g g daily and 0.16 ± 0.01 g g daily in treatment 4.



26. a) Change over time in LER in 4 water treatments. IRRI, 1983. All mean points ± S.E. b) The LER in the 4 water treatments. All mean points ± S.E. Standard errors less than 2.5 mm d are omitted for clarity.



27. a) Average turgid osmotic potential response of all varieties over time in 4 water treatments. IRRI, 1983. Values are means ± standard error of the means of 4 replications. b) Turgid osmotic potential in 4 water treatments on the day after removal of differential irrigation treatment. All mean points ± S.E.

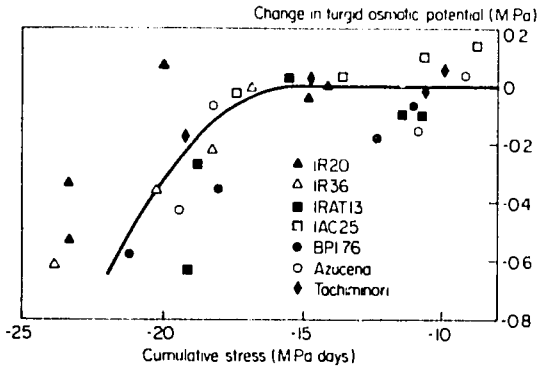
A reduction in applied water rapidly affected the leaf elongation rate (Fig. 26a). In treatment 1, the two lowland varieties had lower LER than the upland varieties (Fig. 26b). The lower LER in the lowland varieties could come from the greater diurnal change in LWP (Fig. 23). LER decreased linearly with midday turgor pressure but without differences among varieties. The degree of diurnal osmotic change in the lowland varieties was insufficient to maintain leaf growth.

Similarity among varieties in the relationship between LER and MPa shows that leaf growth suffers from the greater diurnal change in LWP in lowland compared to upland varieties. Lowland varieties probably reduce water loss by reducing leaf area, and upland ones by leaf rolling. Both decreased DM production equally in all varieties.

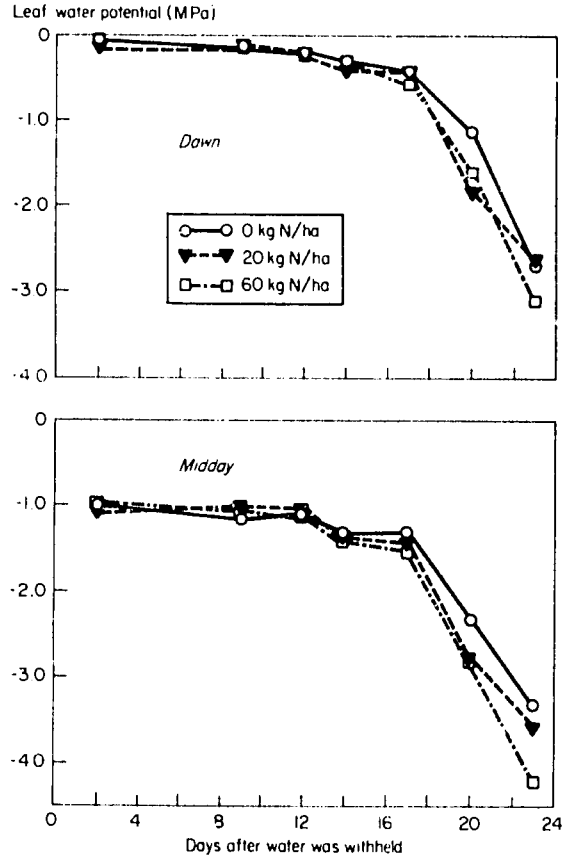
Osmotic adjustment. Figure 27a shows change in turgid osmotic potential (π_{100}) in 4 water treatments. As plant water stress developed, π_{100} decreased from -1.1 MPa in treatment 1 to -1.5 MPa in treatment 4, or an osmotic adjustment of -0.4 MPa. Drought stress can induce a -0.5 to -0.6 MPa osmotic adjustment in lowland varieties (Fig. 27b). However, upland IAC25, IRAT13, and Tachiminori adjusted least. Although stress rate and degree were similar in all varieties, leaf rolling (Fig. 24) reduced water loss, particularly in IAC25 and Azucena. Plant or soil plant resistance presumably induced greater diurnal changes in LWP in lowland than in upland varieties (Fig. 23). Therefore, cumulative stress is different for different varieties.

Figure 28 shows a threshold summary of minimum midday values of water potential (MPa days) for 16 d. There was no significant difference among varieties in the threshold stress or rate of solute accumulation with cumulative stress. IAC25 lacked osmotic adjustment and IRAT13 and Tachiminori had a smaller degree of adjustment perhaps because they experienced less stress than the other varieties. There are no inherent differences in osmotic adjustment.

Nitrogen and water stress interaction. A greenhouse experiment determined how IR36 reacted to water stress after receiving different N rates. Pregerminated seeds were sown in trays (32 × 24 × 10 cm) containing 6.5 kg of sieved soil. The plants were thinned to one plant per tray 11 DAS. P (solophos) and K (muriate of potash) were applied at a rate of 30:30 kg/ha based on 200,000 plants/ha. N treatments were 0, 20, and 60 kg/ha. Stressed



28. Relationship between the change in turgid osmotic potential (differences between treatment 1 and treatment 4 values) and cumulative stress for the period of the differential irrigation treatment. IRRI, 1983.



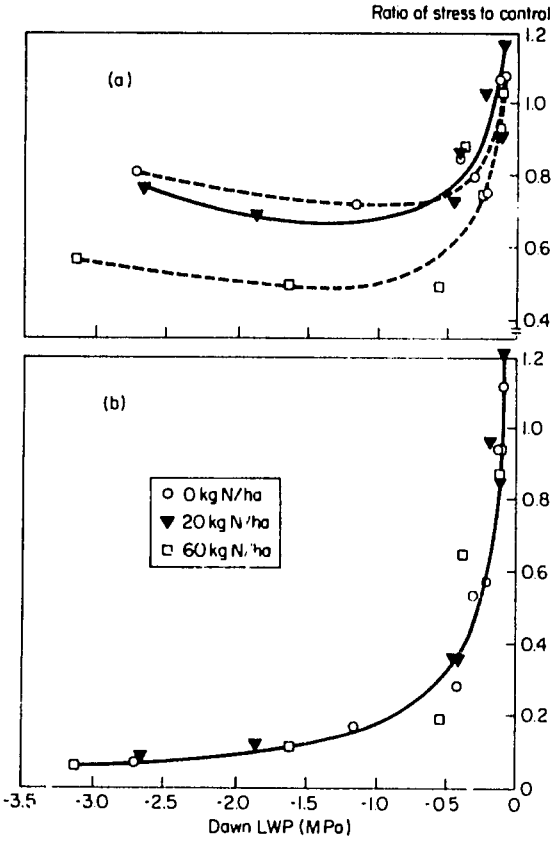
29. Dawn and midday LWP of IR36 grown at 3 N levels during the 23-d stress period. IRRI, 1983.

plants received no water 25 DAS while the control group was well-watered.

Dawn and midday LWP of stressed plants grown at the 3 N levels decreased on day 14 (Fig. 29). Over the next 9 d, LWP dropped to an average of -2.83 MPa at dawn and -3.72 MPa at midday. Control plants maintained dawn LWP above -0.2 MPa and midday values ranged from -0.62 MPa to -1.13 MPa throughout the stress period.

Figure 30 shows the relationship between dawn LWP and the ratio of N uptake in shoot of stressed and control plants. Uptake at all N rates decreased below control levels at -0.2 to -0.45 MPa LWP. However, water stress reduced N uptake by about 50% at 60 kg N/ha and by about 30% at 0 and 20 kg N/ha.

Transpiration rates declined at the same dawn LWP that N uptake decreased. Amount of N had no effect on the transpiration rate ratio between stress and the control at any particular dawn LWP.



30. Relationship of dawn LWP and the ratio of stressed to control plants for a) N uptake and b) total amount of water given daily in IR36 at 3 N levels. IRRI, 1983.

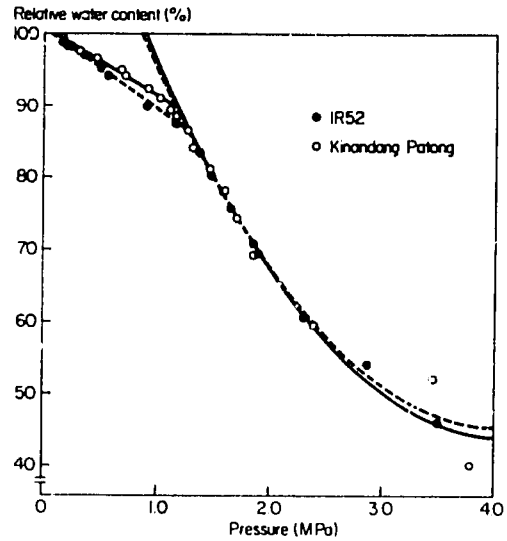
Stress treatment transpiration decreased to 6 to 9% of the control.

Rice leaf elasticity. Tissue elasticity affects turgor response of plants to water stress and is described by its bulk volumetric modulus of elasticity (ε):

$$\varepsilon = \frac{\Delta \Psi_p}{\Delta RWC} \times 100$$

where $\Delta \Psi_p$ is the change in bulk pressure potential and ΔRWC is the change in relative water content of the tissue. High ε means low elasticity and vice versa.

The pressure-volume technique was used to determine leaf elasticity of 10 varieties grown in lowland conditions. The technique uses a pressure chamber to apply a series of pressure on a leaf to determine water potential. The leaf is weighed after each reading. Figure 31 illustrates the pressure-volume curves for IR52 and Kinandang Patong. Change in LWP at high water content was mainly



31. Relationship between LWP or applied pressure and relative water content in IR52 and Kinandang Patong. IRRI, 1983.

due to change in bulk pressure potential. The bulk volumetric modulus of elasticity was calculated from the slope of the linear portion of the curve. Applied pressure (P) or LWP replaces pressure potential. There was no significant difference in ε; flag leaves and second youngest fully developed leaves had similar ε values (Table 19).

Effect of water stress during postanthesis. To increase understanding about rice sensitivity to water stress at postanthesis, a greenhouse experiment was conducted during 1983 WS using diverse varieties: upland rice IRAT13 from West Africa

Table 19. Bulk volumetric modulus of elasticity (ε) of rice grown in lowland fields. IRRI, 1983. Values are means of 3-5 observations (±S.D.)

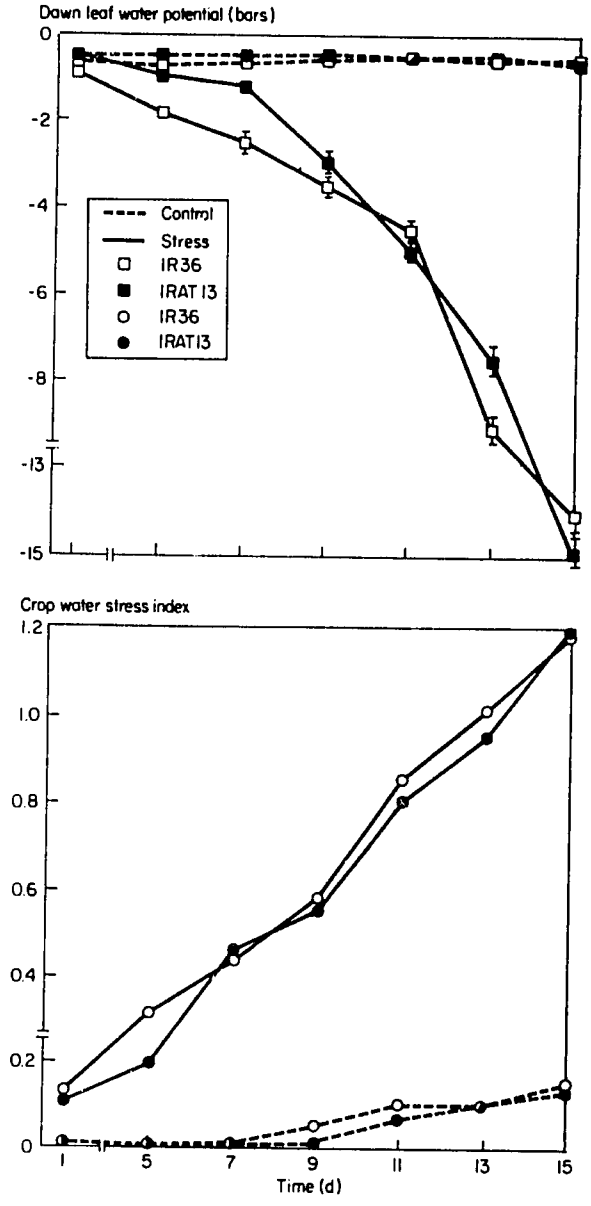
Variety	ε (MPa)
	Flag leaves
Binato	12.3 ± 1
IR46	11.6 ± 0.4
Moroberekan	7.8
Kinandang Patong	11.1
RD19	11.4
	Second leaves
IR20	13.1 ± 1.0
IRAT13	8.7 ± 0.6
Moroberekan	12.1 ± 2.2
Kinandang Patong	8.5 ± 1.8
IR5	10.9 ± 1.6
RD19	10.7 ± 3.5
IR36	12.6 ± 2.8
IR52	11.0 ± 2.4

and modern lowland rice IR36. Pregerminated seeds were sown in rows 25 cm apart in large steel drums (58 cm diam and 49 cm deep) which simulated an aerobic upland clay loam soil with adequate drainage. The crop grew at soil moisture levels near field capacity. Two WAS, plants were thinned to rows of 100 IR36 plants/m and 120 IRAT13 plants/m, maintaining equal leaf area. The crop was adequately fertilized and protected from pests and diseases.

Normal watering in the stress treatment was stopped 1 d after flowering but control plants received full irrigation. Foliage temperature was measured daily at noon with a hand-held infrared thermometer and the crop water stress index (CWSI) was computed using the air wet- and dry-bulb temperature. Based on CWSI and pan evaporation, the stress treatments were differentially irrigated to allow slow and steady water stress development for a 15-d period in both varieties.

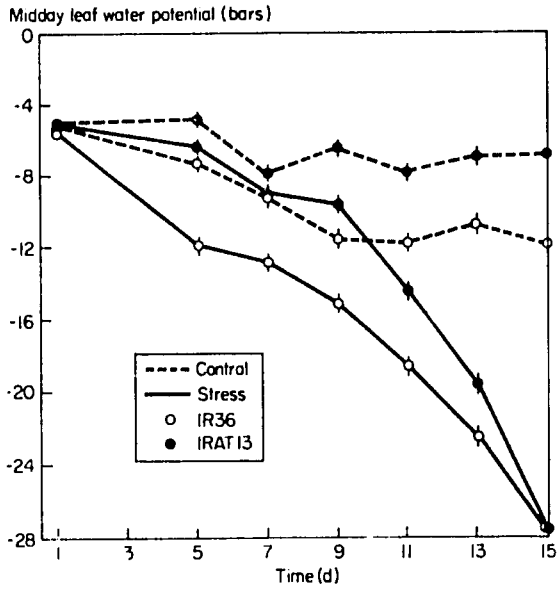
The average CWSI and dawn leaf water potential (DLWP) of control and stress treatment flag leaves are shown in Figure 32. The DLWP of both varieties decreased linearly as CWSI increased. The midday leaf water potential (MLWP) of IR36 deviated from control plants 5 d after the stress treatment was initiated. Significant differences were apparent for IRAT13 between the control and stress treatment after 9 d (Fig. 33). During stress, IRAT13 maintained a higher MLWP than IR36. Panicle water potential (PWP) responded similarly (Fig. 34). The controls maintained high PWP but it decreased markedly in the stressed plants. The responses of both varieties to PWP and MLWP were similar.

Water stress affected yield components of varieties differently (Table 20) with IR36 having 29.0% reduced grain yield compared to 17.4% for IRAT13. A similar reduction occurred in grains per panicle, percent unfilled spikelets, and 100-grain weight. Drought-resistant IRAT13 had high stem weight losses and increased apparent translocation. This indicates that it contributed more stem carbohydrates to grain filling than IR36 did. Maintenance of high LWP, PWP, and increased apparent translocation are probable reasons for the better performance of IRAT13 under water stress conditions at grain-filling stage.

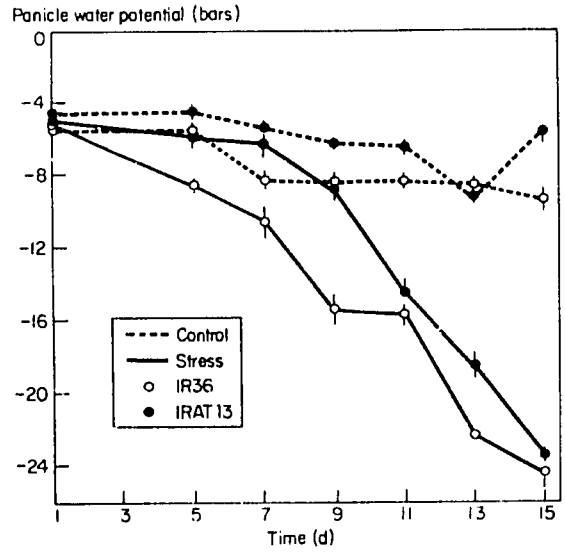


32. Relationship between CWSI (●, O) and DLWP (□, ■) of IR36 and IRAT13 during the 15-d stress period after anthesis. IRRI greenhouse, 1983.

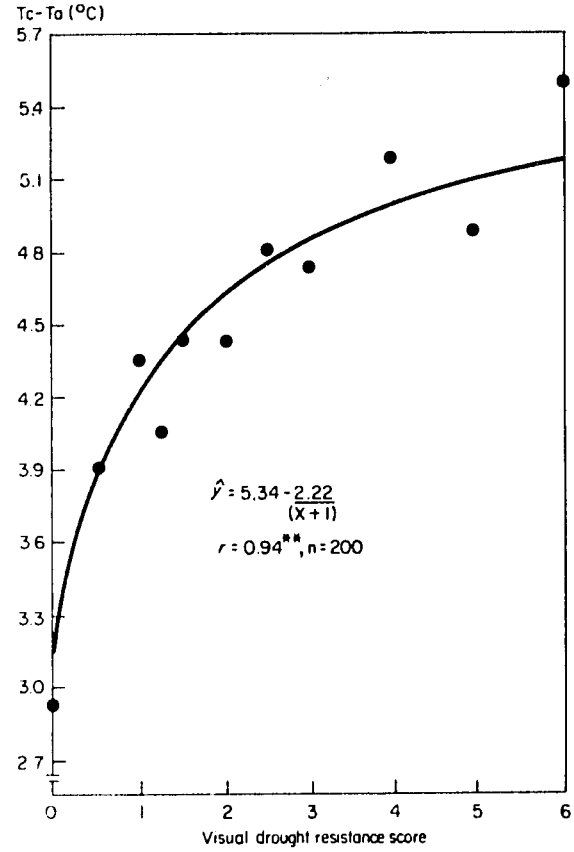
Development of a canopy temperature-based screening method. Over the past few years, IRRI has evaluated the usefulness of remotely sensed canopy temperature as an indicator of water stress. Canopy-minus-air temperature (T_c-T_a) was compared with visual scoring for drought resistance during the 1983 DS using the 1982 International Upland Rice Observational Nursery as the test material. The two-row plots were marked as in the standard DS field screening. They were seeded two replications per entry on 23 Feb 1983 and received



33. Effect of postanthesis water stress on MLWP of IR36 and IRAT13. IRRI greenhouse, 1983.



34. Effect of postanthesis water stress on panicle water potential of IR36 and IRAT13. IRRI greenhouse, 1983.



35. Relationship between canopy-minus-air temperature (T_c-T_a) and visual drought resistance scores of the same replicated plots from the International Upland Rice Observational Nursery. IRRI, 1983 DS.

the last irrigation 25 Apr 1983. Canopy-minus-air temperature and visual drought resistance scoring were recorded on several dates. Plots with poor germination, disease, insect damage, or excessive weeds were discarded. Results from 4 May, 9 d after the final irrigation, compared the screening methods with replicated plots of 203 entries. Analysis of variance showed that entries were significant sources of variance for both evaluation

Table 20. Effect of water stress at postanthesis on yield components of IR36 and IRAT13. IRRI, 1983.

Variety	Treatment	Grain yield (g/container)	Straw yield (g/container)	Grains per panicle	Unfilled spikelets (%)	100-grain weight g)	Apparent translocation (%)
IR36	Control	144.9	235.9	64.1	12.4	2.1	3.2
	Stress	102.9	206.4	41.2	25.7	1.7	24.5
	Difference (%)	(29.0)	(12.5)	(35.7)	(13.3)	(19.8)	(21.3)
IRAT13	Control	145.9	275.8	40.3	6 1	3.7	13.3
	Stress	120.6	216.4	36.3	11.1	3.1	40.6
	Difference (%)	(17.4)	(21.5)	(10.1)	(5.0)	(14.8)	(27.3)
	LSD (.01)	13.6	7.9	2.9	2.2	0.1	10.9

methods. However, the coefficient of variation was 22.0% for T_c-T_a and 61.2% for visual scoring. T_c-T_a values ranged from +2.0 to +6.2° C while visual scores ranged from 0.0 to 6.0. Using Duncan's multiple range test to separate means gave 13 groups for T_c-T_a and only 3 for visual scoring. Visual scoring takes place ≅20 d after irrigation and it may be too difficult to discriminate between entries after 9 d without irrigation and to use this method. T_c-T_a appears more sensitive. Figure 35 illustrates the curvilinear relationship between the two methods. It shows that T_c-T_a can detect differences among entries in the visual scoring range of 0 to 2, a very mild stress level found early in the normal stress period. When the top entries were selected, visual scoring ≤+0.5 gave 31 entries and T_c-T_a ≤+3.0° C gave 9. These 6 entries were common: Chianung Si-Ri-661020, INIAP 415, IR5260-1, IR5853-196-1-P1, IR9560-2-6-3-1, and 343 D.T.

With further experimentation measurements, T_c-T_a may increase preciseness in selecting entries for water stress regimes. T_c-T_a is being tested for screening rainfed lowland rice where 6-10 d rainless periods commonly decrease growth and yield. T_c-T_a also offers interpretation based on water use, which has not been investigated for visual scoring systems.

Genetic evaluation and utilization (GEU) program

Adverse soils tolerance

Soil Chemistry/ Physics, Plant Breeding, and Plant Physiology Departments, and International Rice Testing Program

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SCREENING

Soil Chemistry/Physics, Plant Breeding, and Plant Physiology Departments, and International Rice Testing Program

In 1983, screening continued to identify rice varieties tolerant of soil problems such as salinity, alkalinity, strong acidity, excess OM, B toxicity, Al and Mn toxicities, and deficiencies in Zn, P, and Fe. Screening expanded to accommodate materials from IRTP and Plant Breeding. Collaborative experiments were started with the Tissue Culture Section.

Of 17,701 rices screened, 4,371 were tolerant (Table 1).

Salinity. *Mass screening.* Outstanding among 9,054 entries screened for salinity in the greenhouse were IR36, IR9884-54-3, IR8236-B-B-336-2, IR22107-113-3-3, and international breeding program entries M242, RP975-109-2, and UPR251-101-2.

Of 400 varieties screened in a coastal saline field at Labrador, Pangasinan, 63 were tolerant.

In a salinized field at IRRI, 12 of 238 rices were tolerant. In DS, IR31788-29-3, IR18348-36-3, and IR22105-7-5 were tolerant.

In WS, advanced lines IR29723-143-3, IR21015-80-3, IR21848-65-3, IR27316-96-3, IR28153-10-3, IR32807-11-3, IR32829-123-1, IR29723-12-2, and IR29706-200-3 were tolerant.

IRSATON entries as resistant as or more resistant than the check were IR36, IR52, IR1019866-2, IR10206-29-2, IR14632-22-3, IR15314-30-3, IR2153-26-3, IR2307-247-2, IR2863-35-3, IR4422-6-2, IR4595-4-1, and Nona Sail. IR15314-30-3 was outstanding during both DS and WS.

Yield trials at IRRI. Of 48 rices tolerant in greenhouse tests, 11 yielded more than 1 t/ha in an artificial saline soil. IR54 yielded highest (1.9 t/ha) during DS.

Tests in farmers' fields. Twenty-one rices were tested during DS and WS in coastal saline soils in four locations at Apalit, Pampanga; Bani, Pangasinan; Labrador, Pangasinan; and Cogon Pardo, Cebu. Salinity was from seepage or inundation by brackish creek water. Salt dynamics varied among locations and greatly affected plant performance. Mean grain yields ranged from 2 to 2.5 t/ha. IR4432-28-5, IR10198-66-2, and IR13423-10-2 produced significantly higher yields at most sites.

Table 1. Summary of screening for adverse soils tolerance. IRRI, 1983.

Soil stress	Varieties (no.)	
	Screened	Tolerant
Salinity	9,692	2,780
Alkalinity	4,065	925
Peat	551	266
Acid sulfate	428	19
Fe toxicity	452	35
Zn deficiency	1,799	191
P deficiency	619	141
B toxicity	95	14
Total	17,701	4,371

Alkalinity. *Mass screening.* Of 3,561 entries, 916 were tolerant of alkalinity. Outstanding were IR36, IR42, IR44, IR48, IR50, IR56, and IR60, 40 IR lines, and Pelita I/1.

In the field, 165 entries were tested in a soil made alkaline by added sodium carbonate. In DS, IR25621-94-3 was most tolerant, followed by IR18350-175-2, IR19058-107-1, IR25603-20-2, IR25882-32-1, IR54, and IR36. During WS IR54 and IR19672-155-2 were most tolerant.

IRSATON. Outstanding IRSATON entries were BR10, IR4227-109-1-3, IR19660-131-3-3-3-3, IR36, IR46, and IR8192-200-3-3.

Yield trial at IRRI. On an artificial soil, 7 of 16 rices consistently rated tolerant in mass screening tests gave mean yields of 2.3 to 2.7 t/ha during WS and DS. IR56 gave the highest yield.

Yield trial in a farmer's field. After 3 crops in unamended alkali soils at General Santos, South Cotabato, the average yield of 10 rices was 3.1 t/ha during WS and DS. IR13149-3-2, IR60, IR9764-45-2, IR56, and IR9884-54-3, consistently rated tolerant, gave the highest mean yields.

Acid sulfate soils. *Mass screening.* During 1983 WS and DS, 428 varieties from the international breeding program were screened in fields at Balza, Malinao, Albay (pH 3.7, exchangeable SO_4 = 0.20%). Nineteen lines and varieties showed tolerance for acid sulfate soil conditions: B58b-Mr105-2, UR1529-680-3-2, Mahsuri, Suakoko 8, BR222-B-358, BR51-282-8, Mat Condu, CR149-5010-228, PNA237-F4-57-1, B2791-B-MR257-3-2, IR3518-96-2-2-2, IR10781-75-3-2-2, IR19061-57-4E-P1, IR20880-25-P3, IR21048-41-P1, IR21074-53-P1, IR21836-90-3, IR9217-6-2-2-2-3, and IR4819-77-3-2.

Yield trials in farmers' fields. Yields of 15 varieties in DS and WS ranged from 0.9 to 2 t/ha. Symptoms were more severe during WS and yields were lower. IR9764-45-2 was the consistent top yielder during both seasons but IR46 and IR56 gave comparable yields during DS.

Iron toxicity. *Mass screening.* One hundred and seventy-six anther culture materials were tested in the greenhouse in an Fe-toxic soil from Malinao (pH 3.5, 2.5% active Fe). Rated tolerant were TCP No. 852 (IR48/Suweon 290), TCP No. 664 (Taipei 309/Tatsumi Mochi), and IR4570-124-3-2-2-2 (a parent).

In a farmer's field in San Dionisio, Iloilo (pH 4.5, 2.36% active Fe), 276 entries were screened and 10 were tolerant: IR42, IR52, PM1121, Brasilero, IR21033-31-P2, IR9729-67-3-85, IR12721-24-3-1, IR13525-13-2-3, IR18819-87-2, and IR29725-22-3.

Yield trial in a farmer's field. Twenty cultivars and lines previously found tolerant on acid sulfate soils were tested in an Fe-rich soil in San Dionisio, Iloilo. Highest yields came from IR60 (4.3 t/ha) and IR13540-56-3 (4.5 t/ha).

Peat soil. *Mass screening.* In a farmer's fertilized field in Calauan, Laguna (pH 6.6, 20.3% organic C), 551 entries were tested during DS and WS. Stress was more severe during WS. Six entries were outstanding: IR13525-43-2, IR13540-56-3, IR15314-43-2, IR22105-7-5, IR24637-38-2, and IR19274-26-2.

Yield trials in farmers' fields. In DS 15 selected rices were evaluated in 2 peat soils in Pangil, Laguna, with a basal application of NPK and a zinc oxide root dip. Without Zn stress, IR42 yielded highest at 4.3 t/ha and IR19743-40-3, the lowest at 0.93 t/ha. IR26, which responds to Zn, averaged 4.0 t/ha.

In WS, field tests were conducted in a peat soil with a basal application of NPK in Calauan, Laguna. Of 15 rices, IR19058-107-1, IR56, and IR13525-43-2 yielded highest at more than 3 t/ha, confirming their tolerance for Zn deficiency in a peat soil.

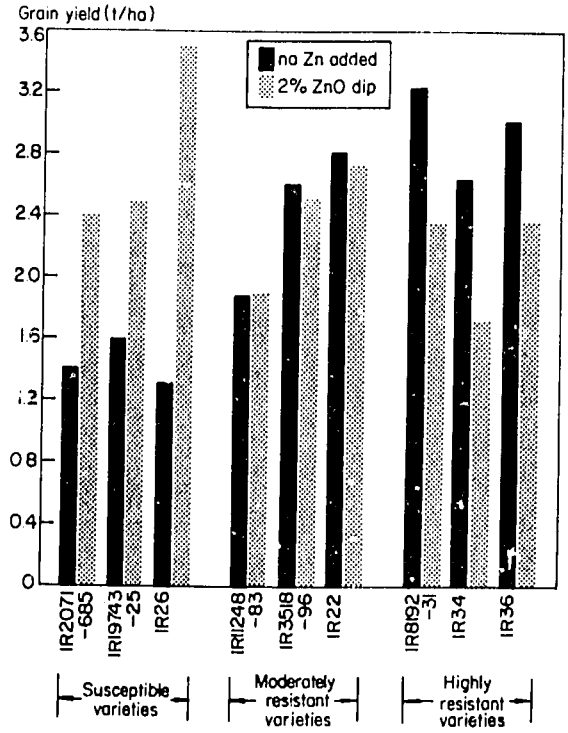
Zinc deficiency. *Mass screening.* Of 1,799 rices screened in a farmer's field in Bay, Laguna (pH 6.7, 0.19 mg available Zn/kg), 191 were tolerant. IR50 displayed remarkable tolerance for Zn deficiency during DS and WS. Other outstanding entries were IR54, IR58, IR21037-2-1-2B-P3-9, IR28905-10-1, B4242-30-2, and B425939-2, 13 entries from the international nurseries, and 4 breeding lines.

Yield trials. Selected rices were grown to maturity with and without Zn in replicated trials at four sites. IR60 yielded highest at 6.1 t/ha with Zn and 2.9 t/ha without Zn.

In severe Zn-deficient sites (0 mg available Zn/kg) such as Tiaong, Quezon and Lagao, Gen. Santos, Zn added 3 t/ha to the yield.

Mechanism of varietal tolerance for zinc deficiency. In the Soil Chemistry/Physics Department field trials in moderately Zn-deficient soils, susceptible varieties responded to Zn addition while resistant varieties gave negative or no response (Fig. 1). Research studied the effects of added Zn on chemical and electrochemical properties of the soil solution from Zn-deficient soils. The growth and mineral nutrition of two rices (IR26 and IR34) differing in tolerance for Zn deficiency were also compared. Culture solution studies showed how Zn addition affects translocation of other nutrients.

In both soil and culture solutions, plant Zn concentrations alone were not enough to account for varietal tolerance for Zn deficiency. A comparison of nutrient-to-Zn and shoot-to-root ratios of



1. Effect of Zn addition on grain yield of some rices in field experiments on marginally Zn-deficient soils. IRRI, 1980 WS, 1981 DS.

Table 2. Nutrient ratios in shoots of IR26 and IR34 grown in Zn-deficient Tiaong soil and in culture solution without added Zn. IRRI, 1983.

Variety	Fe:Zn	Cu:Zn	Mg:Zn	P:Zn
		Tiaong soil		
IR26	8.0 a	0.9 b	432 a	245 a
IR34	4.8 bc	0.5 b	299 b	157 b
		Culture solution		
IR26	7.1 a	0.7 a	126 a	69 a
IR34	4.9 b	0.5 b	129 a	47 a

Table 3. Shoot-to-root ratios of some nutrients in IR26 and IR34 grown in culture solution without added Zn. IRRI, 1983.

Variety	Shoot:root			
	Fe	Cu	Mg	P
IR26	0.3 a	0.20 a	6.5 a	3.0 a
IR34	0.1 b	0.16 a	1.4 b	0.9 c

nutrients was more useful in determining the possible mechanism of varietal tolerance. IR34 tolerated Zn deficiency since it has a lower Zn requirement, more efficient Zn translocation, and the ability to maintain lower Fe:Zn, Cu:Zn, Mg:Zn, and P:Zn ratios in the shoot (Table 2). Culture solution studies revealed that compared with IR26, IR34 had lower translocation of Fe, Mg, and P to shoots and lower absorption of Cu by the roots (Table 3). Adding Zn further reduces translocation of these nutrients (Table 4) and, depending on soil nutrients, could cause deficiencies and mineral imbalances especially of Fe, Cu, and P.

These varietal differences in Zn requirement and Zn interaction with absorption and translocation of plant nutrients shows that recommendations for Zn fertilization need revision. Zn needs to be applied on severely Zn-deficient soils regardless of rice variety. But in marginally Zn-deficient soils, especially those low in Fe, Cu, or P, Zn fertilization is not advisable if resistant varieties are used.

Phosphorus deficiency. Varietal differences in P efficiency were studied by mass screening in the greenhouse and yield trials on a P-deficient field.

Mass screening. Of the 619 rices tested in culture solution, 141 were rated P efficient. Among them were IR28, IR34, IR40, and IR52; Calrose Bulk P. T., BR10, BR151-B-48-2, Cisadane, and ITA235; and the lines IR4432-52-6, IR14632-22, and IR25840-38.

Yield trials. Thirty-two rices were grown without P fertilization during DS. IR9764-45-2, IR13149-3-2, and IR15791-163-2 yielded 4.0 to 5.1 t/ha, confirming earlier results.

Boron toxicity. *Mass screening.* In greenhouse tests on a soil treated with 10 mg B/kg, 14 of 138 entries were rated tolerant: IR20, IR54, IR6115-1, IR21848-65-3, IR19672-140-2, IR12721-4-3, IR19672-155-2, IR21015-80-3-3, IR12979-24-1, IR27316-96-3, IR10011-16-3, IR25560-132-3, IR25582-133, and IR25916-15-3.

Yield trials. Twenty-five IR varieties and lines were compared at two B levels: no B added and 10 mg B/kg added as borax. B addition reduced mean yields by 45%. IR42, IR50, IR54, IR9764-45, IR21820-154, and IR29723-143 were least affected, giving mean yields greater than 2 t/ha. IR34, IR52, and IR58 yielded poorly with the yield of IR58 most reduced.

Aerobic conditions. *Yield trial.* Twelve varieties were exposed to Al and Mn toxicities under aerobic conditions in a naturally occurring acid soil

Table 4. Shoot-to-root ratios of Fe, Mg, and P, and Cu content of plants at 6 wk after transplanting, as affected by added Zn in culture solution. IRRI, 1983.

Variety	Zn added (mg/kg)	Shoot-to-root ratios			Cu (mg/kg)	
		Fe	Mg	P	Shoot	Root
IR26	0	0.34 a	6.5 a	3.0 a	14 a	70 a
	0.3	0.11 c	1.4 b	0.83 bc	12 bc	31 c
	3.0	0.07 d	0.73 b	0.88 bc	12 bc	44 b
IR34	0	0.12 bc	1.3 b	0.94 bc	11 bc	66 a
	0.3	0.07 d	1.0 b	0.74 bc	10 d	58 ab
	3.0	0.06 d	0.97 b	0.72 c	10 d	48 b

Table 5. Performance of 12 rices under strongly acid, aerobic Luisiana clay (pH 4.3). IRRI, 1983 DS.

Entry	Grain (t/ha)
IR20	1.93 bc
IR2415-9-4	2.49 ab
IR5677-22-5	3.17 a
IR7473-118-2	1.55 cd
IR9752-71-3	0.96 d
IR9828-36	1.67 cd
IR10781-105-2	2.46 ab
B44b-50-2	2.74 a
Kinandang Patong	1.35 cd
Salumpikit	1.77 bc
IET1785	2.95 a
IR43-check variety	2.73 a

(pH 4.8) and in a soil with induced acidity (pH 4.3). In DS, plants showed symptoms of Al and Mn toxicities on both soils. IR5677-22-5, IET1785, IR10781-105-2, and B44b-50-2 gave yields comparable to those of check variety IR43 (Table 5).

During WS, Al toxicity became severe when acidity was adjusted to pH 3.9. IR5677-22-5 and B44b-50-2 maintained their superiority over the other entries.

MULTIPLE STRESS TOLERANCE

Soil Chemistry/Physics Department

Rices, previously tested in the greenhouse, were evaluated in 6-m × 8-m concrete beds at IRRI. In these tests (Table 6), IR9764-45 showed multiple stress tolerance for salinity, alkalinity, saline-alkali soils, peat soil conditions, B toxicity, Zn deficiency, and P deficiency. IR43 was tolerant of Al and Mn toxicities and Fe deficiency.

Table 6. Entries found outstanding in concrete bed tests for multiple stress tolerance, 1983.

Soil problem	Outstanding variety or line
Salinity	IR34, IR46, IR50, IR9764-45
Alkalinity	IR9764-45, IR8192-31, IR9884-54
Salinity-alkalinity	IR9764-45, IR8192-3, IR7545-27
Peat	IR34, IR8192-31, IR9764-45
Zn deficiency	IR34, IR8192-31, IR9764-45
P deficiency	IR54, IR52, IR9764-45
B toxicity	IR48, IR8192-3, IR9764-45
Al toxicity	IR43, IR52, IR6023-10-1-1
Mn toxicity	IR43, IR52
Fe deficiency	IR43, IR8055-48, IR3839-1

VARIETAL DIFFERENCES IN NITROGEN UTILIZATION EFFICIENCY

Soil Chemistry/Physics Department

N deficiency is the most important nutritional factor limiting rice yields on most soils, making fertilization necessary. Rice varieties differ in their capacity to extract and utilize soil and fertilizer N. Traditional varieties Peta and H4 respond to low N applications and IR26 responds to high.

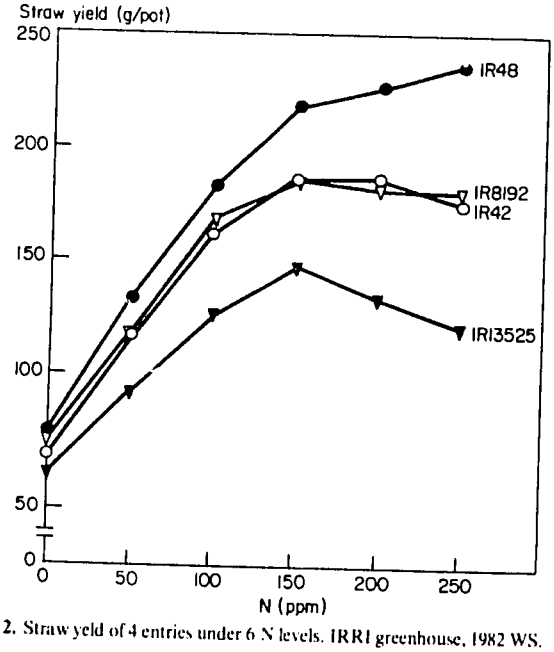
During the 1982 WS and 1983 DS, two IR varieties and two IR lines were planted under six N levels. IR8192-200-3-3 yielded highest and IR48 the lowest at N levels above 50 ppm. IR48 produced the highest straw and total DM yield and IR13525-43-2 the lowest.

Grain yields of all varieties significantly increased with increasing N levels (Fig. 2, 3). Except for IR48, straw and total DM yields of all varieties peaked at 150 ppm N, then leveled off or decreased. Straw and total DM of IR48 still increased at 250 ppm N.

At all N levels, IR48 absorbed significantly less N than the 3 other varieties (at the 5% level by LSD) except at the 50 ppm N level.

Mathematical treatment of grain, straw, and total DM yield can be described by the equation:

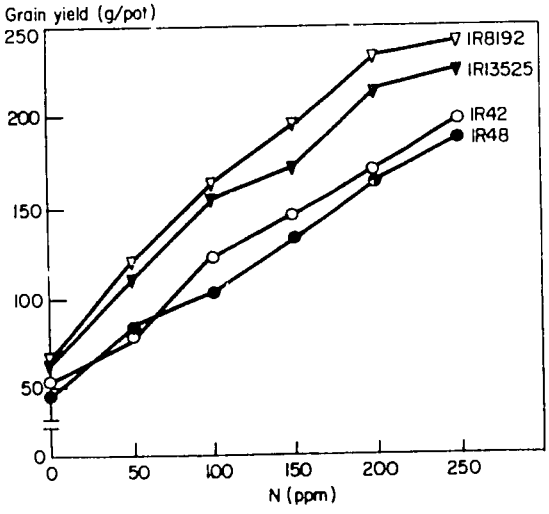
$$y = a + bx + cx^2$$



2. Straw yeld of 4 entries under 6 N levels. IRRI greenhouse, 1982 WS.

where y = yield (t/ha),
$a, b, c,$ = coefficients,
x = N (kg/ha).

Varieties with large a values can exploit soil N efficiently; those with large b values respond to added N markedly, and those with large c decline in yield as the N level goes up. Regressions for grain yield show that IR lines 8192 and 13525, which have higher a values, can utilize soil N better than the two varieties whose higher b values indicate they can use lower N doses more efficiently.



3. Grain yield of 4 entries under 6 N levels. IRRI greenhouse, 1982 WS.

Varieties respond differently to N utilization and to fertilizer N. IR lines 8192 and 13525 are better N users, providing more return per input than IR42 and IR48.

BREEDING FOR SALT TOLERANCE

Plant Breeding and Soil Chemistry/Physics Departments

Rices are being tested for salt tolerance to identify those with good agronomic characteristics for use in breeding programs. Several varieties including tolerant Pokkali and Nona Bokra were evaluated during early development stages. They were judged for tolerance on the basis of morphological characteristics and uptake of major elements at EC 10 dS/m and EC 12 dS/m with the solution culture technique. Table 7 shows the results.

- P content of shoots remained largely unaffected by salinity increase in the nutrient solution. N content decreased slightly.
- K content declined in both roots and shoots as salinity increased in the nutrient solution. K content of the roots was lower than that of the shoots.
- Ca and Na content of shoots increased with salinity level; increase from the control was 233% for Ca and 655% for Na at salinity level of EC 12 dS/m.
- Nutrient uptake of shoots did not show specific trends attributable to varietal differences.

Table 7. Uptake of major elements under saline conditions. IRRI, 1983.

Entry	Uptake (%)														
	Control					At EC 10 dS/m					At EC 12 dS/m				
	N	P	K	Ca	Na	N	P	K	Ca	Na	N	P	K	Ca	Na
Shoots															
Damodar	4.7	0.76	4.8	0.41	0.14	3.4	0.66	3.4	0.93	0.86	4.3	0.81	3.4	1.30	1.06
IR6	4.6	0.89	3.9	0.45	0.21	4.6	0.77	2.8	1.08	1.13	4.7	0.91	2.9	1.08	1.01
IR4630-22-2-5-1-3	4.3	0.76	3.9	0.27	0.16	3.7	0.71	2.9	1.08	1.54	3.9	0.76	2.6	1.51	1.94
Jhona 349	4.3	0.73	4.3	0.25	0.13	3.8	0.69	3.4	0.95	1.06	4.2	0.82	3.2	0.96	0.94
Nona Bokra	4.6	0.74	4.6	0.36	0.13	4.3	0.70	3.6	0.82	0.46	3.5	0.63	3.5	1.08	0.81
Pokkali	4.3	0.79	3.8	0.37	0.13	3.7	0.72	3.0	1.26	1.49	4.2	0.91	3.0	1.10	1.05
Roots															
Damodar	2.8	0.56	3.2	0.14	0.45	3.0	0.50	2.8	0.25	1.62	3.2	0.83	1.8	0.33	1.45
IR6	2.2	0.50	2.2	0.08	0.91	3.3	0.62	2.9	0.22	1.30	3.5	0.90	2.1	0.31	1.30
IR4630-22-2-5-1-3	3.2	0.64	2.7	0.17	0.72	3.2	0.75	2.3	0.29	1.64	3.3	0.99	1.5	0.44	1.54
Jhona 349	2.8	0.54	2.3	0.20	0.78	2.5	0.45	2.9	0.23	1.58	3.5	0.69	2.4	0.29	1.66
Nona Bokra	3.3	0.52	3.2	0.18	0.51	3.1	0.58	3.0	0.25	1.51	3.5	0.56	2.4	0.28	1.90
Pokkali	3.0	0.58	3.2	0.16	0.70	2.7	0.54	2.8	0.29	1.73	3.3	0.73	2.6	0.26	1.92

- Concentrations of N, P, K, and Ca were lower in the roots than in the shoots. Na in roots, however, was always greater than that in the shoots.
- IR6 absorbed higher N and P as a tolerance mechanism as salinity increased.
- IR28 and IR42 could not survive at salinity levels of EC 10 dS/m and EC 12 dS/m.

Genetic evaluation and utilization (GEU) program

Deepwater and flood tolerance

Plant Physiology, Agronomy, and Plant Breeding Departments

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NITROGEN RESPONSE AND YIELD POTENTIAL OF DEEPWATER RICES

Agronomy Department

During 1983 DS, 11 photoperiod-insensitive rices were tested at IRRI in controlled water (maximum depth, 100 cm). IR21037-2-1-2E-P1 and IR21037-2-1-2E-P2 gave the two highest grain yields (maximum 5.4 t/ha) without fertilizer N and with 87 kg N/ha (Table 1). Those lines had maximum plant height of 152-157 cm at 100-cm-deep water, 269-300 tillers, and 251-269 panicles/m^2 (Table 2). High tillering rices such as IR21071-53-2-3-2E-P2 and C-168-134 yielded significantly less because their poor elongation ability kept their panicles submerged and they rotted. Two other rices, DWCT131-4-1-2-2 and HTA7406-111-0-0-2 that had high elongation capacity, were susceptible to RTV and produced low yields. RD17 (check variety) was highly susceptible to RTV and did not produce any grain yield (Table 1).

Submergence tolerance, elongation capacity, resistance to diseases and insects, and lodging resistance are important to get high yields with fertilizer at maximum water depth of 100 cm.

SCREENING FOR SUBMERGENCE TOLERANCE

Plant Physiology and Plant Breeding Departments

Additional facilities for submergence tolerance screening became operational in 1983. More than 23,000 entries — 20,900 from the pedigree nursery — were screened, and tolerant entries were planted in the field for further evaluation by plant breeders.

Surviving plants from 66 crosses evaluated in the RGA program were transplanted in the field and selected for the pedigree nursery.

Table 1. Grain yield of promising deepwater (maximum 100 cm) rices. IRRI, 1983 DS.

Deepwater rice	Grain yield (t/ha)	
	Without fertilizer N	With 87 kg N/ha
IR21037-2-1-2E-P1	3.0 a	4.8 a
IR21037-2-1-2E-P2	3.6 a	5.4 a
IR21071-53-2-3-2E-P2	1.3 bc	2.7 bc
IR7732-B-196-3	0.6 c	1.1 d
HTA7406-111-0-0-2	1.2 bc	1.9 cd
DWCT131-4-1-2-2	1.5 bc	2.5 bc
C-168-134	0.9 bc	2.4 bc
BPI-76NJ	1.8 b	3.1 b
IR21574-15-1E-P1	a	a
IR11288-B-B-69-1	a	a
RD17	a	a

[a]Did not flower in reasonable time.

Table 2. Some agronomic characteristics of promising deepwater (maximum 100 cm) rices that received 87 kg N/ha. IRRI, 1983 DS.

Deepwater rice	Plant ht (cm)	Tillers (no./m^2)	Panicles (no./m^2)
IR21037-2-1-2E-P1	157	300	269
IR21037-2-1-2E-P2	152	269	251
IR21071-53-2-3-2E-P2	124	475	318
IR7732-B-196-3	161	250	177
HTA7406-111-0-0-2	179	175	131
DWCT131-4-1-2-2	167	222	175
C-168-134	133	308	206
BPI-76NJ	137	261	209

EFFECT OF SALINITY ON SUBMERGENCE TOLERANCE

Plant Physiology Department

In many flood-prone low-lying areas, farmers practice early seeding in dry soil to escape from floods. In coastal low-lying areas, soils are saline during early seeding because of previous seawater intrusion and subsequent drying. Early seeded rice experiences soil moisture stress, salt stress, and, later, submergence. Submergence-tolerant rices should be bred with salinity tolerance at the seedling and early vegetative stages. Salinity may change tolerance or susceptibility to submergence.

Five rice varieties with varying submergence and salinity tolerance were grown in trays containing 0%, 0.2%, and 0.4% NaCl. At 10 d after soaking, varieties were tested for submergence tolerance.

At 0.2% NaCl, percent survival after 8 d submergence increased in all varieties compared to the unsalinized control (Table 3).

Seedling height before submergence decreased with increasing salt level in the trays. But plant height after submergence increased with increasing salt levels possibly because of the removal of salt stress after submergence.

At 0% and 0.2% NaCl, dry weight increased after submergence. But at 0.4%, except for highly

tolerant Pokkali, all varieties decreased in dry weight after submergence.

With increasing salt level, N, Na, Ca, and Mg uptake increased while P, K, and Si uptake before submergence decreased. During submergence, N, Mg, Mn, and Si content increased while K and Ca content decreased at all salt levels.

SCREENING DEEPWATER RICE FOR RATOONING ABILITY

Plant Physiology Department

Deepwater rice varieties were screened for ratooning ability during DS. The 118 entries came from germplasm collection varieties with an elongation ability rating of 1, from the 1982 IRDWON, from Chinsurah (India), and 13 segregating populations.

Entries were ratooned at 15 cm aboveground as they matured and scored for ratooning ability 15 d after cutting. Selections were also made for photoperiod sensitivity.

Table 4 lists entries selected for high tiller number (at least three leaves per tiller before flowering) and insect and virus disease resistance in the field. Selected entries are being retested.

SCREENING RICE VARIETIES FROM TAMIL NADU, INDIA, FOR DEEPWATER TRAITS

Plant Physiology Department

More than 12,000 ha of rice lands in Tamil Nadu are usually submerged during the vegetative phase from September to January. It is essential to identify dependable donors for various traits through improved screening technique.

Table 3. Survival of 5 rice varieties grown at different salt levels 7 d after complete submergence for 6 and 8 d. IRRI, 1983.

Entry	Survival (%)			
	6 d		8 d	
	0%	0.2% NaCl	0%	0.2% NaCl
Kurkaruppan	96	98	63	96
Thavalu	89	90	55	89
FR13A	99	95	56	93
IR36	91	80	19	39
Pokkali	79	73	46	80
Av	90.8	87.2	47.8	79.4

Table 4. Entries with good ratooning ability. 1983.

IRDWON 1982	
GEU6050-0-194-1	IR11185-B-B-850-1
IR13260-100-1E-P3	SPR7292-122-2-1
IR11288-B-B-69-1	SPR7292-151-2-1-B-B
RD19	BKN76026-3-2-2-2
IRRI germplasm	
Pathkola	Lal Amon 245
Matia Amon	Khoi Amotar
Sechi Amon	Chol Amon
Bhoro Nepa	Dhol Amon
Kal Amon 113	Roj Bhawalia
Gowai 38-9	Khama 55-22
Matia Amon 70	Gowai 476
Gowai 50-9	Kal Amon 21-7
Kal Amon 24-3	Kal Amon 243
Kal Amon 21-7	Kalimekri 391
Alad Kumar	
Matia Amon 73-23	

Twenty-four varieties (Table 5) from Tamil Nadu were screened for submergence tolerance, salt tolerance, elongation ability, nodal rooting, and kneeing ability.

Submergence tolerance. TNR1, Dhanya, and Birpak showed some degree of tolerance for submergence but they did not recover.

Salt tolerance. Seedlings grown in normal culture solution were transplanted in saline soil with electrical conductivity of 9 mS/cm. TNR1, Ponkambi samba, Kattuvanam, Kar paddy, Dulai Baron, Kala or Black Aman, and Ponni showed a salinity tolerance rating of 3, equal to that of check variety Pokkali.

Elongation ability. Four-wk-old seedlings were submerged in 40 cm water that was increased to 90 cm by raising 10 cm/d. Water was maintained at that level for 7 d. Varieties differed widely in their elongation ability: 17 to 65 cm, or 25 to 129% increase. TNR1 and Ponkambi samba had maximum elongation ability. Chingair and Birpak had more of the elongated internodes and high elongation ability. Early nodal rooting, an important deepwater rice trait, increases nutrient uptake. Chingair, Birpak, Akulu, and Perunel had profuse nodal roots compared to other genotypes.

Kneeing ability. Sixty-five-d-old plants were pulled out gently and randomly placed horizontally on the puddled field in 2-cm water depth. On the third day, plants were scored for their kneeing angle. TNR1 and Birpak scored the best.

Table 5. Rice varieties tested for deepwater traits. IRRI, 1983.

Variety	Submergence tolerance score[a]	Salt tolerance score[a]	Elongation ability			Elongated internodes (no.)	Kneeing ability[a]
			Final height (cm)	Elongated height[b] (cm)	% of elongation		
TNR1	5	3	119	64	114	2	1
Ponkambi samba	9	3	112	63	129	2	7
Kattuvanam	9	3	111	47	73	2	3
Sarapalli samba	9	5	112	55	95	3	5
Sirumani Amon	9	9	115	56	95	2	3
Deepwater type	9	7	86	17	25	1	3
Donradao	9	7	117	50	75	1	3
Kar paddy	9	3	140	63	82	2	5
Dulai Aman	9	9	106	50	89	1	5
Dulai Baron	9	3	92	26	39	1	7
Dhanya	5	7	115	56	95	3	5
Akulu	9	5	118	52	75	3[c]	3
Poongar	9	7	84	37	77	3	9
Kala or Black Aman	9	3	93	42	82	1	5
Chingair	9	5	133	65	96	3[c]	5
Lalkanai	9	9	134	63	89	3	5
Birpak	7	9	140	63	82	4[c]	1
Lakhi	9	9	110	46	72	3	3
Aeb 368 Rip P type	9	9	95	31	48	1	9
Perunel	9	7	102	39	62	3[c]	7
White Ottadan	9	9	109	32	42	2	7
Gutak	9	7	77	27	52	2	9
Mahsuri	9	7	111	37	50	2	7
Ponni	9	3	71	30	73	1	7

[a]By the 1980 Standard Evaluation System for Rice scale. [b]Final height minus height before submergence. [c]Presence of nodal roots.

Photoperiod sensitivity. Plants were subjected to photoperiod treatments of 10, 12, 14, and 16 h. All 10- and 12-h treatments flowered. Sarapalli samba, Aeb 368 Rip P type, and Gutak flowered at the 14-h treatment. Sarapalli samba and Gutak showed photoperiod insensitivity by flowering in the 16-h treatment. Most varieties tested were photoperiod sensitive with a long basic vegetative phase (BVP).

PHOTOPERIOD SENSITIVITY OF RAYADAS

Plant Physiology Department

Rayadas, unlike the traditional deepwater rice varieties of Bangladesh, are cold tolerant at seedling stage, lack seed dormancy, have a longer growth duration (12 mo), and are cultivated in deeper water.

Rayadas are cultivated while mixed with photoperiod-insensitive boro rices which are harvested in April or May while Rayadas remain vegetative. Rayadas continue to grow in subsequent deep water and do not flower until late September and October when daylength is less than 12 h. Rayadas are supposed to be photoperiod-sensitive but they do not respond to the shorter photoperiod in

Table 6. Days to flowering, basic vegetative phase (BVP), and photoperiod sensitive phase (PSP) of 5 strains of Rayada, Habiganj Aman I, and Habiganj Boro V at different photoperiods. IRRI, 1983.

Variety or strain	Days to flowering with indicated photoperiod				BVP (d)	PSP (d)
	10 h	12 h	14 h	16 h		
Rayada 16-02	108	126	a	a	73	140+
Rayada 16-03	108	124	a	a	73	140+
Rayada 16-05	109	126	a	a	74	140+
Rayada 16-06	108	124	a	a	73	140+
Rayada 16-08	105	125	a	a	73	140+
Habiganj Aman I	38	80	a	a	3	140+
Habiganj Boro V	92	92	87	92	57	5

[a]Did not initiate panicles after 140 d of growth.

February and early March when they are planted in November.

Five strains of Rayadas were used to see if they are photoperiod-sensitive varieties with a long BVP. Photoperiod-sensitive Habiganj Aman I and photoperiod-insensitive Habiganj Boro V were the checks. Plants were subjected to 10, 12, 14, or 16 h photoperiods.

Habiganj Aman I and Rayada strains flowered at 10 and 12 h photoperiods and remained vegetative at 14 and 16 h photoperiods (Table 6). Habiganj Boro V flowered at all photoperiod treatments with similar flowering duration. Based on flowering behavior, both Habiganj Aman I and Rayada strains are strongly photoperiod sensitive with a long photoperiod-sensitive phase (PSP) and a critical photoperiod of about 12 h.

Although the BVP range reported in literature varies from 10 to 63 d, none of the strongly photoperiod-sensitive varieties tested had a BVP of more than 49 d. Rayada strains exhibited a long BVP of 70-74 d.

Based on duration of BVP and PSP, rice varieties have been classified into four types. Type A has a short BVP and short PSP, type B has a long BVP and short PSP, and type C has short BVP and long PSP. No type D (long BVP and long PSP) has been reported, but this study establishes Rayadas as type D.

Type D varieties were probably eliminated during domestication since they would have had an unusually long growth duration. This is substantiated since Rayadas exist in less than 10% of the total deepwater rice area in Bangladesh.

Different Rayada strains are strongly photoperiod-sensitive with a BVP of about 70 d and a critical photoperiod of about 12 h. Their nonresponse to shorter photoperiods in February and March after a November planting may be caused by low temperatures in November, December, and January. These temperatures could extend the long BVP so that when the plant is ready for photoinduction, the daylengths are already longer than the critical photoperiod.

Genetic evaluation and utilization (GEU) program

Adverse temperature tolerance

Plant Physiology and Plant Breeding Departments, and International Rice Testing Program

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KOREA-IRRI COLLABORATIVE PROJECT

The success of the Korea-IRRI Collaborative Project on Rice Cold Tolerance at Chuncheon led to the establishment of other substations in Jinbu, Yungduk, Unbung, and Sangju. Yungduk and Sangju have cold water screening facilities similar to those at Chuncheon.

New breeding materials screened at Chuncheon come mostly from Korea, IRRI, Japan, Indonesia, and India, but some have come from as far as Turkey. Several entries from the project have already been or will be named as varieties in other countries.

COLD TOLERANCE SCREENING NURSERY

This year, the cold tolerance screening nursery had 1,270 entries from national programs and continuously provided plant breeders with donor varieties. The nursery also identified promising lines based on leaf color, growth duration, spikelet fertility, and phenotypic acceptability.

Growth duration. Short duration minimizes the risk of low temperatures during the critical reproductive phase.

Many areas need short-duration varieties for cropping and use as donors to shorten the growth of tropical high yielding varieties. Several early-maturing entries with low leaf discoloration scores and short stature were identified. However, all except Sola-iku 110, VL502-2, and IR29279-R-TR-2-4 (RGA selection from Turkey) were severely affected by NBI.

Spikelet fertility. Low spikelet fertility is a common problem in low-temperature areas, but many entries had high spikelet fertility (Table 1). Spikelet fertility was highest (95%) in IR23325-R-R-B-7-3-1, an RGA selection sown and screened in Korea.

Table 1. Entries with >90% spikelet fertility. 1983.

China 988	IR27892-5-2-1-1-1
HR3632-2-4-2	IR36614-2-8
HR3632-48-4-5	IR7167-33-2-3-3-1-3-1
IR18921-41-3	Lengkwang
IR20656-R-R-R-6-1	Sangpungbyeo (Suweon 235)
IR20897-B-6	Seonambyeo (Suweon 305)
IR20913-B-26-1-2-2-3	SR9144-MB-219
IR23325-R-R-B-7-2-2	SR4131-19-3-1
IR23325-R-R-B-7-3-1	Todorokiwase
IR23351-42-1-3-1-3	

Phenotypic acceptability. Diverse, outstanding materials are available for further testing. The following rices have excellent traits in more than five characters:

China 988	HR3629-62-5-3	HR3632-48-4-5
IR20913-B-26-1-2-2-3	IR9129-KI	Jinjubyeo
On 211	Sangpungbyeo	SR3001-48-5-3
SR4095-14-3-1-4	SR5204-91-3-3-6	SR9144-MB-276
SR9144-MB-378	Suweon 306	Todorokiwase

Leaf discoloration. Leaf yellowing is a common symptom of cold temperature damage. IR crosses, mostly indica types, had poor scores for leaf discoloration with none having a score of 1. This problem in transferring genes for leaf discoloration needs greater attention.

Table 2. Materials selected at Chuncheon pedigree nursery for trials in Banaue, Philippines. 1983.

Designation	Cross	Plants selected (no.)
SR42739	IR20654-R-R-R-1-2/ Milyang 23	20
SR42741	IR20654-R-R-R-1-2/IR1347	12
SR42742	IR20654-R-R-R-1-2/ Milyang 54	20
SR42745	IR15429-268-1-2/ IR20654-R-R-R-1-2	30
SR42778	IR20654-R-R-R-1-2/ Milyang 23	15
SR42779	IR20654-R-R-R-1-2/ Milyang 54	15
SR42780	IR20654-R-R-R-1-2/ Milyang 57	30
SR44173	Chiang Tsenf Tao ju/Line 62// Suweon 295-11	10
SR44185	IR9752-71-3-2/Stejaree 45/ Milyang 54	5
SR44186	IR19735-5-2-3-2-1//Tatsumi Mochi//Milyang 54	14
SR44205	IR4744-295-2-3/Dourado Agulha//Milyang 54	41
SR44206	IR4744-295-2-3/Suweon 295-11//Milyang 54	15
SR44207	IR4744-295-2-3/Todorokiwase// Milyang 23	17
SR44217	IR15429-268-1-2-1/Suweon 295-11//Milyang 23	21
SR44254	IR15429-268-1-2-1/Shimokita// IR15429-268-1-2-1/// Milyang 57	20
SR44800	SR8141B-11-2-6-5/Suweon 299	15

PEDIGREE NURSERY AND RGA BULK MATERIALS

The water temperature in the pedigree nursery was kept at 20° C to eliminate plants susceptible to low temperature.

The nursery had 84 F_2 bulk populations, 38 F_3 bulk populations, and 325 pedigree lines mostly in F_4 and F_5. In the 84 F_2 populations (Table 2), 300 lines were selected and screened for cold tolerance at the seedling stage. Only nonchlorotic plants were transplanted in the field. Many plants were selected from the cross involving IR20654-R-R-R-I-2, indicating its good combining ability. IR20654 is a cross between japonica K78-13 and indica IR5908 and was grown for three generations in the RGA facilities.

In 1983, 627 lines were selected from 5 F_4 RGA bulk populations. Selection was based on ability to withstand low water temperature, expressed in optimum growth duration and low sterility, and on high yields.

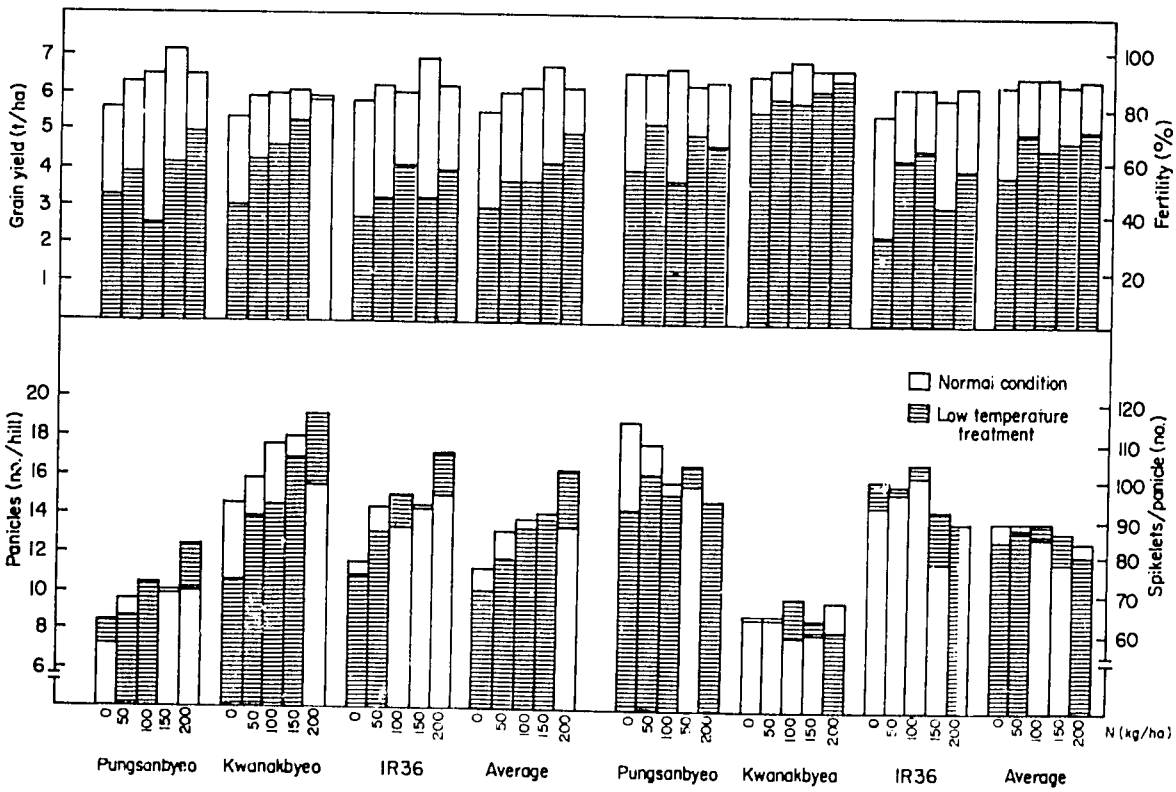
Other RGA bulk materials were planted in Jinbu, Yungduk, and Sangju Experiment Stations for site-specific selection. An RGA selection made 2 yr ago in Chuncheon, JO80-27-R-R-C-37, was outstanding in other substations this year. It was named Suweon 329 and will be included in regional testing in Korea.

Table 3. Entries with plants having >80% fertility at PI during 12-20 Jul 1983 when average minimum temperature was 18.7°C.

China 988	K31-163-3
Ching Hsi	K435
Corallo	Wasetoramochi
IR15685-2-2-2-3	Tatsumi mochi
IR18476-55-2	CR584-11-1-6
IR18476-86-3-3	CI1561-1
IR24312-R-R-19-3	Koon-En-Tsan 16
IR7958-191-2	Nongbaek
K143-1-2	SR5204-39-5-3

SCREENING FOR TOLERANCE FOR LOW AIR TEMPERATURE DURING THE REPRODUCTIVE STAGE

The rice plant is most sensitive to low air tempera-



1. Effect of N levels on grain yield, fertility, panicle and spikelet numbers under low temperature treatment at meiotic stage. 1983.

tures during the reproductive phase (PI and anthesis). It is very difficult to screen for cold tolerance during this phase. It occurs at different times depending on the growth duration of the variety and is therefore subject to the prevailing temperature.

At PI, 17° C is the minimum night temperature that would lead to high spikelet sterility in most varieties. In this trial, the average minimum temperature during PI was 18.7° C for varieties flowering 21 to 31 Aug. Several nights the temperature was below the minimum. Entries with high spikelet fertility despite low night temperatures are shown in Table 3. Contrary to earlier reports, many indicas now have cold tolerance at PI. Examples are IR15685-2-2-2-3, IR18476-55-2, IR18476-86-3-3, IR24312-R-R-19-3, and IR7958-191-2.

OBSERVATIONAL YIELD TRIALS

The observational yield trials (OYT) show progress in breeding rice for low temperatures; of 25 entries, 7 yielded more than 5 t/ha at 100 kg N/ha.

Yields in 1983 OYT were lower than in 1982 because of lodging and fewer daylight hours during grain filling. Highest yielders were IR8866-30-3-1-4, IR5716-18-1, and IR2061-522-6-9 and the Korean recommended varieties Pungsanbyeo and Samgangbyeo. The same IRRI lines were also among the highest yielders in the 1982 OYT at Banaue. IR8866-30-3-1-4 yielded 8.5 t/ha in the 1982 DS Banaue OYT.

N RESPONSE IN LOW WATER TEMPERATURE AT MEIOTIC STAGE

N use is higher during low temperatures perhaps because of changes in N availability, uptake, and utilization. This experiment studied the effect of low temperature at meiotic stage and of low water temperature on N response.

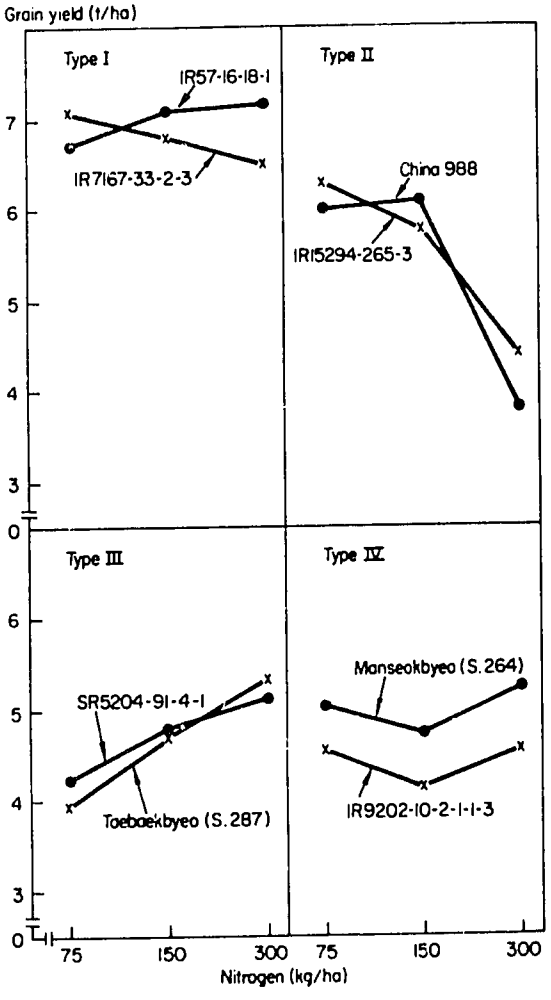
Pungsanbyeo (indica/japonica), Kwanakbyeo (japonica), and IR36 (indica, susceptible to low temperature) with different N levels received a cold water treatment (17° C) for 10 d at meiotic stage.

Under normal field conditions in Chuncheon, grain yield increased with increasing N level up to 150 kg N/ha, then decreased at 200 (Fig. 1).

Previous findings showed high N level increased spikelet sterility and lowered yields. This study showed no significant differences in spikelet fertility among N level treatments.

Table 4. Grain yield response to N fertilizer. IRRI, 1983.

Entry	Grain yield (t/ha)		
	75 kg N/ha	150 kg N/ha	300 kg N/ha
IR51716-18-1	6.7	7.2	7.2
IR7167-33-2-3	7.1	6.8	6.5
China 988	6.0	6.1	3.8
IR15924-265-3	6.3	5.8	4.4
SR5204-91-4-1	4.2	4.8	5.1
Taebaekbyeo	3.9	4.7	5.3
Manseokbyeo	5.0	4.7	5.2
IR9202-10-2-1-3	4.5	4.1	4.4
Average	5.46	5.55	5.24



2. Yield response of 4 varietal types to different N levels. IRRI, 1983.

The cold water treatment at meiotic stage decreased yield and 1,000-grain weight drastically because of lower spikelet fertility. However, yields rose with added N because of increase in panicle

Table 5. Yield and yield components of 8 varieties at different N levels. IRRI, 1983.

Variety	N (kg/ha)											
	75	150	300	75	150	300	75	150	300	75	150	300
	Yield (t/ha)			*Spikelet fertility (%)*			*Panicle no.*			*Spikelets/panicle*		
IR5716-18-1	6.7	7.2	7.2	52	61	61	9.2	10.8	13.0	115	121	127
IR7167-33-2-3	7.1	6.8	6.5	72	70	73	8.7	9.4	11.7	126	115	93
China 988	6.0	6.1	3.8	98	97	69	10.8	12.4	13.4	84	85	86
IR15924-265-3	6.3	5.8	4.4	64	60	57	11.8	12.0	14.0	128	126	111
SR5204-91-4-1	4.2	4.8	5.1	83	77	68	11.6	14.8	16.2	101	79	92
Taebaekbyeo	3.9	4.7	5.2	77	88	82	12.4	11.8	13.8	93	85	97
Manseokbyeo	5.0	4.7	5.2	88	86	76	10.9	14.1	17.0	93	83	80
IR9202-10-2-1-1-3	4.5	4.1	4.4	56	46	36	8.8	9.8	11.9	106	134	114

Table 6. Growth characteristics of eight varieties at different N levels. IRRI, 1983.

Variety	N (kg/ha)					
	75	150	300	75	150	300
		Harvest index			*Culm length (cm)*	
IR5716-18-1	.58	.50	.53	76	80	85
IR7167-33-2-3	.58	.52	.50	96	107	112
China 988	.53	.51	42	101	111	114
IR15924-265-3	.45	.40	32	106	111	122
SR5204-91-4-1	.52	.51	.48	73	80	81
Taebaekbyeo	.41	.48	.52	63	63	66
Manseokbyeo	.52	.45	.40	54	58	56
IR9202-10-2-1-1-3	.35	.33	.38	110	119	122
		Dry w. (g), 30 DT			*Dry wt at heading*	
IR5716-18-1	24	30	38	194	199	234
IR7167-33-2-3	24	31	36	163	180	182
China 988	22	35	40	149	152	171
IR15924-265-3	30	33	38	177	205	206
SR5204-91-4-1	21	25	26	88	107	140
Taebaekbyeo	21	22	26	124	125	147
Manseokbyeo	18	27	28	123	142	158
IR9202-10-2-1-1-3	26	29	41	199	199	185
		LAI, 30 DT			*LAI at heading*	
IR5716-18-1	1.2	1.9	2.2	3.8	4.3	6.7
IR7167-33-2-3	1.4	1.7	2.1	3.2	4.0	5.6
China 988	1.2	1.9	2.6	2.5	3.9	5.1
IR15924-265-3	1.2	1.5	1.8	3.4	3.7	4.6
SR5204-91-4-1	0.9	1.3	1.3	2.4	4.2	5.9
Taebaekbyeo	1.0	1.1	1.3	2.6	3.1	5.1
Manseokbyeo	1.0	1.5	1.7	3.2	3.6	5.2
IR9202-10-2-1-1-3	1.4	1.4	2.4	3.8	4.4	5.8
		Tiller no., 30 DT				
IR5716-18-1	11	13	14			
IR7167-33-2-3	9	10	13			
China 988	11	16	16			
IR15924-265-3	12	13	15			
SR5204-91-4-1	10	12	11			
Taebaekbyeo	11	10	11			
Manseokbyeo	9	12	15			
IR9202-10-2-1-1-3	10	13	17			

number even at 200 N. Although untreated control plants generally showed a decrease in panicle number at 200 N. This increase seems to protect the plant from low temperature and needs further study.

PLANT TYPE FOR HIGH GRAIN YIELD

The previous experiment showed definite varietal responses to N fertilizer. Eight rices were studied to see which plant types produce high grain yields at specific N levels under low temperatures.

Grain yield. IR5716-18-1 produced the highest yield at 150 and 300 kg N/ha (Table 4). However, the average yield of all entries at the 300 kg level was significantly lower than at 75 or 150 N. Several entries selected for their high yields yielded poorly at all N levels.

There were four types of entries (Fig. 2):

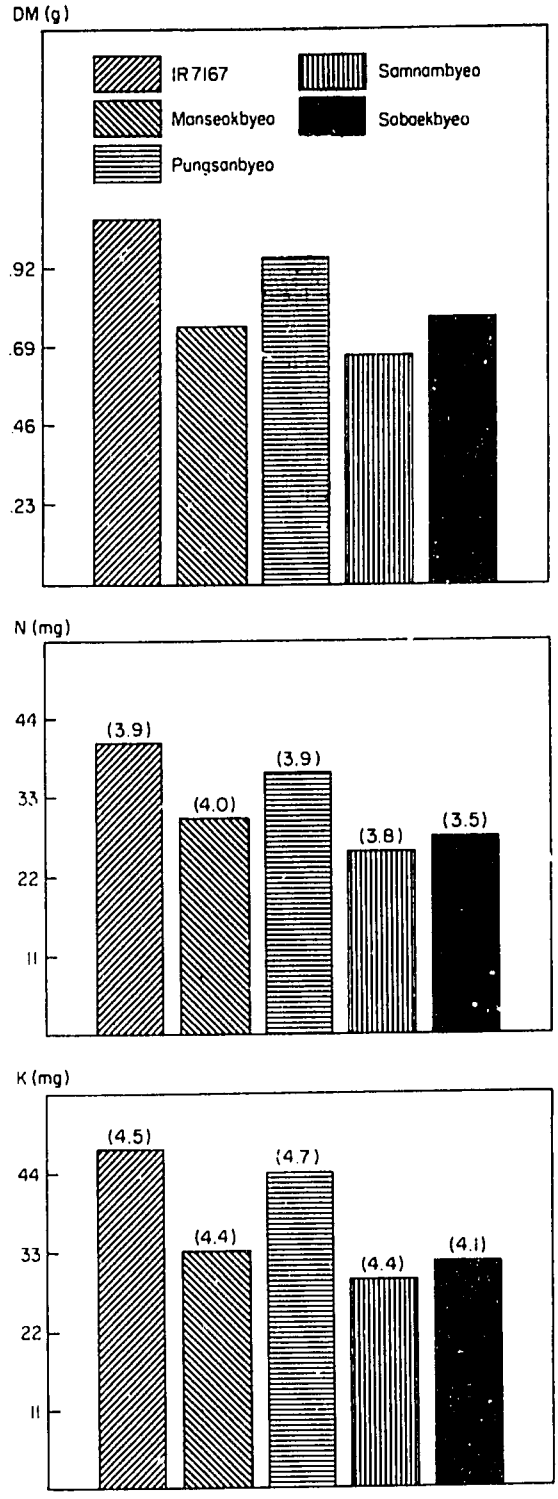
Type I gives consistent high yields at all N levels. Examples are IR5716-18-1 and IR7167-33-2-3. Type I is the ideal plant type. IR5716-18-1 may produce even more at higher N levels. Lodging reduced IR7167-33-2-3 yield at higher N levels.

Type II gives high yields at low N level and low yields at higher N level. Examples are China 988 and IR15924-265-3. Type II works well in the mountainous areas of Nepal and India. Low yields of Nepalese variety China 988 at high N result from lodging. The tall plants (102-122 cm vs 63-81 cm for Korean varieties) produce high yields but will lodge under Korean conditions.

Type III gives low yields at low N and moderately high at higher N. SR5204-91-4-1 and Taebaekbyeo (Suweon 287) belong to this type. Although yields increase with added N, they were not higher at 300 N than those of type I. Comparable higher yields may result at higher N levels. These two entries did not lodge even at high N, showing that the plant type is inefficient in using available N. Its N uptake needs more study.

Type IV gives moderate yields at all N levels. The poor yields of Manseokbyeo and IR9202-10-2-1-1-3 at higher N levels are partly from lodging.

Yield components. Panicle number increased with N level for all varietal types (Table 5). Both entries in Type I had a large number of spikelets per panicle.



3. DM, total N, and K uptake of 5 varieties before low-temperature treatment. Values in parentheses indicate % content in the tissue. IRRI, 1983.

Dry matter production, leaf area index, and harvest index. IR5716-18-1 and IR716733-2-3 had the highest average leaf area index (LAI) and relatively high DM production at heading (Table 6). IR5716-18-1 is short while IR7167-33-2-3 is intermediate, but both had high HI.

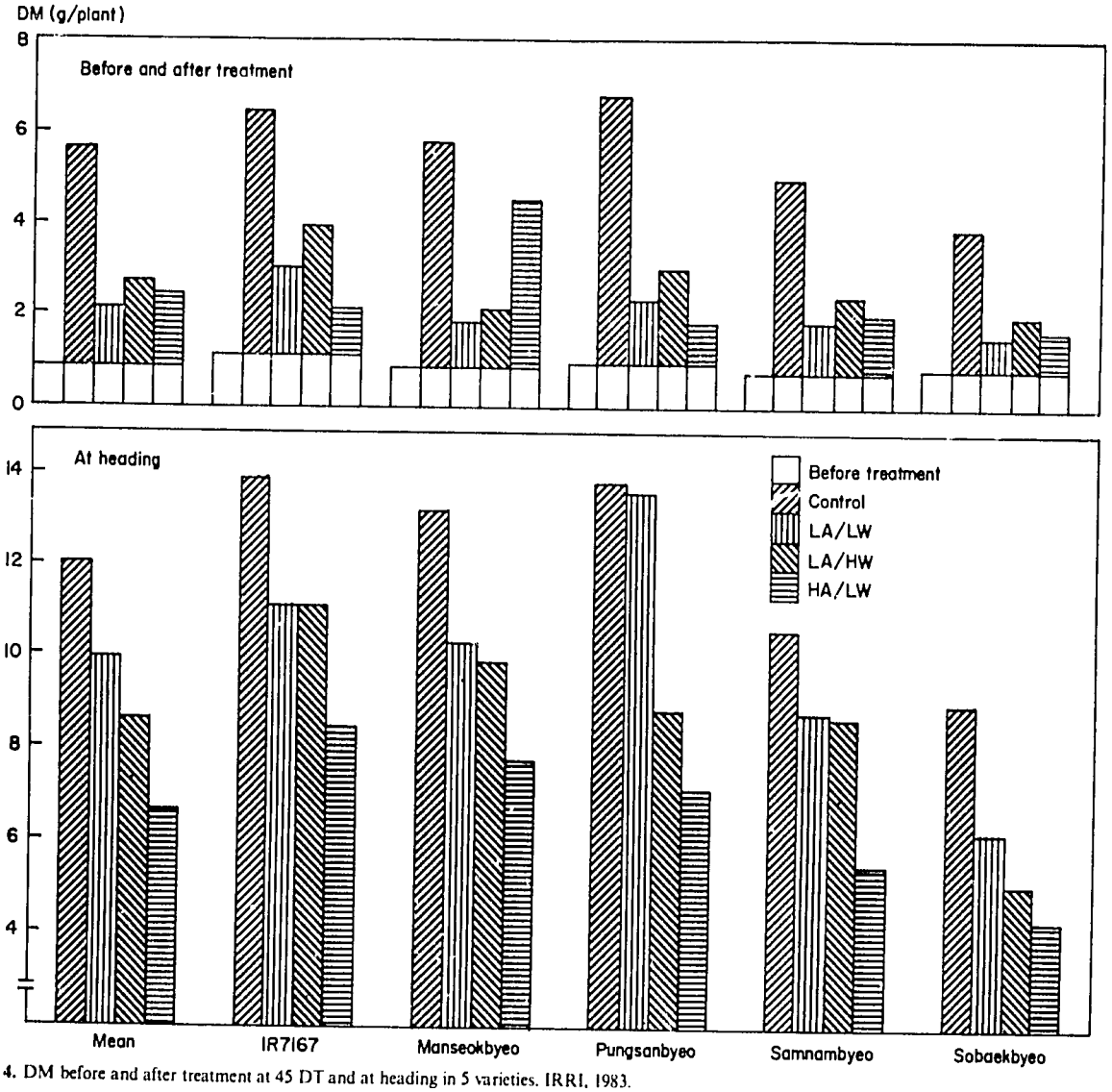
IR15924-265-3 and IR9202-10-2-1-1-3 had high DM at heading. However, their tall stature, low HI, low spikelet fertility, and the low panicle number of IR9202-10-2-1-1-3 resulted in low yields.

Lodging resistance is an important rice characteristic for Korea.

NUTRIENT UPTAKE AND USE AT LOW AIR OR SOIL TEMPERATURE

To study nutrient uptake, especially N, at low soil or air temperatures, plants were grown outside the greenhouse until 30 DT and then subjected to different temperature treatments for 15 d: control-normal condition (outside temperatures), low air/low water (LA/LW) — 18/18°C, low air/high water (LA/HW) — 18/23°C, and high air/low water (HA/LW) — 27/18°C.

Nutrient status before treatment. IR7167 and



4. DM before and after treatment at 45 DT and at heading in 5 varieties. IRRI, 1983.

Pungsanbyeo had highest DM before treatment and Samnambyeo had least (Fig. 3). DM content correlates with N (r = 0.97*) and K (r = 0.98*) uptake. Percent N and K in plant tissues are similar for all varieties. DM and increased N and K uptake are responsible for high total N and K content.

Pungsanbyeo showed high percent and high total P. Total Si content was high in IR7167, Pungsanbyeo, and Sobaekbyeo. There was no trend among varieties for P and Si content.

Nutrient status after treatment. *DM weight.* The mean of five varieties showed that low air or soil temperature reduced DM by 62%. DM reduction was higher at LA/LW and HA/LW than at LA/HW (Fig. 4). Manseokbyeo had relatively high DM at HA/LW treatment. That may indicate a superior mechanism for overcoming low water treatment. Low air temperature had the least effect on DM of IR7167.

DM at heading shows the amount of recovery after treatment. HA/LW had the most adverse effect. A growth imbalance, producing relatively high DM but poor nutrient uptake, is probably responsible for this poor recovery. LA/LW had the least negative effect on plant growth, followed by LA/HW.

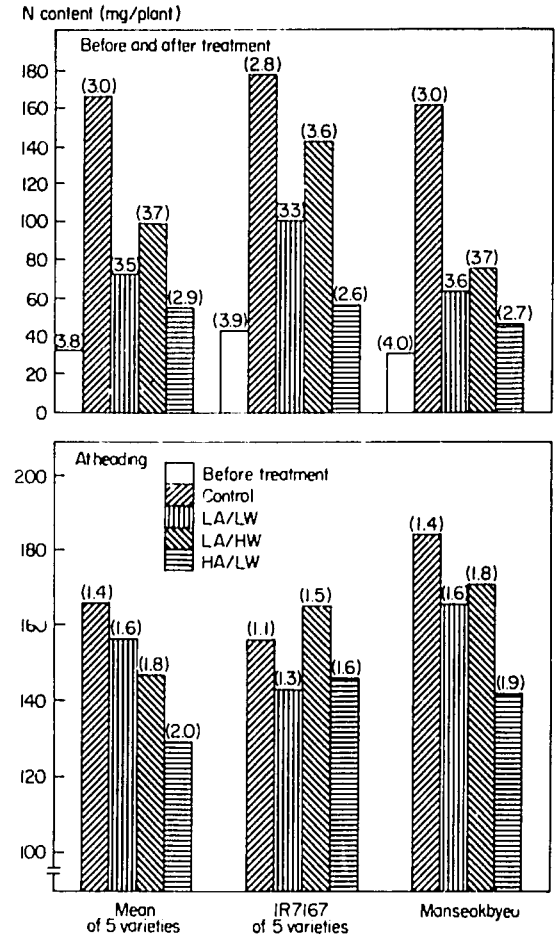
Nitrogen. Low temperatures greatly reduced N uptake (Fig. 5) partly because of reduced DM. Decreased N was greatest at HA/LW treatment. At LA, N accumulated in the plant even if DM remained constant and regardless of water temperature. Percent N was higher than in the control.

IR7167 had highest N uptake at LA, regardless of water temperature. HA and LW affected N uptake greatly. Manseokbyeo was the least efficient in N uptake during treatment (Fig. 5). In some cases, as in LA/HW for IR7167 and Samnambyeo, total N uptake was greater at heading in treated plants than in the control. Recovery was least in HA/LW. Varietal differences exist in reaction to LA/HW.

Potassium, phosphorus, and silica. As with N, K uptake was greatly reduced at HA/LW and least reduced at LA/HW. IR7167 showed the least reduction in K uptake.

At heading, recovery was evident but not comparable with that of N. Plants in the treatment HA/LW recovered least.

P uptake was similar to that of K and N,

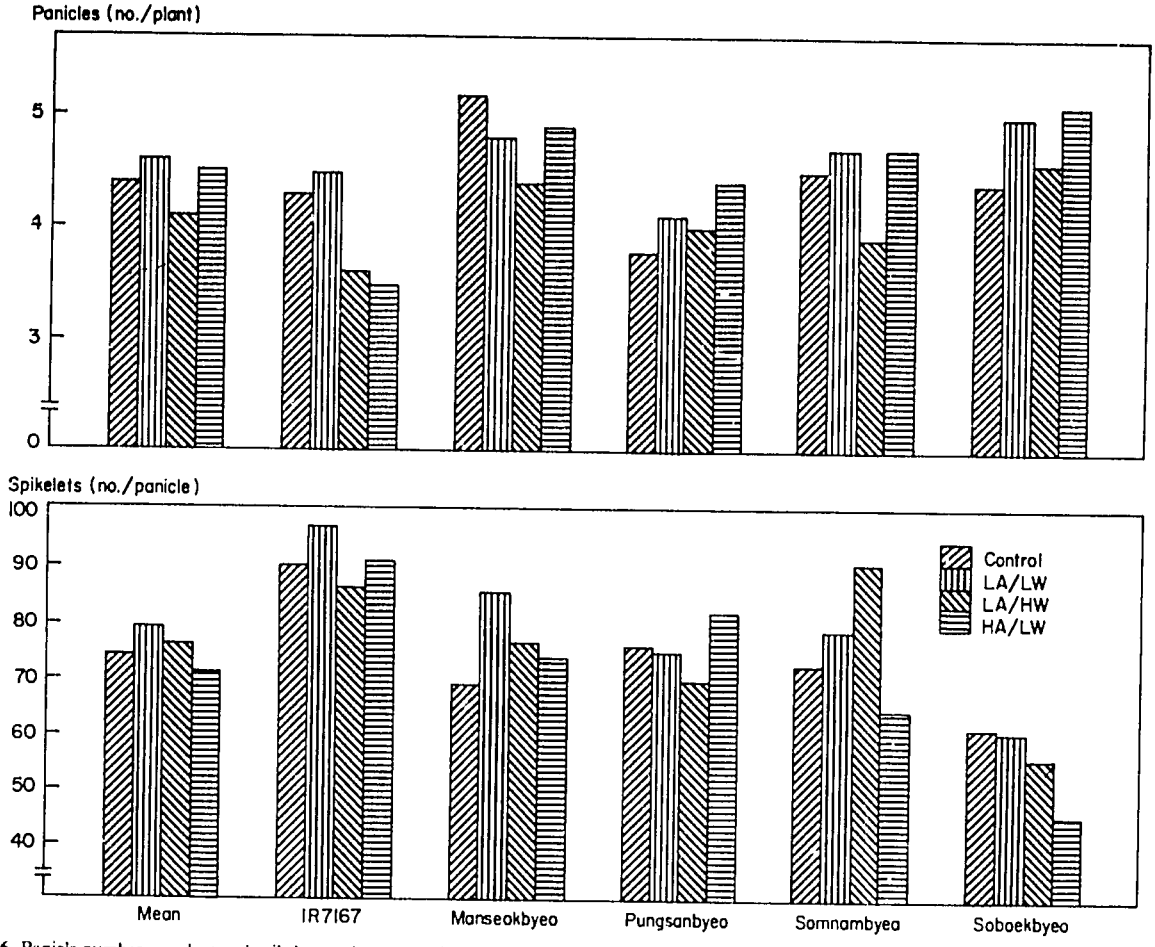


5. N uptake in 2 varieties before and after treatment and at heading. Values in parentheses indicate % N in tissue. IRRI, 1983.

inhibited by low temperature and most severely at HA/LW.

Recovery at heading was poor in terms of P uptake. It was poorest at HA/LW. Unlike K and N, P content of treated plants was low. Most P uptake occurs during the vegetative phase, and adverse conditions at that time affect total P content. Varietal differences were significant, with IR7167 showing the least adverse effect followed by Sobaekbyeo. Pungsanbyeo had the lowest P uptake.

Low temperatures also reduced Si uptake. As in N, P, and K, the HA/LW treatment had the lowest Si uptake. Because DM production was inhibited, percent Si in tissues was higher in treated than in control plants. Si uptake was not greatly affected by low temperature treatment. Reduced DM ac-



6. Panicle number per plant and spikelet number per panicle in 5 varieties after various low temperature treatments. IRRI, 1983.

counted for low Si uptake.

Si uptake showed recovery at heading with Pungsanbyeo showing the best recovery. Unlike P, Si content was higher in treated plants than in control plants.

N, P, K, and Si uptake was inhibited by low temperature treatment during vegetative stage, especially at HA/LW.

Recovery in N, K, and Si uptake was evident at heading. N, K, and Si content at heading were equal to, if not higher than, the control. P content was low and low temperature had the greatest effect on that nutrient in the plant.

IR7167, followed by Sobaekbyeo had the highest nutrient uptake in most low temperature treatments. Efficient nutrient uptake and DM production need further study,

Grain yield and yield components. Treatments during the vegetative phase had little effect on grain yield. The HA/LW treatment had the lowest yield, but differences were not statistically significant. Nutrient uptake decreased most in HA/LW and lowered grain yields.

Low temperatures had the least effect on Manseokbyeo yield.

Spikelet fertility was affected by low temperatures, but differences among treatments were not clear. LA/LW resulted in higher spikelets per panicle.

Panicle number per plant. Low temperatures affected the number of panicles per plant, with differences between varieties (Fig. 6).

Yield decreases at low temperatures were caused not only by panicle number, fertility, or spikelet number per panicle. Decreases varied with variety, with panicle number being the main factor in

IR7167. Reduced spikelets per panicle caused lower yield in Manseokbyeo, Samnambyeo, and Sobaekbyeo. Decreased spikelet fertility was common to all entries except Sobaekbyeo.

SCREENING FOR HIGH-TEMPERATURE TOLERANCE

The 1981 and 1982 International Rice for Arid Regions Observational Nursery entries were tested for high temperature (35° C) tolerance in the IRRI phytotron. Of 107 selections screened, the most heat tolerant in terms of spikelet fertility were Jubiliene, ES-17-164, and IRAT128.

Jubiliene, a japonica variety from Italy, had 88% spikelet fertility compared to 84% for resistant check N22. Nona Bokra and its selected variants were heat susceptible.

Genetic evaluation and utilization (GEU) program

Innovative breeding methods

Plant Physiology, Plant Breeding, and Agricultural Economics Departments, and Collaborators in the Philippines and Korea

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TISSUE CULTURE

Plant Physiology Department

Anther culture. Anther culture-derived plants from 13 crosses and 5 varieties were scored for cold tolerance at seedling stage (Table 1). In some cases, anther culture-derived plants from two susceptible parents such as IR48 and Suweon 290 had scores indicating higher tolerance than their parents. Anther culture is a potential tool in breeding for increased cold tolerance.

Gametoclonal variation in cold tolerance response was observed among anther culture-derived plants from varieties. Taipei 309 (score of 3) produced lines with tolerance scores less than, equal to, or higher than that of the parent. Therefore, it is possible to increase cold tolerance in varieties by passing them through anther culture.

Tolerance for Fe toxicity of anther culture-derived plants from varieties and F_1 sexual crosses were tested against that of the parents (Table 2). Gametoclonal variation in Fe toxicity tolerance was also observed in varieties. All Taipei 309 lines tested were more tolerant than the parent.

Anther culture-derived plants from F_1 crosses had higher tolerance for Fe toxicity than their susceptible parents. In a Taipei 309/Tatsumi Mochi cross, 20 of 21 plants scored 3 to 8 while both parents scored 9. Increased tolerance of regenerated plants suggests gene complementation or mutation.

Somatic cell culture. *Effect of Al-citrate and Al-EDTA on callus growth.* Al solubility is drastically changed by pH. It is low at pH 4.7 to 7.5, but below pH 4.0 and above pH 9.2, it increases rapidly. However, in a culture medium containing phosphate, Al precipitates even at pH 4.0. Very low pH reduces precipitation, but it also reduces callus growth.

Adding Al-EDTA to the culture medium overcame Al precipitation. However, it is possible that the presence of a chelating agent is detrimental since it could chelate other essential cations, thereby reducing their number in the culture medium. The agent could be toxic since it may be absorbed by the cells.

A study was therefore conducted to determine the effect of chelating agents on callus growth. The culture medium used was Murashige and Skoog's.

Table 1. Cold tolerance response of anther culture-derived plants. IRRI, 1983.

Entry	Lines tested (no.)	Lines (no.) with indicated cold tolerance score at seedling stage[a]				
		1	3	5	7	9
	Variety					
Taipei 309	113	1	27	83	2	0
Suweon 290	2	0	0	0	0	2
Giza 170	4	0	2	2	0	0
Minehikari	1	0	1	0	0	0
Pai-Kan-Tao	2	0	0	2	0	0
	Cross					
IR48/BG90-2	6	0	0	0	1	5
IR48/Suweon 290	31	0	0	11	20	0
Tatsumi Mochi/IR48	1	0	0	0	1	0
Tatsumi Mochi/T309	1	0	0	1	0	0
Taipei 309/IR20	1	0	0	1	0	0
Taipei 309/IR30	1	0	0	0	1	0
Taipei 309/IR36	1	0	0	0	1	0
Taipei 309/BG90-2	1	0	1	0	0	0
Suweon 290/BG90-2	8	0	0	0	7	1
BG90-2/Tatsumi Mochi	4	0	0	0	3	1
MI48/Pokkali	3	0	0	3	0	0
IR19226-355-1-1-16/ IR520-1-26	1	0	0	0	1	0
IR9752-71-3-2/IR19792-15-2-3-2-3	7	0	0	1	6	0
Parent		*Score of parent*				
IR20						9
IR30						9
IR36						9
IR48						9
Taipei 309			3			
Tatsumi Mochi			3			
BG90-2						9
MI48				5		
Pokkali					7	
Suweon 290						9
Silewah			3			
Taichung 65			3			
Giza 170		1				

[a]Scale of tolerance: 1 = seedlings dark green, 3 = seedlings light green, 5 = seedlings yellow, 7 = seedlings brown, 9 = seedlings dead.

Each litre of medium was supplemented with 100 mg myo-inositol, 5 mg nicotinic acid, 5 mg pyridoxin·HCl, 1 mg thiamine.HCl, 20 mg glycine, 2 g yeast extract, 2 g casein hydrolysate, and 2 mg 2,4-D. Calluses from Taichung 65 seeds were induced and subcultured 4 times (16 wk) in the same medium. Al was added as $AlCl_3 \cdot 6H_2O$, citric acid as citric acid·H_2O, and EDTA as EDTA·$2H_2O$. The pH of the medium varied.

Table 2. Fe toxicity tolerance response of anther culture-derived plants. IRRI, 1983.

Entry	Lines tested (no.)	Lines (no.) with Fe toxicity tolerance score[a] of						
		3	4	5	6	7	8	9
	Variety							
Taipei 309	16	0	3	6	2	5	0	0
Giza 170	21	0	0	5	4	9	1	2
IR30	1	0	0	0	1	0	0	0
	Cross							
IR48/Suweon 290	4	1	0	3	0	0	0	0
Suweon 290/BG290-2	5	0	0	1	1	3	0	0
Silewah/Taichung 65	1	0	0	1	0	0	0	0
MI48/Pokkali	2	0	0	1	0	0	0	1
Tatsumi Mochi/ BG290-2	14	0	0	1	5	5	3	0
Tatsumi Mochi/ BG90-2	5	0	0	0	2	0	2	1
Tatsumi Mochi/S 290	11	0	0	1	1	7	1	1
Taipei 309/Tatsumi Mochi	21	1	4	5	6	2	2	1
BG90-2/Tatsumi Mochi	6	0	0	1	1	4	0	0
IR48/BG90-2	6	0	0	0	0	5	1	0
IR48/Suweon 290	7	0	0	1	2	2	0	2
BG90-2/Taipei 309	9	0	0	1	1	4	1	2
Taipei 309/BG90-2	1	0	0	0	0	1	0	0
Sabanet Taungpyan/ New Sabarmati	5	0	0	0	0	1	0	4
Pawsanbaykyar/IR4570-124-3-2-2-2	1	0	0	0	0	0	0	1
IR9252-71-3-2/IR19792-15-2-3-3-3	3	0	0	0	0	2	0	1
Ngakywe/IR4570-124-3-2-2-2	2	0	0	0	0	1	0	1
New Sabarmati/IR27300-124-2	2	0	0	0	0	1	0	1
Parent				*Score of parent*				
Taipei 309								9
Giza 170				5				
IR30					6			
IR48				5				
Suweon 290					6			
BG90-2				5				
Silewah					6			
Taichung 65							8	
MI48						7		
Pokkali				5				
Tatsumi Mochi								9
IR19792-15-2-3-3-3				5				
IR27300-124-2				5				
IR29				5				
IR4570-124-3-2-2-2		3						
IR9752-71-3-2				5				
Pawsanbaykyar						7		
Sabanet Taungpyan			4					

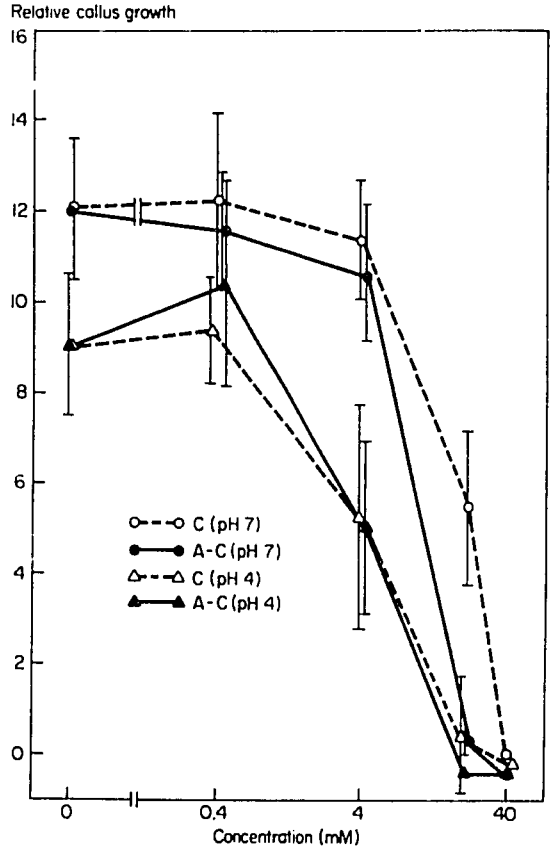
[a]Scale of tolerance: 3-4 = tolerant, 5 = moderately tolerant, 6-9 = susceptible.

At pH 7.0, white precipitate was found in the medium after sterilization. Al and EDTA do not form a stable chelate compound at pH 7.0. With Al-citrate, precipitation at 0.4 m*M* was not caused by Al since no precipitation occurred at higher concentrations. No precipitation occurred at pH 4.0.

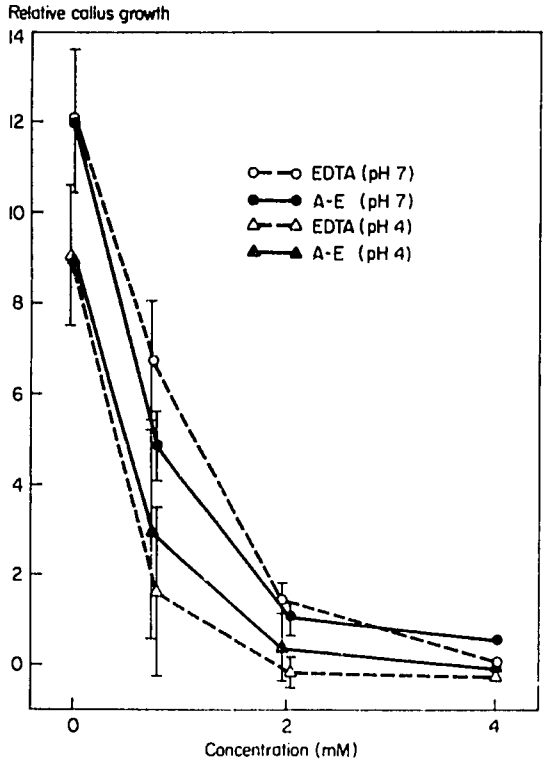
At pH 7.0, neither Al-citrate nor citrate had an inhibitory effect on callus growth at 0.4 and 4 m*M* (Fig. 1). At 22 m*M* Al-citrate completely repressed callus growth while citrate reduced growth to 43%. At 40 m*M*, both compounds completely repressed callus growth.

There was no difference in growth of calluses cultured in Al-citrate and citrate when the medium was adjusted to pH 4.0 (Fig. 1). At this pH, H^+ ions repressed the growth of the control.

When the medium was adjusted to both pH 7.0 and 4.0 (Fig. 2) Al-EDTA was more toxic to the



1. Effect of Al-citrate (A-C) and citrate (C) on callus growth at pH 4.0 and 7.0 after 4 wk incubation at 26°C. IRRI, 1983. Vertical lines present standard deviation



2. Effect of Al-EDTA (A-E) and EDTA on callus growth at pH 4.0 and 7.0 after 4 wk incubation at 26°C. Vertical lines present standard deviation. IRRI, 1983.

callus than Al-citrate. Like Al-EDTA, EDTA also had detrimental effects at both pHs.

The study shows that EDTA is not a suitable chelating agent to prevent Al precipitation in the culture medium. Citric acid adjusted to pH 7.0 is not an ideal chelating agent, but is better than EDTA. Al-citrate and citrate had no toxic effect on callus growth at 0.4 and 4 m*M* but repressed growth at higher concentrations.

Other studies are needed to investigate better methods of preparing culture media with higher Al content for screening callus tissues.

Callus induction and growth. Three kinds of media were used to induce and grow calluses: Murashige and Skoog (MS), MS + yeast extract and casein hydrolysate (MSYC), and Linsmaier and Skoog (LS) and HE medium. Mature seeds and young inflorescences were used as explants. Taichung 65, Reiho, Nona Bokra, IR36, IR50, IR52, IR54, and IR56 provided mature seeds. Only IR lines were used for young inflorescences.

The callus induction rate from seeds varied according to media and varieties used. Casein hydrolysate alone or combined with yeast extract in the medium markedly increased the callus induction rate for all varieties except IR54.

When panicles were used as explants, callus induction rates were high for all varieties regardless of media.

Calluses from seeds and panicles showed highest growth in casein hydrolysate and yeast extract.

Plant regeneration from calluses of mature seeds and young inflorescence. Mature seeds and young inflorescences were used for callus induction, proliferation, and subculture in MS, MSYC, and LS media. Plants were regenerated by two methods. The standard method uses MS medium. The two-step method first uses LS medium with added abscisic acid (ABA) and then LS medium alone. Two japonicas (Taichung 65 and Reiho) and six indicas (IR52, IR54, IR50, IR56, IR36, and Nona Bokra) were tested using mature seed explants. Only IR lines were tested using young inflorescence.

In both types of explants, both methods had very low regeneration percentage, and the two-step method was very inferior. In both methods, regeneration frequencies from all varieties were highest when MS was was used for callus induction and proliferation. After the first regeneration (R_1) using the standard method, plants from mature seeds used as explants produced 14.0% regeneration in Taichung 65 and Nona Bokra, 9% in Reiho, 3% in IR52 and IR56, and 2% in IR54. These values increased slightly after R_2. Using the two-step method, R_1 values were obtained only from IR50 (6.0%), and Taichung 65 and Nona Bokra (2.0%). R_2 values were obtained only from Taichung 65 (3.0%) and Reiho (2.0%). No plants were regenerated with either method from young inflorescence after R_1 and R_2.

R_5 calluses have been obtained from mature seeds and R_4 from immature panicles. Regenerated plants from either method are few, especially those of IR varieties.

Plant regeneration from long-term callus cultures. Four media and three varieties were used to define optimum conditions for high plant regeneration frequency from long-term callus cultures, particularly of IR varieties (Table 3).

Plant regeneration was poor in seed-derived

Table 3. Percent plant regeneration from callus cultures.

Medium[a] for callus induction	Plant regeneration[b] (%)			
	4 wk	12 wk	16 wk	20 wk
	IR36			
MS1	0	0	–	0
MS2	0	–	0	0
MS3	3	3	0	0
MS4	8	13	0	3
	IR5			
MS1	0	0	0	–
MS2	7	–	4	3
MS3	7	16	8	2
MS4	8	5	0	0
	Nona Bokra			
MS1	3	0	–	0
MS2	11	–	3	7
MS3	16	13	3	10
MS4	30	29	13	2

[a]MS1 = MS + 2 g casein hydrolysate + 2 g yeast extract + 2 mg 2,4-D + 30 g sucrose/litre; MS2 = MS + 2 mg 2,4-D + 1 mg zeatin + 30 g sucrose/litre; MS3 = MS + 2 mg 2,4-D + 1 mg BAP + 30 g sucrose/litre; MS4 = MS + 0.5 mg 2,4-D + 9.3 mg NAA + 5.6 mg BAP + 30 g sucrose/litre.
[b]– = not studied.

callus cultures in all media-variety combinations. However, MS-4 had higher regeneration than the others, with 28.8% of Nona Bokra from a 12-wk-old callus and 12.7% of IR36. Regeneration was reduced drastically in 16- and 20-wk-old callus cultures.

MS-4 was modified (MS4 + 60 g sucrose/litre) to improve plant regeneration frequency. IR58 and IR36 regenerated with reasonably high frequency (50-60%) from 6-to 8-wk-old callus cultures. One experiment regenerated more than 500 IR58 plantlets which have been transplanted into soil. Their progeny will be screened for somaclonal variation in salinity tolerance and other agronomic characteristics.

These compact and slow growing callus cultures germinate quickly. Plantlets probably arise from multiple shoot formation as well as somatic embryogenesis. The mechanism of the origin of these plantlets is being investigated.

Embryogenic callus induction. Five media, four varieties, and two explants (mature seed and immature panicle) were tested to induce somatic embryogenesis. The type of variety, explant, and media influenced induction of embryogenic callus (E-callus). Varieties differed in their response to the same medium for embryogenesis, with IR52 and IR54 more responsive than IR36 and IR50. Mature seed was more effective than immature panicle as explant for inducing E-callus. Medium No. 3 (HE medium + 2 mg 2,4-D/litre, 2 mg NAA/litre + 3 mg Kn/litre + 1360 mg YE/litre + 33 mg CH/litre) and No. 5 (MS + 2 mg 2,4-D/litre + 2 mg NAA/litre + 3 mg Kn/litre + 1360 mg YE/litre + 300 mg CH/litre) were most effective in producing E-callus. NAA and kinetin, special YE (yeast extract), and CH (casein hydrolysate) in the supplement composition were important in inducing callus development.

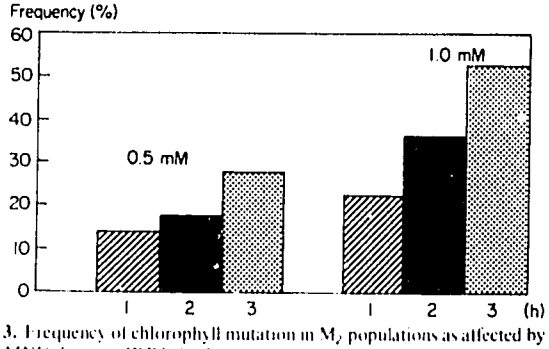
Nonembryogenic callus (NE-callus) usually emerged first on the embryo scutellum, and then E-callus developed on the face of NE-callus. E-callus is white, granular, and compact.

Nine media were tested on IR36 and IR54 to determine the optimum media for subculture.

One medium formed 55% in R_1 and 80% of them were maintained in two subsequent subcultures.

Although E-callus germinated and formed green spots and green leaves, most of them turned brown and died and only a few plantlets developed (Table 4).

Fertilized egg cell for mutation induction. Seed is usually used for mutagen treatment. Since the seed contains a multicellular embryo, mutagen treatment leads to chimera formation and lower mutation rates from diplontic selection. These losses can be avoided by mutagenizing with a fertilized egg cell at the unicellular (zygote) stage. A study was designed to induce mutation by treating a fertilized egg cell with N-methyl-N-nitrosourea (MNU) at monocell stage and to evaluate frequency of mutation and occurrence of chimera in plants derived from treated cells.



3. Frequency of chlorophyll mutation in M_2 populations as affected by MNU dosages. IRRI, 1983.

Table 4. E-callus regeneration. IRRI, 1983.

	1st passage	2d passage	3d passage	4th passage
	IR54			
Calluses transferred (no.)	36	56	48	30
Green spots (no.)	26	34	34	20
%	72.2	60.7	70.8	66.6
Calluses regenerated into green plantlets (no.)	12	9	3	0
%	33.3	16.0	6.2	0
	IR36			
Calluses transferred (no.)	40	32		
Green spots (no.)	17	11		
%	42.5	34.4		
Calluses regenerated into green plantlets (no.)	3	0		
%	7.5	0		

Table 5. Biological effects of MNU treatment of fertilized egg cell of rice on M1 plants. IRRI, 1983.

MNU dosage[a]	Fertilized egg cells treated (no.)	Seed setting (%)	Seed germination (%)	Seedling height (%)
0 (control, water)	256	92	100	100
0.5 m*M* for 1 h	497	86	86	94
0.5 m*M* for 2 h	1737	90	82	89
0.5 m*M* for 3 h	787	87	85	83
1.0 m*M* for 1 h	800	85	80	90
1.0 m*M* for 2 h	1493	84	71	74
1.0 m*M* for 3 h	1057	85	60	56
1.5 m*M* for 1 h	1132	84	74	86
1.5 m*M* for 2 h	678	78	65	60
1.5 m*M* for 3 h	1035	72	51	41

[a]All treatments were made 12 h after anthesis.

Fertilized egg cells of Taichung 65 were selected from uniformly pollinated spikelets and treated in situ by dipping panicles in MNU solution. Panicles were exposed to MNU concentrations (0.5, 1.0, 1.5 m*M*) for 1, 2, and 3 h beginning 12 h after anthesis. Treated fertilized egg cells were grown to maturity in the spikelet. Seed setting markedly decreased at higher doses of MNU (Table 5). Germination percentage and seedling height decreased as dosage and treatment duration increased. MNU treatment had the most severe effect on panicle fertility. The percentage of plants surviving after transplanting decreased as the mutagen concentration increased.

Chlorophyll mutation rates in the M_2 population consistently increased as dosage increased (time × concentration), with the highest rate at 52% (Fig. 3). MNU did not have any effect in inducing specific chlorophyll mutations (Table 6). A comparison of chlorophyll mutation in two random panicles from a plant progeny showed that all panicles had the same type of mutation. Mutagenesis of a fertilized egg cell at unicellular stage possibly eliminates chimera. The use of a fertilized egg cell is effective for inducing mutation.

Inducing variability in aluminum tolerance. Development of Al-tolerant varieties through induced mutation is being studied as an approach in improving rice productivity on Al-toxic soils. Mutations were induced by treating fertilized egg cells of Taichung 65 at the unicellular stage with MNU.

The M_2 population was screened for Al tolerance in a nutrient culture solution containing 30 ppm Al. Tolerance for Al was determined by relative root length (RRL). The M_2 population varied widely (Table 7), showing increased Al tolerance as well as more sensitivity than the parent. Among

Table 6. Relative frequencies of different types of chlorophyll mutation in M2 under different MNU treatments.

Type	Frequency (%) at MNU dosage of					
	0.5 m*M* for 1 h	0.5 m*M* for 2 h	0.5 m*M* for 3 h	1.0 m*M* for 1 h	1.0 m*M* for 2 h	1.0 m*M* for 3 h
Albina	52	43	50	30	39	26
Viridis	28	26	30	51	41	42
Xantha	7	17	6	8	7	11
Alboviridis	5	8	5	3	5	2
Viridoalbina	0	1	0	1	6	5
Xanthoalbina	0	0	0	0	1	1
Striata	3	1	5	6	1	1
Tigrina	5	5	4	1	1	13

Table 7. Induced variability in Al tolerance in the M2 population derived from MNU treatment of a fertilized egg cell. IRRI, 1983.

MNU dosage	Total progeny (no.)	M2 progeny response (%)			Total seedlings (no.)	M2 seedling response (%)		
		Sensitive	Moderately tolerant	Highly tolerant		Sensitive	Moderately tolerant	Highly tolerant
0.5 m*M* for 3 h	130	9	69	21	2227	57	40	3
1.0 m*M* for 2 h	134	10	76	13	2416	56	42	2
1.0 m*M* for 3 h	47	9	72	19	816	52	46	2
Total	311	10	73	18	5459	56	42	3

MNU treatments, the lower dose drew a much wider Al reaction. Of 5,459 M_2 seedlings screened, 2.6% showed high Al tolerance. The Al-tolerant progenies are being tested in M_3. Mutagen treatment of a fertilized egg cell is an effective technique for inducing variability in Al tolerance in rice.

Inducing variability in salt tolerance. The development of salt-tolerant genotypes through induced mutation is being explored. In Taichung 65, variability was induced by treatment of a unicell fertilized egg cell with MNU.

The M_2 population was screened for salt tolerance using standard nutrient culture solution containing 0.5% NaCl. Salinity stress was imposed at the third-leaf stage in seedlings. Seedling response to salinity was rated by visible damage, and seedlings were categorized as sensitive, intermediate, and tolerant. The M_2 population possesses wide variability in salt tolerance. Of 244 M_1 plant progenies, 71 produced salt-tolerant seedlings; among 15,000 M_2 seedlings, only 1.29% were salt tolerant. Salt-tolerant plants selected from the M_2 population are being investigated in the M_3.

HYBRID RICE

Plant Breeding, Plant Physiology, and Agricultural Economics Departments; Collaborators in the Philippines and Korea

Heterosis studies (*Plant Breeding and Plant Physiology; collaborators in the Philippines and Korea*). *Performance of some experimental F_1 rice hybrids and commercial varieties.* DS trials produced some very early (105+ d) and early (110+ d) F_1 hybrids which outyielded the highest yielding check varieties — 1.3 t/ha over very early IR58 and 0.9 t/ha over early IR36 (Table 8). All hybrids except Zhen Shan 97A/IR13420-6-3-3-1 were derived from cytoplasmic male sterile and restorer lines developed or identified at IRRI. F_1 seed of these combinations was produced for further testing in 1984.

In the late-maturity group (125-130 d), an intervarietal F_1 hybrid IET3257/IR42 yielded 1.8 t/ha higher than check variety IR42 at 7.8 t/ha. Bulk quantity of F_1 seed cannot be produced for further evaluation because a stable cms line in the genetic background of the female parent IET3257 is not ready. Heterotic combinations derived from the stable cms lines in the late-maturity group need to be identified.

WS replicated yield trials including F_1 hybrids and check varieties were affected by a severe typhoon and floods which destroyed several plots and led to inconclusive results. Very early hybrid IR19792-15-2-3-3A/IR56 yielded 0.3 t/ha more than IR58, and early Jikkoku Seranai 52-37A/IR54 yielded 0.5 t/ha more than IR36. Both are

Table 8. Comparative performance of experimental F_1 rice hybrids and check varieties in replicated yield trials at IRRI during 1983 DS.

Hybrid or variety	Growth duration (d)	Yield (t/ha)
Very early		
MR365A/IR18349-22-1-2	105	8.0
Zhen Shan 97A/IR13420-6-3-3-1	101	7.6
IR19799-17-3-1-1A/IR54	105	7.5
IR58 (check)	102	6.7
Early		
IR19657-34-2-2-3-3A/IR54	111	7.9
MR365A/IR13420-6-3-3-1	109	7.9
MR365A/IR2307-247-2-2-3	108	7.8
IR36 (check)	110	7.0
Late		
IET3257/IR42	130	9.6
IR42 (check)	126	7.8

F_1 hybrids derived from IRRI cms and restorer lines.

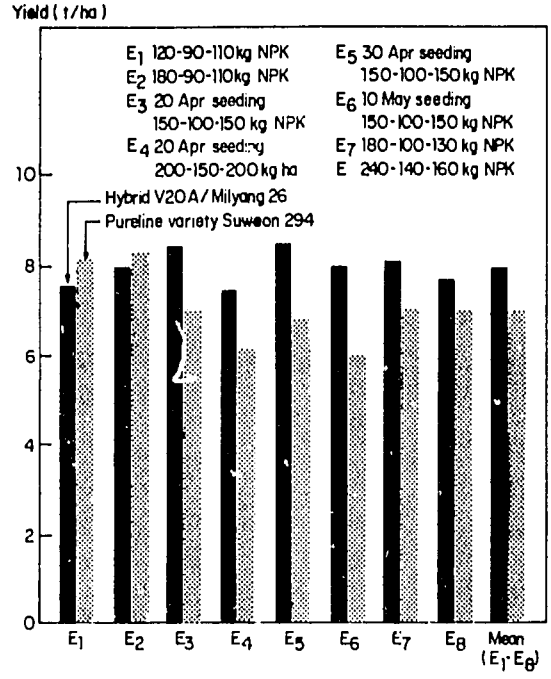
Some experimental F_1 rice hybrids were also evaluated outside the IRRI farm at Muñoz, Nueva Ecija in the Philippines and Suweon and Iri in South Korea. Five very early F_1 hybrids outyielded IR58 and one early F_1 hybrid outyielded IR36 although yields were rather low (Table 9). Two F_1 hybrids V20A/IR54 and V20A/IR13419-113-1 outyielded even late-maturity IR42. However, these hybrids will not be recommended for the tropics since the female parent (V20A) is highly susceptible to major diseases and insects, making it difficult to produce bulk hybrid seed.

Eleven experimental rice hybrids were evaluated at three locations in eight different environments in South Korea. Results show that V20A/Milyang 46 produced 0.9 t/ha more than the best check variety Suweon 294 at 7 t/ha (Fig. 4). Hybrid seed of this combination is being produced at IRRI for further evaluation in Korea and elsewhere during 1984. Chinese cms lines may be useful in developing rice hybrids for Korean conditions using locally adapted restorer lines such as Milyang 46.

Yield heterosis in rice. Several agronomic and physiological traits of four F_1 rice hybrids, their parents, and check varieties were studied during 1983 DS in a replicated yield trial. Mean values of F_1s and mean heterosis (F_1 - midparent), heterobeltiosis (F_1 - better parent), and standard heterosis

Table 9. Comparative performance of experimental F_1 rice hybrids and check varieties in replicated yield trials at MRRTC, Muñoz, Nueva Ecija, during 1983 DS.

Hybrid variety	Growth duration (d)	Yield (t/ha)
Very early		
V20A/IR54	107	4.8
V20A/IR2797-105-2-2-3	107	3.8
Zhen Shan 97A/IR2797-105-2-2-3	108	4.1
Zhen Shan 97A/IR13420-6-3-3-1	107	3.5
IR58 (check)	107	2.8
Early		
V20A/IR13419-113-1	111	4.7
IR36 (check)	116	4.0
IR56 (check)	116	4.0
Medium		
IR54 (check)	128	3.6
Late		
IR42 (check)	141	4.0



4. Performance of the highest yielding rice hybrid (V20A/Milyang 46) and the highest yielding check variety (Suweon 294) in South Korea, 1983.

(F_1 - check variety) values for various agronomic and physiological traits (Table 10) led to the following conclusions.

- Higher yield in hybrids was due to heterosis for DM and HI.
- Heterosis for DM in the hybrids could be caused by heterosis for LAI and possibly heterosis for height. There was no heterosis for tiller number per plant.
- Hybrids also showed heterosis for cumulative growth rate (CGR) during preflowering and postflowering stages.
- Heterosis for leaf area ratio (LAR) was usually negative.
- Increased hybrid HI was mostly from heterosis for spikelet number per panicle and 1,000-grain weight.
- Hybrids showed negative heterosis for panicle number/m^2 but their spikelet number/m^2 (spikelet/panicle x panicle/m^2) was higher. This indicated that their reduced tiller number was overcompensated for by the increased spikelet number/panicle.
- Hybrids showed high heterosis, heterobeltiosis, and standard heterosis for productivity

Table 10. Mean values and mean heterosis, heterobeltiosis, and standard heterosis values for various agronomic and physiological traits in 4 rice hybrids evaluated at IRRI, 1983 DS.

Trait	Mean value	Percent mean		
		Heterosis	Heterobeltiosis[a]	Standard heterosis[b]
Yield (t/ha)	8.1	39	28	20
DM (kg/m²)	1.6	21	14	9
LAI at flowering	7.1	17	9	10
Height (cm)	110	4	9	9
Tillers/plant	22	1	5	0
CGR (g/m² per wk)				
Preflowering	147	25	22	20
Postflowering	116	18	22	3
LAR (cm²/g)	62	4	−7	−5
HI	0.50	17	12	12
Spikelet no./panicle	126	44	41	18
1,000-grain (wt (g)	25	5	5	3
Panicles/m²	316	−6	−12	8
Filled spikelets/m² (1 X 10³)	39	34	24	11
Spikelet fertility (%)	84	−2	−2	+4
Productivity/day (kg/ha)	82	47	33	16

[a]Estimated in comparison to the better yielding parent. [b]Estimated in comparison to the highest yielding check variety.

per day. Hybrids are physiologically more efficient.

Physiological analysis of heterosis in rice. Thirty-five rice hybrids and their parents were grown in pots and analyzed for photosynthetic rate and leaf area. These factors are usually associated with DM accumulation. There was no heterosis or heterobeltiosis for leaf photosynthetic rate, but there was positive heterosis and heterobeltiosis for leaf area (Table 11). Heterosis in leaf area showed linear correlation with heterosis in shoot DM (Fig. 5).

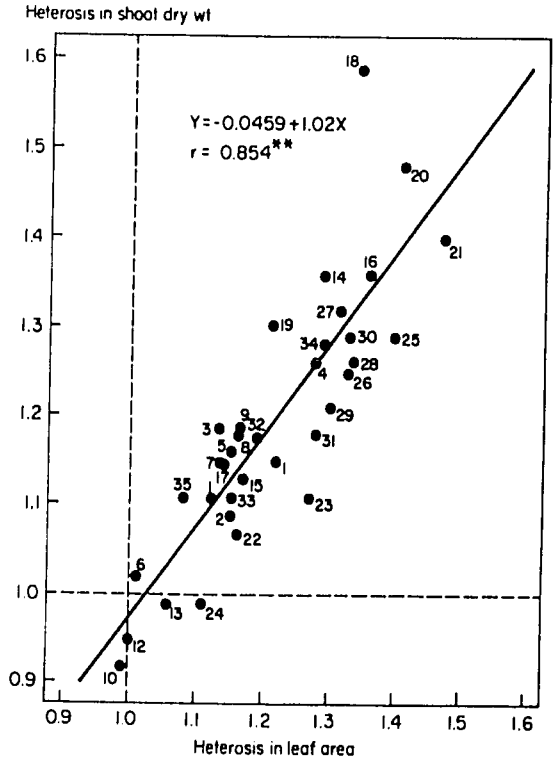
Heterosis for leaf area was positively correlated with total leaf number and mean leaf size (Table 12). The total leaf number increase may come from increased tillering. The correlation between heterosis for leaf area and physiological age was positive but nonsignificant. Heterosis for leaf area was negatively correlated with specific leaf area although nonsignificant.

In spite of their high tillering ability, F_1 hybrids also showed heterosis for shoot weight per tiller estimated from shoot dry weight/shoot number (Fig. 6).

Table 11. Average of heterosis and heterobeltiosis of 35 F_1 hybrids. IRRI, 1983.

	Heterosis (%)	Heterobeltiosis[a] (%)
Leaf photosynthetic rate	−1	−4
Total leaf area	21	18
Shoot dry wt	19	8

[a]Estimated in comparison to the better parent for shoot DM at IRRI, 1983 DS.

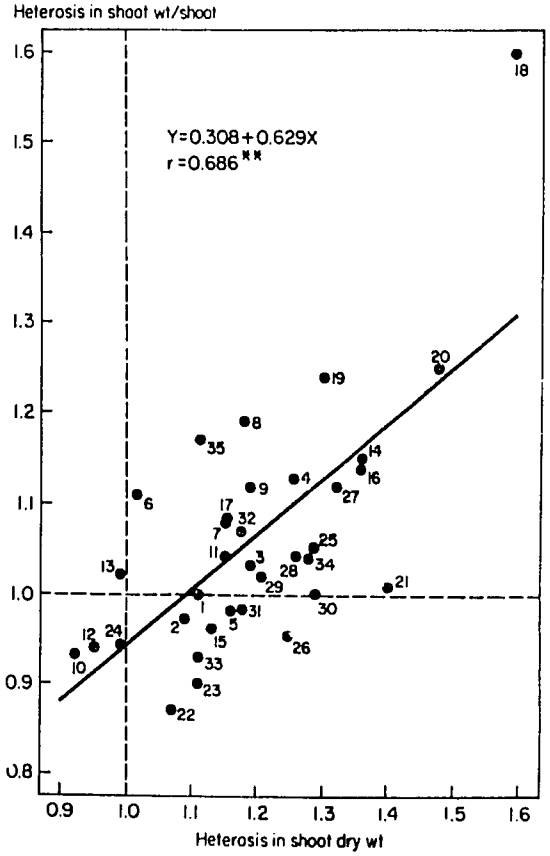


5. Relation between heterosis in leaf area and in shoot dry weight. The number on each spot represents a different F_1 hybrid. IRRI, 1983 DS.

Table 12. Correlation coefficients for heterosis for leaf area and plant DM with heterosis for some physiological traits. IRRI, 1983.

Heterosis for	Correlation coefficient for heterosis for				
	Leaf area	Leaf number	Mean leaf size	Specific leaf area	Physiological age
Leaf area	–	0.85**	0.82*	-0.22^{ns}	0.62^{ns}
DM	0.99**	0.84**	0.83*	-0.36^{ns}	0.64^{ns}

Cytoplasmic genetic male sterility and fertility restoration (*Plant Breeding*). *Development of cytoplasmic-genetic male sterile lines of rice for the tropics.* Seven stable cytoplasmic-genetic male sterile lines were developed for the tropics by transferring nuclear genes of the elite lines into cytoplasm (WA type) of Chinese cms lines Zhen Shan 97A and V20A. Major agronomic and floral traits of these lines were comparable with those of the Chinese cms line Zhen Shan 97A (Table 13).



6. Relation between heterosis in shoot dry wt and in shoot wt/shoot. The latter was calculated by dividing shoot dry wt by shoot number. The number on each spot represents a different F_1 hybrid. IRRI, 1983 DS.

Seeds of these lines and their maintainers have been supplied to collaborators in India, South Korea, and Indonesia for evaluation and use in developing F_1 hybrids. These early lines (105-110 d) can grow in the tropics better than Chinese cms lines although they still do not possess a broad spectrum of disease and insect resistance. Two of these lines, IR46829A and IR48483A, appear to have good combining ability and are being used to develop hybrids for the tropics. Some very early to early experimental F_1 hybrids derived from these cms lines appear promising and will be evaluated in 1984 trials. Other nearly stable cms lines with broader disease and insect resistance and early (110 d), medium (120 d), and late maturity (130-135 d) are in BC_4-BC_6 generations and should be available next year.

Identification of additional sources of cytoplasmic male sterility. Oryza glaberrima (Acc. 102726) cytoplasm reported last year to give high pollen sterility in successive backcrosses with IR36 continued to show similar behavior. Some partial male sterile plants continued to occur even up to BC_7 generation. Meiotic behavior of chromosomes in the partial male sterile (pollen fertility 10-30%) and highly male sterile plants (pollen fertility 0-10%) was normal. The mechanism of male sterility in this interspecific cross needs further study.

Other crosses also indicated cytoplasmic-genetic interaction for male sterility. They include UPRB 31/Iri 346, UPRB 31/Suweon 299, ARC13829-26/IR10179-2-3-1, Suweon 290/N 22, Lead/CR179-1-717, *Oryza perennis* (Acc. 102178)/IR54, *O. perennis* (Acc. 102178)/Suweon 290, *O. sativa* f. *spontanea* (Acc. 102172)/IR36, *O. sativa* f. *spontanea* (Acc. 102172)/IR54, Khao Lo/IR42, Khao Lo/IR52, Khao Lo/IR54, Khao Lo/IR56, and Khao Lo/IR11248-242-3-2. Backcrossing with male parents of these crosses is being continued to see if new stable cms lines can be developed.

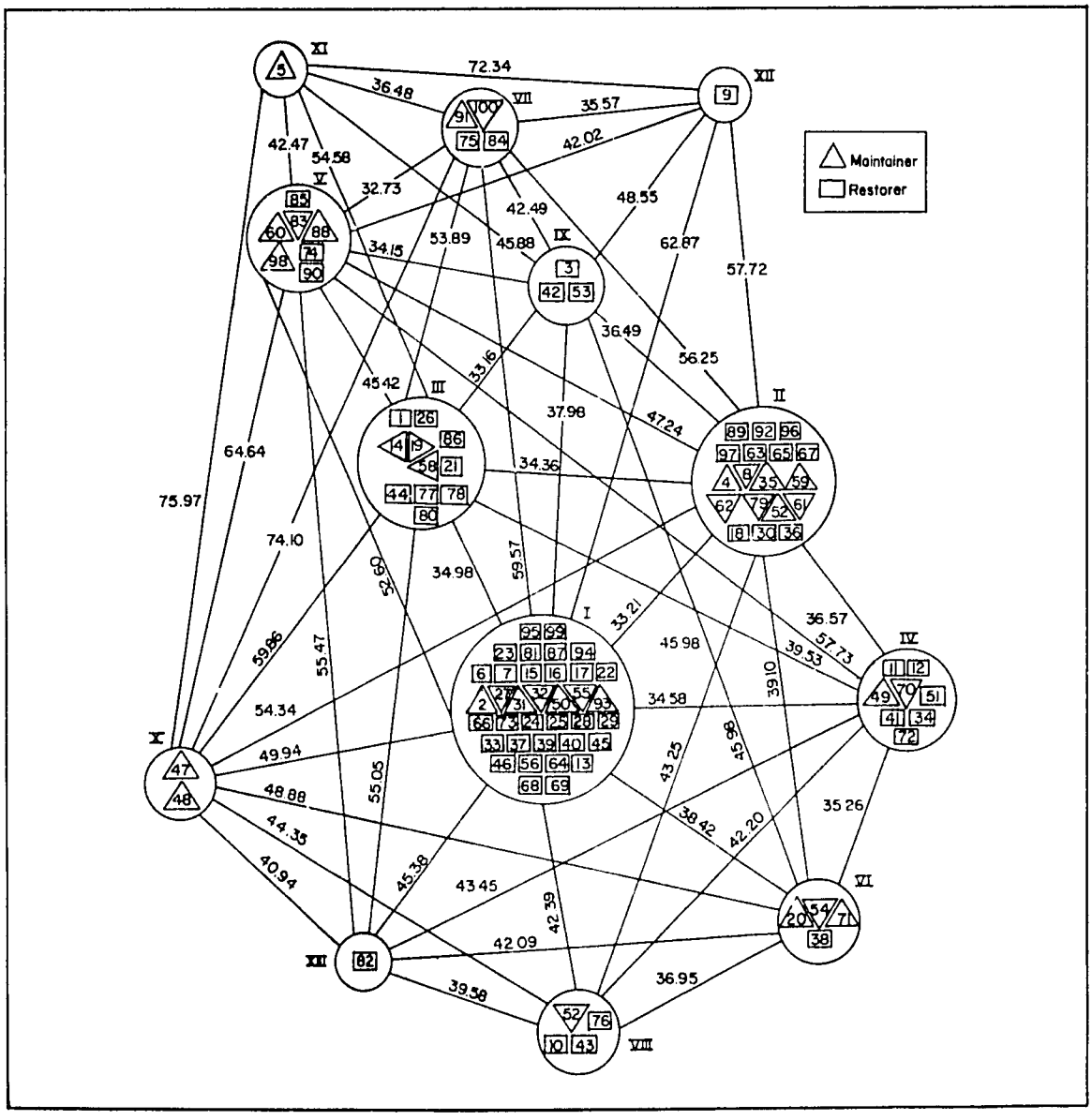
Table 13. Agronomic and floral traits of 7 stable cms lines developed at IRRI. 1983.

Line	Pedigree	Growth duration (d)	Height (cm)	Tillers (no./hill)	Days to heading		Reaction to								Floret angle (°)	Duration of flower opening (min)	Stigma exsertion (%)
							Diseases				Insects						
											BPH			GLH			
					83 DS	83 WS	BL	BLB	GSV	RTV	1	2	3				
IR4682A	97A/7*IR10154-23-3-3	95	77.0	31	70	65	-	-	-	-	-	-	-	-	34	122	18
IR46826B	IR10154-23-3-3	91	74.0	19	67	65	-	5	31	90	3	9	3	9	32	72	15
IR46827A	97A/6*IR10176-24-6-2	95	73.0	35	65	61	-	-	-	-	-	-	-	-	31	95	12
IR46827B	IR10176-24-6-2	90	71.0	20	62	60	0	1	73	59	-	-	-	5	32	73	17
IR46828A	97A/6*IR10179-2-3-1	95	76.0	29	68	59	-	-	-	-	-	-	-	-	35	158	36
IR46828B	IR10179-2-3-1	92	83.0	18	68	59	0	5	67	93	5	9	5	9	34	63	40
IR46829A	V20A/5*IR19792-15-2-3-3	95	81.0	29	74	66	-	-	-	-	-	-	-	-	36	110	6
IR46829B	IR19792-15-2-3-3	92	86.0	19	74	63	1	5	35	88	-	-	-	-	32	70	19
IR46830A	V20A/5*IR19807-21-2-2	95	71.0	34	68	65	-	-	-	-	-	-	-	-	33	150	15
IR46830B	IR19807-21-2-2	92	70.0	23	71	66	4	1	8	58	3	9	3	5	33	76	27
IR46831A	V20A/5*Jikkoku Seranai	95	75.0	22	76	73	-	-	-	-	-	-	-	-	36	115	5
IR46831B	Jikkoku Seranai	92	83.0	20	73	72	6	-	14	96	-	-	-	-	36	54	6
IR48483A	97A/6*MR 365	95	97.0	21	72	61	-	-	-	-	-	-	-	-	26	-	19
IR48483B	MR 365	92	98.0	15	72	61	7	-	26	96	-	-	-	-	22	-	20
Zhen Shan 97A	(introduction	95	56.0	22	76	60	-	-	-	-	-	-	-	-	-	-	-
Zhen Shan 97B	from China)	95	99.0	15	76	61	4	-	-	-	9	9	9	9	-	-	-

Genetic divergence among selected maintainer and restorer lines. Sixty-seven restorer and 33 maintainer lines were evaluated in replicated trials for 9 agronomic traits: plant height at 40 DT, plant height at maturity, days to maturity, tillers per plant, panicles per plant, spikelets per panicle, fertile spikelets per panicle, 1,000-grain weight, and yield per m^2. By using Mahalanobis D^2 and canonical analysis with those traits, the magnitude of genetic diversity among selected lines was ascertained. Then the 100 genotypes were grouped into 13 clusters (I to XIII), 3 of which had 1 variety each (Fig. 7). The key to the variety or line number 1-100 in the various clusters is in Table 14. The most divergent clusters were IV, VI, VIII, X, and XIII from cluster VII; and clusters XI and XII from I, IV, VI, VIII, X, and XIII. The least divergent clusters were VII and IX from V and II, III, and IV from cluster I. Yield, tillers per plant, days to maturity, and 1,000-grain weight contributed most to divergence among varieties. Crosses made between varieties belonging to different clusters usually show more F_1 heterosis than those between varieties belonging to the same cluster. Similarly, F_1 hybrids from parents belonging to more divergent clusters show higher heterosis than those developed from parents belonging to less divergent clusters. Follow-up experiments on heterosis using parents with different genetic diversities will test these theories. If confirmed, this analysis will be used to select appropriate parents among available cms and restorer lines developed and/or identified in the hybrid breeding program.

The study showed no relationship between geographic distribution and genetic diversity. IRRI's elite maintainer and restorer lines contain enough genetic diversity. It should be possible to develop heterotic F_1 rice hybrids for the tropics using parental lines bred at IRRI.

Seed production (*Plant Breeding*). IRRI continued using techniques developed in China to multiply seeds of cms and maintainer lines. Hybrid seeds of some experimental rice hybrids were also produced in small plots ranging from 10 to 60 m^2. During DS 20-43% natural outcrossing observed on cms lines resulted in a seed yield of 0.16 to 1.6 t/ha. During WS, natural outcrossing varied from 4 to 23% and seed yield ranged from 0.007 to 0.6



7. Classification of 100 maintainers and restorers of rice by D^2-statistic. IRRI, 1983. Distance (not shown) in figure: IV from VII, IX, and X is 63.68, 41.33, and 49.75. VI from III, V, VII, XI, and XII is 44.80, 58.13, 69.14, 69.28, and 70.65. VIII from III, V, VII, IX, XI, and XII is 51.05, 59.67, 69.70, 58.78, 73.52, and 72.30. IX from X and XIII is 62.40 and 60.32. XI from I, II, IV, and XIII is 64.53, 59.90, 69.22, and 74.27. XII from III, IV, X, and XIII is 56.26, 66.56, 74.58, and 73.70. XIII from II and VII is 51.27 and 70.82.

t/ha. Seed yield appeared to depend on season, synchronization of flowering in male and female parent, and agronomic and floral traits of parental lines.

Economics of hybrid rice production in China (*Agricultural Economics*). Adoption of hybrid rice technology depends on its economics. China is the only country in the world where hybrid rice is commercially grown. A collaborative project between the IRRI Economics Department and the Institute of Agricultural Economics of the Chinese Academy of Agricultural Sciences (CAAS) was undertaken to look at the economics of hybrid rice and hybrid seed production in China. Production data for 1982 were obtained through interviews with farmers in Fujian and Hunan Provinces.

Hybrid rice production. The average yield of the sample hybrid rice farmers was 8.4 t/ha in Fujian

Table 14. Maintainer (M) and restorer (R) lines studied for genetic divergence. IRRI, 1983.

Variety no.	Designation
1	B441b-126-3-2-1 R
2	BG379 M
3	BPI-RI-4 R
4	IET 3257 M
5	IR10154-23-3-3 M
6	IR10781-143-2-3 R
7	IR11248-148-3-2-3-3 R
8	IR11248-242-3-2 M
9	IR11297-49-1-3 R
10	IR13146-243-2-3 R
11	IR13149-9-3-2-2 R
12	IR13149-23-2 R
13	IR13149-71-3-2-3 R
14	IR13240-6-3-MR-8 M
15	IR13240-108-2-2-3 R
16	IR13292-5-3-1 R
17	IR13419-113-1 R
18	IR13429-150-3-2-1-2 R
19	IR13429-196-1 M
20	IR13458-52-1-1-3 M
21	IR13524-21-2-3-3-2-2 R
22	IR13525-2-3-3-2-1 R
23	IR13538-6-2-2-3-2 R
24	IR13539-41-2-2-2-3-2 R
25	IR15314-43-2-3-3 R
26	IR15324-12-2-3-3-2 R
27	IR15429-268-1-2-1 M
28	IR15795-232-3-3-3-2 R
29	IR15797-74-1-3-2 R
30	IR15847-215-2-1 R
31	IR17429-18-10-2-2-2 M
32	IR17492-18-10-2-2-2 M
33	IR17494-32-2 R
34	IR17521-2-7-2-2-2-2 R
35	IR17525-278-1-1-2 M
36	IR18342-4-3 R
37	IR18349-22-1-2 R
38	IR18349-65-1-3 R
39	IR18599-68-1 R
40	IR19058-107-1 R
41	IR19083-22-2-2 R
42	IR19090-224-3-2 R
43	IR19431-72-2 R
44	IR19575-85-2-2-3 R
45	IR19577-80-3-1 R
46	IR19588-166-3-1 R
47	IR19657-34-2-2-3-3 M
48	IR19657-87-3-3 M
49	IR19657-90-3-3-2 M
50	IR19660-109-3-2-3-2 M
51	IR19660-187-2-2-3-2 R
52	IR19661-3-2-2-3-1 M
53	IR19661-63-1-2-3 R
54	IR19661-150-1-2-3-2 M
55	IR19672-140-2-3-2 M
56	IR19672-195-2-2 R
57	IR19722-9-1-3-2-1 M
58	IR19746-27-3-3-1-3 M
59	IR19792-15-2-3-3 M
60	IR19799-17-3-1-1 M
61	IR19805-12-1-3-1-2 M

Table 14 continued

Variety no.	Designation
62	IR19819-31-2-3-1-1 M
63	IR20985-93-5-2 R
64	IR2015-180-3-3 R
65	IR2035-182-3-2 R
66	IR21178-26-1 R
67	IR21526-4-3-3 R
68	IR21734-70-3-2 R
69	IR21734-88-3-1 R
70	IR21845-90-3 M
71	IR21845-90-3-1 M
72	IR21912-9-2 R
73	IR2307-247-2-2-3 R
74	IR24 R
75	IR26 R
76	IR2797-105-2-2-3 R
77	IR2863-39-2-8 R
78	IR32 M
79	IR34 R
80	IR36 R
81	IR42 R
82	IR46 R
83	IR4763-73-1-11 M
84	IR50 R
85	IR52 R
86	IR54 R
87	IR56 R
88	IR747B2-6-3-1 M
89	IR7963-30-4-3 R
90	IR8073-43-3-2 R
91	IR9215-69-1-2 M
92	IR9217-6-2-2-2-3 R
93	IR9708-51-1-2 M
94	IR9761-19-1 R
95	IR9761-45-1-3 R
96	IR9802-50-1-2-2 R
97	IR9828-41-2-1 R
98	Jikkoku Seranai M
99	Milyang 46 R
100	MR365 M

and 7.0 t/ha in Hunan (Table 15). Average net returns for hybrid rice production in Fujian ranged from $231 to $1,506/ha depending upon prices of paddy and straw, and $98 to $1,203/ha for Hunan. Comparison between the average net returns of hybrid and conventional rice growers in Fujian showed that profitability depends largely on the price of paddy (Table 16). At quota prices, average net returns of hybrid and conventional rice growers were about equal. The economic advantage (average net return) of hybrid rice showed clearly only at above quota prices. When profitability is viewed as return from labor, hybrid rice growers had a slight edge over conventional rice growers at all price levels. When profitability is viewed as return per

Table 15. Av yield of sample farmers in Fujian and Hunan, China, 1982.

Category	Fujian		Hunan	
	Sample size	Av yield (t/ha)	Sample size	Av yield (t/ha)
Conventional rice[a]	6	7.2	6	5.8
Hybrid rice[a]	6	8.4	6	7.0
Male sterile seed	2	0.6	4	1.2
Hybrid seed	4	2.0	4	1.4

[a]Late season crop only.

unit cost, conventional growers showed more favorable returns at all price levels. Nonlabor input cost as a proportion of total revenue was higher for hybrid rice growers. Farmers with cash constraints might be less inclined to adopt hybrid rice technology.

Hybrid seed production. Table 17 gives the average net return of male sterile seed production of sample farmers in Fujian and Hunan. Except for Fujian male sterile seed producers, other groups of seed producers in both provinces had profits more than 50% higher than those of hybrid rice growers. If the provincial average yield instead of the sample average was used, the seed:paddy exchange rate could be lowered from the present 1:10 to 1:6 for male sterile seed and 1:7 for hybrid seed in Hunan. This would still allow seed producers to earn 30% higher profits than hybrid rice growers.

RAPID GENERATION ADVANCE

Plant Physiology Department

The rapid generation advance (RGA) facilities at IRRI continued to serve plant breeders by advancing their breeding lines and screening for some traits saving them 1-3 yr of work.

Number of populations planted. A total of 333 populations representing F_2, F_3, and F_4 of 230 crosses were grown in RGA. Of these, 136 were photoperiod-sensitive, deepwater/rainfed lowland crosses and 94 were low-temperature crosses. An average of 28 populations (about 36,000 plants) were grown monthly for an annual total of 441,000 plants.

Forty-five more populations were planted in 1983 than in 1982, but the number of plants was less because of the small amount of F_2 seeds provided by RGA cooperators.

Screening or selection. Some screening was done to obtain advanced materials selected for particular traits.

During DS, 65 F_3 and F_4 crosses were screened for submergence tolerance at the seedling stage. Surviving plants were transplanted in the field. Individual plant selections were made for 27 crosses which did not lodge and were resistant to field pests and diseases. Selections will be grown by pedigree method during 1984 WS.

Fourteen F_3 and F_4 deepwater crosses were screened for ratooning ability during the DS. Five crosses had excellent ratoon rating: CN646 (NC214/Mahsuri), CN667 (NC128/Pankaj), CN657 (CNL231-B-B/Pankaj), CN581 (Jaladhi 2/CR1005), and CN665 (Pankalash/OC1383).

Because of limited facilities and their heavy use, only 9 F_4 crosses were screened for low temperature tolerance at seedling stage.

Long grain progenies were selected from 10 RGA crosses for low temperature areas in Burma: Yn 213 (Mahsuri/Kulu), Yn 262 (Pelita-1/Kulu//

Table 16. Profitability[a] of production of hybrid rice (HR) and conventional rice (CR) farmers at different prices. Fujian sample, late rice crop, 1982.

Paddy price ($/kg)	Net returns ($/ha)		Returns to labor ($/labor d)		Total benefit-cost ratio	
	HR	CR	HR	CR	HR	CR
0.116	364	349	2.70	2.44	1.49	1.58
0.172	829	750	4.75	4.01	2.12	2.24
0.202	1083	968	5.86	4.87	2.46	2.61
0.253	1506	1332	7.73	6.29	3.03	3.21
0.116/0.172[b]	596	549	3.72	3.23	1.80	1.91

[a]Straw value of $0.02/kg was included in the computation of benefits. Wage rate used was $1.01/d for ordinary operations and $1.26/d for plowing/harrowing, transplanting, and harvesting. [b]Assumed that 50% of output was priced at $0.116/kg and the remaining 50% at $0.172/kg.

Genetic evaluation and utilization (GEU) program

Computerized data management

Statistics and Plant Breeding Departments, International Rice Germplasm Center, and International Rice Testing Program

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RICE GENETIC ANCESTRY SYSTEM **134**
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GERMPLASM BANK

Statistics Department and International Rice Germplasm Center

By the end of 1983, the germplasm computer data bank contained 2,065,143 records. These represent all existing information on the 45 basic morphoagronomic characters (Table 1) and 35 GEU traits of 59,342 accessions (Table 2). An average of 3,628 new accessions have been added to the bank each year since 1976 (Fig. 1). Eighty percent are of indica type, 9% japonica, 7% javanica, and 4% hybrid. There is a large variation among accessions in morphoagronomic traits (Fig. 2) and GEU traits (Fig. 3).

To facilitate smooth, rapid information flow from individual GEU scientists to the germplasm bank,

- an *update rule* for GEU traits was standardized (Table 2),
- an operations manual was prepared, and
- computer-generated data sheets were provided for scientists' use in recording screening results for various GEU traits. More than 90 sets of data sheets were used in 1983.

Activities on the seed inventory system (SIS) and the germplasm bank information retrieval system (GBIRET) were accelerated in 1983 by the installation of the IBM 4331 system, IRRI's first in-house large-scale computer. More than 100 GBIRET runs were made in response to requests from GEU scientists at IRRI and from national programs. The compilation of a clearly defined evaluation system for each GEU trait has also improved interpretation of the information retrieved by the users. By the end of 1983, the SIS master file contained information on 7,714 accessions of *O. sativa*. Two-hundred-fifteen new accessions of wild species of *Oryza* were added to the wild species master file during the year.

RICE GENETIC ANCESTRY SYSTEM

Statistics and Plant Breeding Departments

The rice genetic ancestry system maintains records on the parentage of all crosses made at IRRI and in national breeding programs. At the end of 1983, the files contained data from 46,831 IR crosses and 35,900 crosses from 10 countries (Table 3).

With the constant increase in file size and

Table 1. The 45 basic morphoagronomic characteristics and the number of accessions in the germplasm computer data bank described for each character, 31 Dec 1983.

Character	Accessions (no.)	Character	Accessions (no.)
Variety group	43,298	Secondary branching	12,105
Seedling height	43,357	Panicle exsertion	43,247
Leaf length	43,214	Panicle axis	12,038
Leaf width	43,221	Panicle shattering	11,660
Blade pubescence	43,369	Panicle threshability	42,836
Blade color	43,364	Awning	43,296
Basal leaf sheath color	43,345	Awn color	8,064
Leaf angle	12,095	Apiculus color	43,294
Flag leaf angle	43,144	Stigma color	43,234
Ligule length	43,190	Lemma and palea color	42,858
Ligule color	43,364	Lemma and palea pubescence	11,642
Ligule shape	12,102	Sterile lemma color	33,771
Collar color	43,363	Sterile lemma length	42,249
Auricle color	43,352	Spikelet sterility	42,818
Seeding to 50% headed	11,967	100-grain weight	42,607
Culm length	43,190	Grain length	42,258
Culm number	43,199	Grain width	42,258
Culm angle	43,291	Seedcoat color	42,239
Culm diameter	43,155	Endosperm type	42,239
Internode color	43,251	Scent	6,857
Culm strength	43,113	Leaf senescence	42,780
Panicle length	42,175	Maturity	43,132
Panicle type	43,138		

Table 17. Comparison of av net return of seed and hybrid rice production, Fujian and Hunan, 1982.

Category	Net return ($/ha)	Return from labor ($/labor d)
Fujian		
Male sterile seed producers	794	3.02
Hybrid seed producers	4515	12.66
Hybrid rice farmers[a]	596	3.72
Hunan		
Male sterile seed producers	2120	5.86
Hybrid seed producers	3194	10.84
Hybrid rice farmers[a]	439	2.91

[a]Assume 50% of output priced at $0.116/kg and the remaining 50% at $0.172/kg.

Kulu), Yn 265 (IR34/Kulu//Kulu), Yn 274 (Weiyou 2/C22), Yn 279 (Weiyou 3/X72-7-8), Yn 294 (Kulu/IR2053-43-4-1-2-3), Yn 296 (Kulu/C22), Yn 320 (Seintalay/Kulu), Yn 321, and Yn 322 (BR51-91-6/Kulu).

Seeds from cooperators. In 1983, 8 cooperators sent in 183 crosses, mostly F_2 materials: 120 were from IRRI, 40 from Thailand, 13 from India, and 10 from Vietnam. IRRI crosses included those specifically requested by national breeders.

RGA materials included in the nurseries. The progress of RGA, which began 5 yr ago, is shown by the increase of RGA entries in the pedigree and screening nurseries. IRCTN had these entries in 1983: IR20654-R-R-R-15-3 (IR9129-192-2-3/IR10183-7), IR22623-R-R-4-3 (Paro Local/IR36), IR24312-R-R-19-3-B (Paro Local/IR5868-112-1-2//IR26), TK5331-R-R-R-R-28-3, and IR22623-R-R-4-2 (Paro Local/IR36).

IRDWON had two RGA entries: IR23426-R-R-35-1E-P1 and IR7732-RGA-B-496-1.

RGA materials sent to cooperators. Fourteen seed requests, representing 427 crosses were processed and sent to cooperators for testing and selection at different sites. Of those, 47% were materials for low temperature, 15% for deepwater, and 38% for rainfed lowland areas.

Table 2. The 35 GEU traits and the total number of accessions in the germplasm computer data bank screened[a] for each trait, as of 31 Dec 1983.

GEU trait	Accessions (no.)	GEU trait	Accessions (no.)
BLB[c]	39,582	Amylose[b]	17,669
BI[c]	20,494	Gelatinization temperature[b]	14,854
ShB[c]	22,829	Drought[d]	
RTV[d]	8,897	Seedling vigor	14,718
GSV[d]	7,468	Rate of recovery	
RSV[d]	1,788	After 1st stress	7,666
BPH[c]		After 2d stress	7,574
Biotype 1	21,685	Field resistance	
Biotype 2	4,122	Early vegetative	12,882
Biotype 3	5,908	Late vegetative	12,415
GLH[c]	46,668	Reproductive	6,980
SSB[c]	14,539	Field tolerance (3-4 bars)	1,515
YSB[c]	6,862	Field tolerance (9-10 bars)	969
RWM[c]	22,791	Rate of recovery after exposure to 9-10 bars	969
WBPH[c]	41,373	Alkalinity[b]	2,279
LF[b]	7,713	Salinity[b]	7,727
Zigzag leafhopper[c]	2,354	Zn deficiency[b]	553
Brown rice protein[b]		Elongation[b]	1,192
DS crop	17,587	Flood tolerance[b]	7,198
WS crop	13,631	Cold tolerance[b]	3,953

[a]Superscripts [b], [c], and [d] refer to the specific *update rule* (i.e., the value maintained in the GB file when more than one screening is done) used: [b] = value from the latest test, [c] = higher value, [d] = average value over all tests ever made.

number of data sources, maintaining uniformity of parentage names has become a major problem. A *warning system* was developed in which all "new parents" (those coming into the system for the first time) are automatically flagged and thoroughly checked against their original sources.

In 1983 WS, rules were drafted to designate materials developed from the hybrid rice programs.

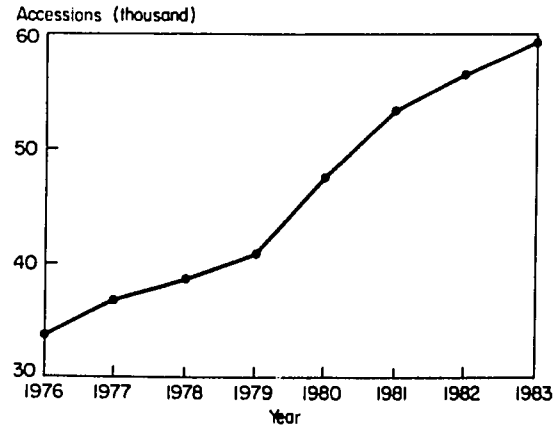
- An IR cross number with a proper suffix will be given to a breeding line (or variety) sterilized through backcrossing using one of the sources of cytoplasmic male sterility (such as Zhen Shan 97A). The suffix "A" designates the cytosterile line (eg, IR46826A) and suffix "B" designates its counterpart.
- The letter "R," placed at the end of the line name, designates a stable and purified breeding line (or variety) with capacity to restore the fertility of the male sterile line (eg, IR9761-19-1R).
- The suffix "H," added to the IR cross number, designates an elite hybrid combination involving cms lines and restorer lines. An F_1 combination, such as IR50201A/IR541R, which is promising, may be designated as IR5515OH.

All alpha suffixes previously used with IR cross numbers were eliminated. All affected entries in the history-of-cross files were modified.

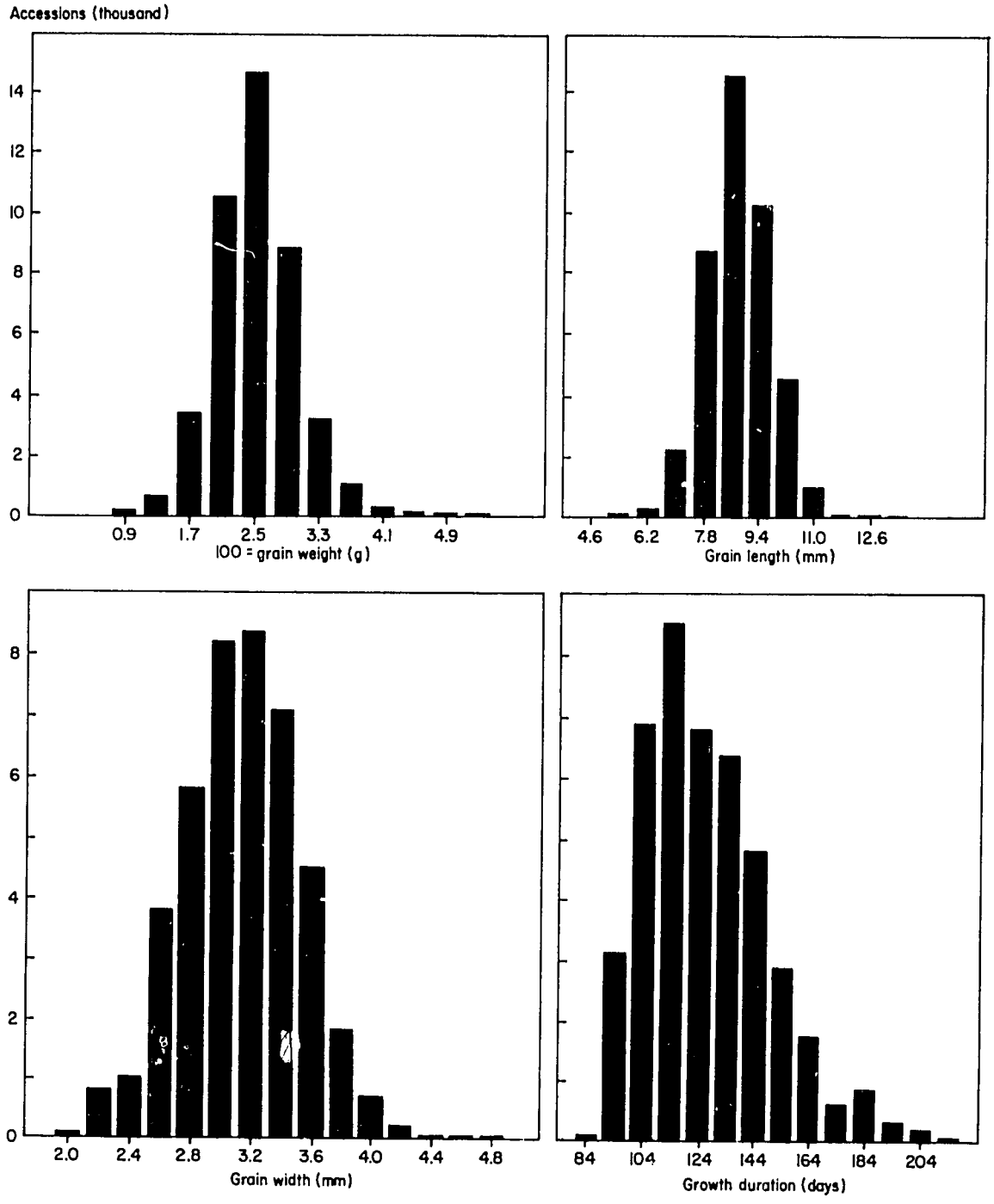
EVALUATION OF BREEDING LINES

Statistics and Plant Breeding Departments

The breeding line evaluation system inventories all selected lines tested in various generations at IRRI.



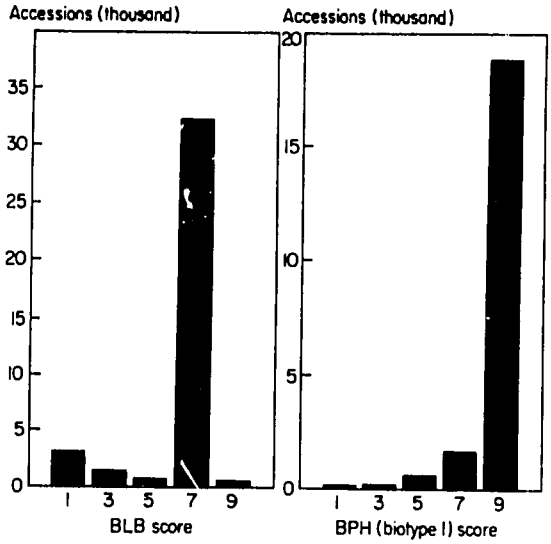
1. Total number of accessions in the germplasm computer data bank, by year, 1976-83.



2. Frequency distributions of 4 morphoagronomic characters (grain weight, grain length, grain width, and growth duration) of 42,258 to 43,132 accessions in the germplasm computer data bank, 31 Dec 1983.

It covers the F_1 hybrids, F_2 nursery, pedigree nursery, hybridization block, observational yield trial, replicated yield trial, and elite lines. Except for the pedigree nursery, which is tested monthly, the rest of the trials are conducted twice a year — in DS and WS.

In 1980, when the pedigree nursery was first computerized, only irrigated pedigree nurseries



3. Frequency distributions of resistance levels to BLB and to BPH (biotype I) of accessions in the germplasm computer data bank, as of 31 Dec 1983. Total accessions were 39,582 (BLB) and 21,685 (BPH).

were covered. Now, all 12 monthly pedigree nurseries (irrigated, rainfed, and deepwater) are computerized. This facilitates composition of the nurseries with materials coming from a large number of sources.

In 1983, standardization of the file format and scoring system for various traits was emphasized in all data files in the GEU system. This facilitates cross-reference and search for desired information from all files. An appropriate *validation rule* was devised and implemented for each GEU trait. For example, only data lying within the permissible range of scores or values are accepted by the system.

Table 3. Crosses from national breeding programs of 10 countries with information on their parentage stored in the rice ancestry master file, 1983.

Country	Crosses (no.)
Bangladesh	2,517
Brazil	176
Dominican Republic	283
India	9,774
Indonesia	4,591
Korea	8,304
Pakistan	486
Sri Lanka	879
Thailand	6,538
USA	2,352
Total	35,900

Alpha designation use in IRRI breeding lines has been standardized:

- "B" designates bulk generation: IR11288-B-B-118-1 signifies that F_3 and F_4 populations of the cross IR11288 were grown in bulk.
- "R" designates RGA generation: IR40000-R-R-R-110-3 indicates that F_3, F_4, and F_5 populations of the cross IR40000 were grown in RGA and plant selections were made in F_5.
- "C*i*", where *i* is numeric, designates composite population of the *i*th cycle: IR41235-C3-11 refers to plant selection number 11 selected from the third cycle of a composite population of the cross IR41235.
- "AC" designates true breeding materials obtained from anther culture: IR42002-AC-1

Table 4. International Rice Testing Program computerized nurseries, 1983.

Nursery name	Acronym	Years for which data are in computer files	
		No.	Period
International Rice Yield Nursery-Early	IRYN-E	8	1976-83
International Rice Yield Nursery-Medium	IRYN-M	8	1976-83
International Rice Yield Nursery-Late	IRYN-L	4	1977-80
International Upland Rice Yield Nursery	IURYN	7	1976-81, 1983
International Rice Observational Nursery	IRON	8	1976-83
International Upland Rice Observational Nursery	IURON	8	1976-83
International Rainfed Lowland Rice Observational Nursery	IRLRON	6	1978-83
International Rice Cold Tolerance Nursery	IRCTN	6	1978-83
International Rice Blast Nursery	IRBN	8	1976-83
International Rice Tungro Nursery	IRTN	8	1976-83
International Rice Sheath Blight Nursery	IRSHBN	2	1976-77
International Rice Stem Borer Nursery	IRSBN	2	1976-77
International Rice Gall Midge Nursery	IRGMN	6	1976-80, 1982
International Rice Brown Planthopper Nursery	IRBPHN	8	1976-83
International Rice Yield Nursery-Very Early	IRYNVE	4	1980-83
International Rainfed Lowland Rice Yield Nursery	IRLRYN	3	1981-83

refers to the first line selected through anther culture from the cross IR42002.

INTERNATIONAL RICE TESTING PROGRAM

Statistics Department and International Rice Testing Program

The IRTP computerized system was revised to accommodate the processing of the International Rice Yield Nursery-Very Early and the International Rainfed Lowland Rice Yield Nursery. Now 16 nurseries have data for 1976 to 1983 crop years stored in the computer files (Table 4).

The IRTP master entry file has 9,068 entries, 7,567 of which have been tested in at least one of the IRTP nurseries.

Genetic evaluation and utilization (GEU) program

International Rice Testing Program

International Rice Testing Program

1982 NURSERY RESULTS **140**
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1982 NURSERY RESULTS

The IRTP composed 30 types of nurseries in 1982 (Table 1) and dispatched them to 50 countries in the international network. Of 2,630 entries, 1,578 were nominated from national programs and 1,052 from IRRI. Results were received from about 300 test locations and data were analyzed and published as individual nursery reports.

Yield nurseries. Promising entries in the yield nurseries for irrigated conditions (IRYN-VE, IRYN-E, IRYN-M) and for rainfed lowland (IRLRYN) are presented in Tables 2-5. Yield data and days to flowering of the best performing entries in these nurseries were evaluated and analyzed by site, region, and worldwide performance. Relevant data on climatic factors such as rainfall, atmospheric temperature, and solar radiation during the cropping season were also determined and reported. Participating scientists can readily analyze the adaptability range of tested varieties and determine those highly suited for their countries.

Table 1. Nursery sets distributed in 1982.

Yield nurseries	
Irrigated	• International Rice Yield Nursery-Very Early (IRYN-VE) • International Rice Yield Nursery-Early (IRYN-E) • International Rice Yield Nursery-Medium (IRYN-M)
Rainfed	• International Rainfed Lowland Rice Yield Nursery (IRLRYN)
Observational nurseries	
Irrigated	• International Rice Observational Nursery (IRON)
Rainfed	• International Upland Rice Observational Nursery (IURON) • International Rainfed Lowland Rice Observational Nursery (IRLRON-E; IRLRON-L) • International Rice Deepwater Observational Nursery (Screening Subset I – Flood Tolerance) • International Rice Deepwater Observational Nursery (Screening Subset II – Deepwater) • International Rice Deepwater Observational Nursery (Screening Subset III – Floating Rice) • International Rice Deepwater Observational Nursery (Screening Subset IV – Tidal Swamp)
Nurseries for specific stresses	
Temperature	• International Rice Cold Tolerance Nursery (IRCTN)
Soil	• International Rice Salinity & Alkalinity Observational Nursery (IRSATON) • Iron Toxicity Screening Set • Acid Sulfate Screening Set • Peat Soils Screening Set • Acid Upland Soils Screening Set
Diseases	• International Rice Blast Nursery (IRBN) • International Rice Bacterial Blight Nursery (IRBBN) • International Rice Tungro Nursery (IRTN) • Ragged Stunt Screening Set • Cercospora Screening Set • Sheath Rot Screening Set • Brown Spot Screening Set
Insects	• International Rice Brown Planthopper Nursery (IRBPHN) • International Rice Gall Midge Nursery (IRGMN) • Leaffolder Screening Set • Yellow Stem Borer Screening Set • Rice Thrips Screening Set
Specific environment	• Arid Regions Screening Set

Table 2. Best performing entries in the second IRYN-VE, 1982, based on overall and regional mean yield.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall (41)	IR50	IRRI	84	4.8
	IR9729-67-3	IRRI	77	4.7
	UPR103-80-1-2	India	81	4.5
	BG367-7	Sri Lanka	80	4.5
	IR19743-25-2-2-3-1	IRRI	79	4.5
	BG276-5	Sri Lanka	82	4.5
	IR15429-268-1-2-1	IRRI	77	4.5
East Asia (4)	IR50	IRRI	100	6.1
	UPR103-80-1-2	India	97	5.9
	IR9729-67-3	IRRI	95	5.6
	TKM9	India	97	5.5
	IR9752-71-3-2	IRRI	92	5.5
Southeast Asia (10)	IR50	IRRI	78	4.4
	IR9729-67-3	IRRI	73	4.3
	IR19743-25-2-2-3-1	IRRI	76	4.1
	TKM9	India	75	3.9
	IR15429-268-1-2-1	IRRI	73	3.9
South Asia (15)	IR50	IRRI	81	4.5
	TKM9	India	80	4.4
	UPR103-80-1-2	India	78	4.3
	BG276-5	Sri Lanka	78	4.3
	IR9729-67-3	IRRI	74	4.3
W. Asia and N. Africa (1)	DR92	India	101	9.7
	IR19735-5-2-3-2-1	IRRI	100	9.7
	OR63-252	India	114	9.2
	IR50	IRRI	101	9.0
Sub-Sahara Africa (7)	HPU 741	India	77	5.0
	IR19743-25-2-2-3-1	IRRI	82	4.7
	IR9752-71-3-2	IRRI	81	4.7
	BG367-7	Sri Lanka	82	4.6
Latin America (4)	UPR103-80-1-2	India	82	6.3
	Kaohsiung sen yu 252	Taiwan	94	6.2
	BG367-7	Sri Lanka	79	5.8
	HPU741	India	76	5.8

[a]Figures in parentheses are number of trials.

Observational nurseries. Outstanding entries in the observational nurseries (IRON, IURON, IRLRON, and IRDWON-I, II, III, and IV) were determined by phenotypic acceptability ratings (Table 6). Many entries were either resistant or tolerant to one or more important stresses at trial locations. There were 350 entries in the IRON, 185 in the IURON, 120 in the IRLRON, and 197 in the IRDWON-I to IV.

Specific stress nurseries. The best entries were selected for resistance to individual stresses: diseases, insects, low temperature, and problem soils (Table 7, 8).

1983 NURSERY DISTRIBUTION

A total of 1,195 sets of 23 types of nurseries were composed and distributed in 1983 to 62 countries belonging to the IRTP network (Table 9). Test entries (Table 10) were composed into 12 nurseries for rice cultural types and 11 for specific stress tolerance. Overall for 1983, a total of 2,578 entries were distributed to rice scientists around the world.

In Latin America, 77 sets of 12 types were distributed to national programs for evaluation. There were 5 yield nurseries, 6 observational, and 8 for low temperature screening. Of 242 nurseries

Table 3. Best performing entries in the ninth IRYN-E, 1982, based on overall and regional mean yield.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall (38)	IR21015-80-3-3-1-2	IRRI	93	4.8
	IR13240-82-2-3-2-3-1	IRRI	93	4.7
	IR9828-91-2-3	IRRI	91	4.6
	IR13429-196-1	IRRI	89	4.6
	IR36	IRRI	90	4.6
East Asia (1)	V41A/IR36 (local check)		108	6.6
	Tainung sen 12	Taiwan	104	6.5
	Taichung sen yu 285	Taiwan	102	6.5
	Chianung sen yu 30	Taiwan	107	6.4
	Chianung sen yu 13	Taiwan	105	6.3
	IR13429-196-1	IRRI	99	6.3
Southeast Asia (12)	IR21015-80-3-3-1-2	IRRI	84	5.0
	IR13240-82-2-3-2-3-1	IRRI	83	4.7
	IR13429-196-1	IRRI	81	4.7
	IR9828-91-2-3	IRRI	82	4.6
	Local check		85	4.5
	IR36	IRRI	81	4.5
South Asia (16)	IR21015-80-3-3-1-2	IRRI	93	4.4
	UPR254-24-1	India	88	4.4
	Tainung sen 12	Taiwan	92	4.2
	UPR238-42-2-3-TCA1	India	89	4.2
West Asia and North Africa (1)	Giza 172 (local check)	Egypt	118	10.1
	CR155-5029-216	India	103	8.0
	IR13429-287-3	IRRI	118	7.8
	UPR82-1-7	India	110	7.8
	IR36	IRRI	123	7.7
	UPR254-24-1	India	122	7.7
	HPU734	India	106	7.7
Sub-Sahara Africa (7)	Chianung sen yu 30	Taiwan	90	5.3
	IR21015-80-3-3-1-2	IRRI	93	5.2
	IR13429-196-1	IRRI	90	5.2
	IR36	IRRI	93	5.1
	IR13240-82-2-3-2-3-1	IRRI	93	5.0
Latin America (1)	UPR307-7-1-1	India	90	5.8
	UPR254-24-1	India	88	5.5
	Chianung sen yu 13	Taiwan	96	5.3
	IR21015-80-3-3-1-2	IRRI	96	5.2
	CR155-5029-216	India	83	5.1

[a]Figures in parentheses are number of trials.

distributed in sub-Sahara Africa, 84 were for the West Africa Rice Development Association (WARDA) in Liberia for testing in the member countries. The remaining 158 sets went to the National Cereals Research Institute (NCRI) and the International Institute of Tropical Agriculture (IITA) in Nigeria and to Cameroon, Kenya, Uganda, Tanzania, Zaire, and Zambia.

Utilization of IRTP nursery entries. National cooperators continue to make good use of IRTP nurseries (Table 11). Other entries are frequently used in further yield testing (Table 12). Outstanding entries in stress screening nurseries are often used as donors in the hybridization program.

MONITORING TOURS AND WORKSHOPS

Monitoring tours and workshops continue to bring together rice scientists in national and international programs. They observe local and IRTP trials and discuss action to solve rice research and production problems. IRRI scientist participation continued to be emphasized to strengthen linkages among national programs and the IRRI GEU program.

Table 4. Best performing entries in the ninth IRYN-M, 1982, based on overall and regional mean yield.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall (32)	IR13540-56-3-2-1	IRRI	103	4.9
	BG400-1	Sri Lanka	111	4.8
	IR19670-263-3-2-2-1	IRRI	106	4.8
	IR54	IRRI	104	4.8
	B2489B-PN-1-76-8	IRRI	110	4.8
	IR22082-41-2	IRRI	99	4.8
Southeast Asia (8)	IR13540-56-3-2-1	IRRI	88	5.8
	IR22082-41-2	IRRI	88	5.7
	IR42	IRRI	101	5.4
	B2489B-PN-1-76-8	Indonesia	100	5.4
	IR54	IRRI	89	5.4
South Asia (16)	IR13540-56-3-2-1	IRRI	117	4.3
	BG400-1	Sri Lanka	122	4.1
	BR51-282-8	Bangladesh	112	4.1
	B2489B-PN-1-76-8	Indonesia	118	4.1
	IR1552 (purple check)	IRRI	114	4.1
Sub-Sahara Africa (7)	BG400-1	Sri Lanka	104	6.4
	RP1125-1526-2-2-3	India	105	6.3
	IR19670-263-3-2-2-1	IRRI	105	6.1
	IR54	IRRI	103	6.0
	IR22082-41-2	IRRI	98	5.7
Latin America (1)	BR51-282-8	Bangladesh	97	7.6
	B2489B-PN-1-76-8	Indonesia	110	7.5
	MR24	Malaysia	104	7.0
	RNR29692	India	98	6.9
	BG400-1	Sri Lanka	105	6.8

[a]Figures in parentheses are number of trials.

Table 5. Best performing entries in the second IRLRYN, 1982.

Region[a]	Designation	Origin	Av days to flowering	Yield (t/ha)
Overall (11)	IR8192-166-2-2-3	IRRI	107	4.1
	BR4	Bangladesh	104	4.0
	IR46	IRRI	96	4.0
	IR14753-49-2	IRRI	101	3.9
	IR14632-2-3	IRRI	100	3.9
	IR13146-45-2-3	IRRI	111	3.9
Southeast Asia (6)	IR46	IRRI	92	4.5
	IR13146-45-2-3	IRRI	104	4.2
	IR8192-166-2-2-3	IRRI	101	4.2
	IR52	IRRI	85	4.2
	IR975-109-2	IRRI	101	4.1
South Asia (4)	BR4	Bangladesh	113	3.6
	IR13358-85-1-3	IRRI	123	3.5
	IR8192-166-2-2-3	IRRI	120	3.5
	IR4819-77-3-2	IRRI	109	3.5
	IR10781-75-3-2	IRRI	109	3.4
	IR14753-49-2	IRRI	111	3.4
Sub-Sahara Africa (1)	BR4	Bangladesh	111	3.4
	IR8192-166-2-2-3	IRRI	94	5.7
	IR46	IRRI	89	5.1
	Mahsuri	Malaysia	90	5.0
	IR13146-45-2-3	IRRI	106	4.9

[a]Figures in parentheses are number of trials.

Table 6. Entries in the 1982 observational nurseries that received best phenotypic acceptability ratings.

Nursery	Variety	
IRON 82	AD9246	M12C-34-3
	IR17525-278-1-1-2	Si-pi 692033
	IR18349-94-2-1-1-3	Si-pi 662106
	IR19349-135-2-3-2-1	UPR79-85
	IR24632-60-3-3-2	UPR231-28-1-2-TCA2
	IR8608-82-1-3-1-3	Tainung sen 12
	IR9852-22-3	
IURON 82	M18	IRAT 101
	Local check	BG35-2
	UPL Ri-7	B2997B-TB-73-4-2-3-3-3-2
	B2997C-TB-60-3-3	ITA 139
	B3016B-TB-260-3-2-1-1-3	TOX502-2-SLR2-LS3-B1
IRRSWON 82	IR46	IR15853-89-7E-P3
	IR13146-45-2	IR10781-75-3-2-2
	IR19083-22-2-2	IR13564-95-1
	IR19256-88-1	IR4829-89-2
	IR21141-24-2	Pelita I-1
		RP1045-25-2-1
IRDWON		
I. Flood tolerance	B981D-SI-35-1	CR149-5010-228
	CN540	IR20880-25-3
	CNM539	Jalaj
II. Deepwater	BKNFR76014-1-9-2	RD19
	BKNFR76014-1-9-3	SPR7282-151-2-1
	HTA7406-110-1-1	SRP7282-2-0-24-1
	TCA180-4	
III. Floating rice	IR11141-6-1-4	HTAFR77043-1
	IR11288-B-B-118-1	HTA7205-11
	SPR7411-7-2-1	HTA7421-8-1
	BR222-B-191-3-2	Leb Mue Nahng 111
IV. Tidal swamp	B2791B-MR-196-2-3-1-3	IR5657-33-2-2-3
	B2791B-MR-196-2-3-3-5	IR8192-166-2-2-3
	B3063B-CK-8-MD-14-2-1	IR9830-26-3-3
	B3063C-PN-151-2	Kajalsail
	Cisadane	Mahsuri
	IR13146-45-2	
	IR4819-77-3-2	

Table 7. Best performing entries in the 1982 regular disease, insect, problem soils, and cold tolerance nurseries.

Screening set	Promising entries	
Diseases		
IRBBN (BI)	CIAT-ICA 5	BG367-7
	IRAT 104	Cheolweon 32
	IR1905-81-3-1	IR15314-53-2-3-3
	IR2793-30-1	IR2793-80-1
	IR3259-8-172-5	ITA 231
	IR5533-PP856-1	P1377-1-15M-4-1M-1
	Tetep	Suweon 300
	Ta-poo-cho-z	16877
	Tres Marias	16879
IRBBN (BB)	Cisadane	
	IR13525-43-2-3-1-3-2	
IRTN (RTV)	ARC11554	Utri Rajapan
	Utri Merah	Nava Bachi
Insects		
IRBPHN (BPH)	PTB33	IR15324-117-2-2-3
	Mudgo	IR15324-12-2-3-3-2
	Babawee	IR199661-23-3-2-2
	Rathu Heenati	

Table 7 continued

Screening set	Promising entries	
IRGMN	RPW6-17	IR13429-287-3
	W1263	IR14632-181-1
	CR94-CRRP51-6288	IR8608-189-2-2-1
	IR9829-41-2-1	IR9828-94-3
Problem soils		
IRSATON (salinity and alkalinity)		
Salinity	A69-1	M152
	IR4422-6-2-3-1	Nonasail
	IR4630-22-2-17	PNL 36-184-3-2
	Pokkali	PNL 5-30
	IR9884-3-3	
	Mahsuri	
Alkalinity	IR8608-139-1-1-3	IR2307-247-2-2-3
	IR13149-3-2-2	Pokkali
	IR2071-105-9-1	Suakoko 8
Acid upland	Azucena	ITA116
	IR3646-8-1-2	Salumpikit
	IR6023-10-1-1	IR9410-80
	BPI Ri-6	IR9671-1-4-6-8
	B733c-167-3-2	
IRCTN (cold tolerance)	Deog Jeog Jodo	Shoa-Nan-Tsan (check)
	IR18476-86-3-3	Khudwani (check)
	IR19126-42-1	Suweon 235 (check)
	RP1848-109-2-1-1	IR9202-5-2-2-2

Table 8. Best performing entries in the 1982 special screening sets for diseases, insects, problem soils, and arid environment.

Screening set	Promising entries	
Diseases		
LSc	BR189-103-2-1-4-1-1	CR1002
	BR189-103-2-1-5-1-1	IR13146-41-3
	BR236-2-1-6-1-1	IR5677-22-5-2
	BR51-282-8	IR5726-31-2
RSV	IR13525-43-2-3-1-3-1	IR19661-364-1-2-3
	IR19661-131-1-3-1-3	IR19660-131-3-3-3-3
Insects		
LF	GEB24	T2005
	PTB33	W1263
	TKM6	
YSB	CO18	IR8608-75-3-1-3
	IR15723-45-3-2-2-2	W1263
	IR19373-44-3-2-2	W1253
	IR36	
Thrips	Dahanala 2220	CO 32
	Dahanala	IR4829-89-2-1
	Kalubalawee	IR8
	CO 29	IAC47
Problem soils		
Acid sulfate	IR2153-26-3-5-6	RPCB-2B-849
	IR4422-428-2-3-3	IR36
	IR46	IR43
	IR50	
Peat soils	IR3397-44-1-4-3	
	IR4422-51-1-1-2	
	IR34	
Fe toxicity	IR4422-480-2-3-3	IR52
	IR4683-54-2-2-3	IR36
Arid region	IR19725-1-2-2	IRAT 118
	CR548-4-2-1	IR19743-46-2-3
	GZ839-5-2-1	IR19746-28-2-2
	DRN9	Giza 172

Table 9. IRTP nurseries[a] dispatched from IRRI in 1983.

Region, country	Nurseries (no.) for different cultural types												Nurseries (no.) for specific stresses											Total
	Yield					Observational																		
	Y_{01}	Y_{02}	Y_{03}	Y_{04}	Y_{05}	O_{01}	O_{02}	O_{03}	O_{04}	O_{05}	O_{06}	O_{07}	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	7	4					9	1	2				6	3	1		7	6		8	1	3	3	61
Japan	1	1											1							1				4
Korea		1					1						3	2			4	1		1	1			14
Taiwan	4						2						1				2			2	1			12
Southeast Asia																								
Burma		1	1					1	1	1			1	1	1	1	2	2		1	1	1		16
Indonesia	3	2	1	2			3	9	2	1	1	2	2	3	4	7	2	1	1	8	4	1		59
Malaysia	2	3	3	1	2		2	2	2	1							1	1	1	1	1	1		24
Philippines	6	5	5	20	10	1	29	13	7	2	1	4	3	3	2	3	9	1	2	2	1	1		130
Thailand	5	5	3	3	10		5	7	7	5	4	2	3	3	5		6	6	3	1	1	3		87
Vietnam	5	4	4	2	1		3	1	2	2	3	1	2	3	1	2		2						38
South Asia																								
Bangladesh	8	6	9		4		10	3	4	2	2	1	2	2			3	3	3	1			1	64
Bhutan	1	1											1											3
India	20	19	14	12	5	1	21	11	7	9	4	4	20	14	5	4	19	13	7	10	8	8	1	236
Nepal	2	2	2	3	3		2	3	3	1			4				4	2		1	2	3	1	38
Pakistan	5	1	1	1	1	1	4	2	1	1			3	3			1			2	2			29
Sri Lanka								1					2	4	2					1		1	1	12
West Asia and North Africa																								
Egypt	2	2				2	2	2					2	2			2							16
Iran		2				2	2										4							10
Iraq						1																		1
Oman	1	1				1																		3
Sudan						1	1	1																3
Turkey	3	2				1								2			1							9
Sub-Sahara Africa																								
Burundi													1											1
Cameroon	4	3	3		1		3	3	2				4	1	1		3							28
Ethiopia	1		1				3	1		1			2											9
Kenya		1	1	1				1					1											5
Thru WARDA (Liberia)	7	6	5	6	2		7	5	12	4	5	2	3	6	3	1	6	4						84
Benin				1					[illegible]															
Ghana	1	1	1	1	1		1	1	[illegible]					1			2							
Guinea	1	1		1										1										
Guinea Bissau														1										
Ivory Coast				1				1																
Mali	1	1	1															1						
Niger																		1						
Senegal	2	1	1				2						1	1	1			1						
Togo			1										1				1							
Liberia	2	2	1	2	1		3	2	10	4	5	1	1	1	1	1	2	1						
Sierra Leone							1	1				1		1	1									
Upper Volta																	1							

Malawi	1	1						1	1				1				1							6
Mauritania	1												1											2
Nigeria -- IITA	3	3	3	2	2		2	3	2				3		3	2	3							31
-- NCRI	2	2	2	1	2		2	1	2	1	1		1		1	1	1							20
Sierra Leone	1		1																					2
South Africa	2												2											4
Tanzania	1	4	1	2				1	5				1	1			1							17
Uganda	2	2	2		1		1		1															9
Upper Volta		1	1	1				1					1											5
Zaire	1	1	1		1		1																	5
Zambia	3	3	2				1	1	1				1				2							14
Latin America																								
Argentina															1			1						2
Brazil	1							2					1				4							8
Chile	2												1											3
Colombia	2	1	1	2			1	3		2			1	1	1	1	1							17
Costa Rica								1																1
Cuba	1	1																						2
Mexico	3	1	2	2	1		1	1	1	1	1	1	1	3			4							23
Peru	1	1	1				2	2		1	1	1	1	1		2	5					1		20
Venezuela																					1			1
Europe																								
Italy													1				1							2
United Kingdom														1										1
Oceania																								
Australia	1	1	1																	1				3
Solomon Islands																								1
Total	115	94	71	61	46	11	120	84	65	35	23	18	84	59	31	24	99	43	17	41	24	23	7	1195

[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 (IURYN), Y_{05} = International Rainfed Rice Shallow Water Yield Nursery (IRRSWYN), O_{01} = International Rice for Arid Regions Observational Nursery (IRARON), O_{02} = International Rice Observational Nursery (IRON), O_{03} = International Upland Rice Observational Nursery (IURON), O_{04} = International Rainfed Rice Shallow Water Observational Nursery (IRRSWON), O_{05} = International Rice Deep Water Observational Nursery (IRDWON), O_{06} = International Floating Rice Observational Nursery (IFRON), O_{07} = 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 Rice Whitebacked Planthopper Nursery (IRWBPHN), N_{10} = International Rice Stem Borer Nursery (IRSBN), N_{11} = Rice Thrips.

Table 10. Origin and types of entries in 1983 IRTP nurseries dispatched from IRRI.

Nursery[a]	Sets dispatched (no.)	Entries[b] (no.)	Entries from: National programs: Improved: No.	Improved: %	Traditional: No.	Traditional: %	IRRI: Improved: No.	Improved: %	Germplasm bank: No.	Germplasm bank: %	Packets (no.)
Yield											
• Irrigated											
IRYN-VE	115	29	13	45	0	0	16	55	0	0	10,005
IRYN-E	94	28	16	57	0	0	12	43	0	0	7,896
IRYN-M	71	29	15	52	0	0	14	48	0	0	6,177
• Rainfed											
IURYN	61	20	10	50	0	0	10	50	0	0	3,660
IRRSWYN	46	23	7	30	0	0	16	70	0	0	3,174
Observational											
• Irrigated											
IRON	120	347	180	52	0	0	167	48	0	0	41,640
IRARON	11	79	47	60	5	6	26	33	1	1	869
• Rainfed											
IURON	84	200	139	70	3	1	52	26	6	3	16,800
IRRSWON	65	144	47	33	3	2	94	65	0	0	9,360
IRDWON	35	49	51	74	0	0	18	26	0	0	2,415
IFRON	23	41	34	83	4	10	3	7	0	0	943
ITPRON	18	66	38	58	6	9	22	33	0	0	1,188
Stress screening											
• Diseases											
IRBN	99	325	192	59	41	13	89	27	3	1	32,175
IRBBN	43	200	100	51	6	3	92	46	0	0	8,600
IRTN	17	196	84	43	10	5	99	50	3	2	3,332
• Insects											
IRBPHN	41	234	102	44	8	3	96	41	28	12	9,594
IRWBPHN	24	115	8	7	16	14	70	61	21	18	2,760
IRSBN	23	91	40	44	0	0	45	49	6	7	6,279
Rice thrips	7	31	7	23	10	32	11	35	3	10	651
• Problem soils											
IRSATON	59	107	33	31	3	3	71	66	0	0	6,313
Acid upland	24	43	16	37	2	5	25	58	0	0	2,064
Acid lowland	31	60	12	20	1	2	47	78	0	0	3,720
• Temperature											
IRCTN	84	101	54	53	3	3	31	31	13	13	8,484
Total	1,195	2,578	1,247	48	121	5	1,126	44	84	3	188,099

[a]See footnote of Table 9 for explanation of acronyms. [b]Local check is not included.

Three monitoring tours/workshops were sponsored during the year:

- Rice Improvement for Adverse Soils
- Rice Disease and Insect Resistance in China
- Fifth Conference on IRTP in Latin America

Rice improvement for adverse soils. In more than 80 million ha of adverse soils in the tropical and subtropical zones of Asia, physiography and hydrology favor rice cultivation. But the crop cannot grow profitably because of an excess or deficiency of mineral elements. Increasing attention is being placed on how to increase yield of present lands having soil stress and how to bring uncultivated areas into production.

The Rice Improvement for Adverse Soils monitoring tour enabled soil scientists and plant breeders to assess current varieties and practices for rice production on adverse soils, particularly

saline and acid sulfate. During visits to Thailand, Bangladesh, and eastern India, IRTP nurseries and INSFFER nutrient management trials were evaluated. The following recommendations were made:

- The IRTP/INSFFER adverse soils nurseries should be expanded and strengthened. More attention should be given to site selection and characterization. The number of sites should be increased to better reflect the range of conditions.
- The screening methodology for adverse soils tolerance should be carefully evaluated and modifications introduced to improve repeatability of results. Trials should be replicated and include more local varieties. Materials should be evaluated at two fertilization levels, depending on site fertility.
- More basic information on chemistry and fertilization of adverse soils is needed. More INSFFER trials are needed in adverse soil environments.
- For best results in adverse soils screening nurseries, a breeder and a soil scientist should work jointly on the research.
- All local rice varieties grown in adverse soils areas should be collected, characterized, and sent for IRTP testing and preservation in the IRGC at IRRI.

Table 11. Utilization of 1983 IRTP nursery entries.[a]

Region, country	Entries (no.) used for			
	Hybridization	Yield testing		
		Local	State	National
East Asia				
China	134	30	–	–
Korea	44	–	–	–
Southeast Asia				
Burma	–	51	–	–
Indonesia	3	42	5	–
Thailand	60	49	–	–
Vietnam	–	10	–	–
South Asia				
India	75	132	26	2
Pakistan	6	33	–	–
West Asia and North America				
Egypt	45	45	–	–
Iran	–	2	–	–
Turkey	2	4	–	–
Sub-Sahara Africa				
Nigeria	27	27	–	–
Kenya	4	–	–	–
Latin America				
Colombia	6	–	–	246[b]
Europe				
Italy	3	–	–	–
Oceania				
Solomon Islands	16	–	–	–

[a]Based on data received as of 6 Feb 1984. [b]International testing in Latin America for 1984.

Table 12. IRTP 1983 entries frequently used in further yield testing in different countries.[a]

BR201-51-1-J8	IR25925-84-3-2
BR51-282-8-HR83	IR28154-101-3-2
B2997c-Tb-60-3-3	IR28210-96-4-3-3
Chianung sen yu 26	IR29692-65-2-3
C894-7	IR50
ECIA 31-104-2-1-7	IR9698-16-3-3-2
Iri 352	KAU1727
IR13240-82-2-3-2-3-1	MRC5720-3427
IR18348-36-3-3	Tainung sen 12
IR22623-R-R-4-2	UPL Ri-5
IR24632-145-2-2-2-3	UPL Ri-7
IR25571-31-1	UPR103-80-1-2
IR25588-7-3-1	UPR231-28-1-2
IR25863-35-3-3	UPR254-35-3-2
IR25924-51-2-3	UPR82-1-7

[a]Based on data received as of 6 Feb 1984.

Monitoring tour in China. A monitoring team visited China 4-13 Oct 1983. Ten scientists from seven countries (including IRRI) participated. They visited the Provincial Agricultural Academies of Guangdong, Hunan, Zhejiang, Jiangsu, and Shanghai, and Zhejiang Agricultural University. The team observed IRTP nurseries and local breeding materials and their reactions to BB and Bl. The Chinese BPH biotype is similar to biotype I in the Philippines and other Southeast and East Asian countries. IRTP nurseries are a good source of germplasm for Chinese scientists who want more entries with shorter growth duration.

Fifth Latin American IRTP conference. The fifth Latin American conference of the IRTP was held at CIAT on 9-14 Aug 1983. Ninety-three rice scientists (including 2 from IRRI, and 1 from IITA) from the national programs of 21 countries participated.

Main topics were the exchange of varietal improvement information, regional IRTP activi-

ties, recent studies on the *Hoja blanca* virus and its vector, upland production systems, and future research problems and needs. The program included a visit to eastern Colombia (Llanos Orientales) to see upland ecosystems where CIAT and ICA rice programs are working. Participants also observed genetic materials under high pressure from common stresses.

Genetic evaluation and utilization (GEU) program

Integrated GEU program

Plant Breeding Department

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IRRI RICES NAMED IN NATIONAL PROGRAMS

At present, 127 varieties from IRRI breeding materials are planted on more than 30 million ha in countries of Asia, Africa, Latin America, and Oceania. During 1983, national programs named the following IRRI breeding lines as varieties.

- IR2071-586-5-6 -3, a line with multiple insect and disease resistance and tolerance for many problem soils, was named Pyi Lone Chan Tha in Burma. The name in Burmese means wealth for the whole country. A reselection of this line was also released in Tamil Nadu State of India under the name of AU42/ I. This line was first recommended by the Philippine Seed Board in 1977 as IR42 and has since been released as a variety in Indonesia, Malaysia, Vietnam, Kampuchea, and Nigeria. Grown under different names in different countries, IR42 is now the second most widely grown rice variety in the world after IR36.
- IR790-39-5-3, a sturdy-stemmed selection with good grain quality, was released as Faro 7 in Nigeria.
- IR661-1-170-1-3 is grown under the commercial name of IR661 in western Australia's Kununura region.
- IR2058-78-1-3-2-3 was released in Brazil as Pesagro 102. This line was released as IR46 in the Philippines in 1977 and has also been recommended in Cameroon.
- IR8208-146-1 was recommended as Pesagro 101 in Brazil.
- IR2071-199-3-6, a sibling line of IR36 and IR42, was released as BR15 (Mohini) in Bangladesh. It is suitable for cultivation during boro and aus seasons. In Bangladesh, it is resistant to RTV, BLB, BLS, ShB, SR, and Bl.
- IR2793-80-1 was recommended as BR16 (Shahi Balam) in Bangladesh for boro and aus. In Bangladesh, it is resistant to RTV, BLB, SR, and Bl.
- IR758-15-2 was named as BAU63 (Varasha) in Bangladesh and approved for cultivation during boro. It is a sturdy-stemmed, lodging-resistant variety with moderate levels of resistance to BB, Bl, ShR, and RTV.
- IR2071-625-1-252 was recommended in Anhui Province, China. This line was first recommended as IR36 by the Philippine Seed Board in 1976 and has since been recommended in Indonesia, Vietnam, Kampuchea, and India. It is the most widely grown rice variety in the world.
- IR13429-209-2-2-1, a line with multiple disease and insect resistance and resistance to all known BPH biotypes, was recommended in Indonesia. This line was released as IR56 by the Philippine Seed Board in 1982.
- IR9752-71-3-2, a very early-maturing selection with multiple disease and insect resistance and excellent grain quality, was released as IR58 by the Philippine Seed Board. It matures in 100 d and is the earliest maturing of the IR varieties (Fig. 1). It inherited its early maturity from Kwang Chang Ai, brought from China in 1974.
- IR13429-299-2-1-3 was released as IR60 by the Philippine Seed Board (Fig. 2). This early-

1. IR58, named by the Philippine Seed Board in 1983, is the earliest maturing of IR varieties.

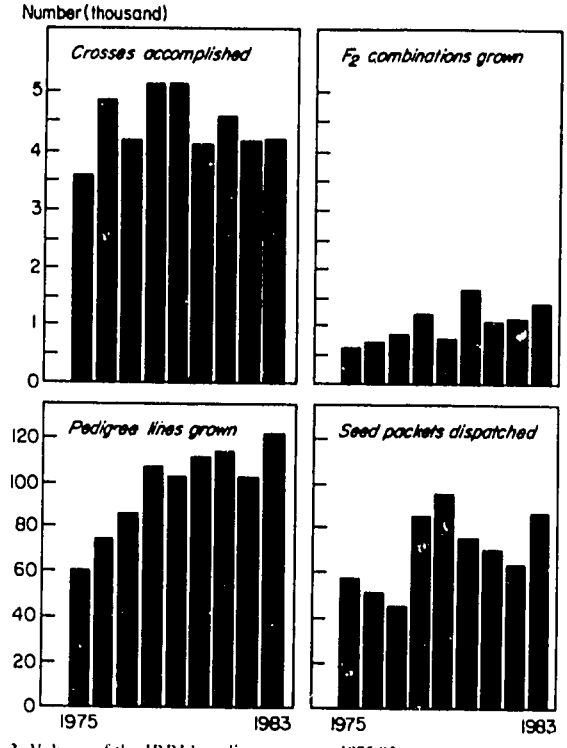
2. IR60, named by the Philippine Seed Board in 1983, is an early-maturing, multiple disease- and insect-resistant variety with strong dormancy

maturing selection (105 d) has multiple resistance to various diseases and insects and is resistant to all known BPH biotypes. It was recommended for cultivation primarily in Mindanao, Philippines, where biotype 3 is prevalent. IR60 has long slender grains with high milling recovery and strong dormancy.

BREEDING OPERATIONS

IRRI made 4,147 crosses in 1983, grew F_2 populations from 1,388 crosses, evaluated 122,614 pedigree nursery rows, tested 1,120 breeding lines in the replicated yield trials, and sent 88,204 seed packets of IRRI breeding lines abroad (Fig. 3). Of the total, 22,426 seed packets of IRRI breeding lines filled 192 seed requests and the remaining 65,778 packets were sent through IRTP nurseries.

In 1983, efforts were intensified to develop improved germplasm for less favored areas.



3. Volume of the IRRI breeding program, 1975-83.

PROGRESS IN DEVELOPING IMPROVED GERMPLASM FOR CULTURAL TYPES

Irrigated rice. During the year, 789 crosses were made; F_2 populations from 461 cross combinations were grown; 66,802 pedigree nursery rows were tested; and 966 breeding lines were evaluated in replicated yield trials. From IRRI tests, Philippine Seed Board trials at 12 locations, and international yield nurseries coordinated by IRTP, several promising lines were identified. The most outstanding ones are listed below.

- IR13540-56- 3-2 -1, an early-maturing line, is resistant to all known BPH biotypes and other major diseases and insects. It has long, slender, translucent grains and high yield potential. It was the highest yielding entry in the IRYN-M for the last 3 yr.
- IR29723-143-3-2-1 is a high yielding selection that matures in 135 d, has sturdy stems, and is lodging resistant. It has long, slender, translucent grains with high milling recovery and multiple resistance to diseases and insects including 3 BPH biotypes.
- IR31868-64-2-3-3-3 is an early-maturing selection that matures in 105 d. It has excellent yield potential, medium-long, slender, translucent grains with intermediate gelatinization temperature and intermediate AC. It has multiple resistance to major insects and diseases and a high level of resistance to BI.
- IR31851-63-1-2-3-2 is an early-maturing line that matures in 100 d. It has long, slender, translucent grains with intermediate gelatinization temperature and intermediate AC. It has multiple resistance to major diseases and insects.

Other promising lines for irrigated conditions are listed in Table 1. Many promising lines with intermediate gelatinization temperature and intermediate AC are now in the advanced stages of testing. The irrigated rice breeding program continues to seek multiple disease and insect resistance, shorter growth duration, and superior grain quality.

Cold-tolerant rice. Breeding continued to emphasize the combination of cold tolerance with high yield and other desirable attributes. During 1983, 281 single crosses and 114 multiple crosses were made.

In addition, 31 multiple crosses were made between diverse cold-tolerant varieties and the IR36 male sterile line to create an intermating

Table 1. Some promising breeding lines with multiple attributes suitable for irrigated lowland culture. IRRI, 1983.

Designation	Cross	Growth duration (d)	AC (%)	Gelatinization temperature	Reaction[a] to							
					BI	BLB	RTV	GSV	GLH	BPH biotype		
										1	2	3
IR13525-43-2-3-1-3	Ptb 33/IR30//IR36	115	25	I	4	1	3	1	3	1	1	1
IR21820-154-3-2-2	IR1529-680-3/IR4432-52-6-4-//IR7963-3C-2	130	23	I	6	1	3	1	3	1	1	7
IR22082-41-2	IR54/IR5657-33-2	130	24	I	7	1	1	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
IR28128-45-2	IR36/IR10154-23-3-3//IR9129-209-2-2-2-1	105	22	I	5	1	3	1	3	1	1	7
IR29723-143-3-2-1	IR19661-131-1-2/IR4570-124-3-2-2-2	130	26	L	7	1	3	1	3	1	1	1
IR29658-69-2-1-2	IR13471-71-2/IR13429-196-1	105	26	L	1	1	3	1	3	1	1	1
IR31802-48-2-2-2	IR13168-143-1/IR13240-10-1//IR9129-209-2-2-2-1	107	22	I	3	1	3	1	3	1	1	1
IR31805-20-1-3-3	IR13429-62-2/IR2415-90-4-3-2//IR9129-209-2-2-2-1	125	26	L	1	1	3	1	3	1	1	1
IR31851-63-1-2-3-2	IR17491-5-4-3-3/IR2415-90-4-3-2//IR9129-209-2-2-2-1	110	22	I	1	1	3	1	3	1	1	7
IR31868-64-2-3-3-3	KDM 105/IR50//IR9129-209-2-2-2-1	105	22	I	1	1	3	1	3	1	1	7
IR32307-12-2-1-2	IR13240-108-2-2-3/IR9129-209-2-2-1	105	25	I	1	1	3	1	3	1	1	1
IR32429-68-3-3-3	IR19058-143-2-3/IR9129-209-2-2-2-1	110	24	I	1	1	3	1	3	1	1	1
IR32822-21-2-3-1	IR4442-46-3-3-3/IR1529-680-3-2//IR19661-131-1-2	135	27	I	1	1	3	1	3	1	1	1

[a]Based on 1980 SES scale.

composite population. Continued selection on this population, grown initially under normal temperature and later under low temperature, may eventually lead to an accumulation of cold tolerance genes.

Evaluation and selection of breeding lines continued during the year both at IRRI and at Banaue, Ifugao, Philippines (about 1200 m elevation). At IRRI, 46 F_2 populations were grown during DS and 2,063 plants were selected. During WS, 1,149 plants were selected from 24 single and multiple crosses. In pedigree nurseries, 936 plants were saved from 2,846 F_3-F_9 lines in both seasons.

At Banaue, the expanding breeding nurseries were transferred to bigger adjacent fields. A weather station was established in cooperation with the Agroclimatic Service Unit of the IRRI Multiple Cropping Department. The new station permitted the evaluation of more breeding lines in collaboration with scientists from the Philippine Bureau of Plant Industry. In DS, 2,415 single-plant selections were made from 77 F_2 populations. In the pedigree nursery, 613 plants were selected from among 1,712 F_3-F_{10} lines. Agronomic characteristics were evaluated from 101 varieties and lines in the International Rice Cold Tolerance Nursery and 246 selections in the International Rice Observational Nursery. A replicated yield test during DS further confirmed the high yield potential of several lines as compared to local check variety Pinidua (Table 2).

During WS, serious rat infestation from unplanted terraces destroyed all the nurseries except the pedigree nursery from which 351 plants were selected.

Rainfed lowland rice. Breeding work on rainfed lowland rice has focused on three major cultural types: drought-prone; drought- and submergence-prone; and medium-deep, stagnant water. The goal is to incorporate tolerance for drought, submer-

Table 2. Yield and agronomic characteristics of some promising cold tolerant lines grown in[a] replicated yield trial, Banaue, Ifugao, Philippines, 1983 DS.

Selection	Yield (t/ha)	Days to flowering	Height (cm)	Sterility (%)	Reaction[a] to		Amylose (%)	Gel consistency (mm)
					BI	BLB		
IR8866-30-3-1-4-2	5.4	117	74	18	8	1	25	32
IR9202-5-2-2-2	4.9	110	82	20	8	1	26	30
IR13155-60-3-1-3	4.8	106	102	14	9	1	27	34
IR5716-18-1	4.8	118	79	25	8	3	25	32
IR9758-K2	4.6	106	78	12	8	1	24	30
IR15579-135-3	4.6	118	103	9	8	3	27	34
IR2061-522-6-9	4.4	117	86	18	8	1	25	30
Pinidua (local check)	4.2	132	131	12	6	7	25	68

[a]Scoring based on 1980 SES scale.

gence, and stagnant flooding into breeding lines with good plant type and disease and insect resistance. Collaboration with national programs for improvement of rainfed lowland rice was strengthened.

During 1983, 283 single crosses and 538 multiple crosses were made. F_2 populations from 225 crosses and 24,355 pedigree nurseries were grown and 125 entries were evaluated in replicated yield trials.

Drought and submergence tolerance. Drought tolerance is essential in both drought-prone and flood-prone environments. Both early- and long-duration varieties are needed for rainfed lowland areas with different moisture regimes. In DS, pedigree lines were screened from the F_4 in the drought screening nurseries at IRRI. Advanced lines that performed well in a drought-screening nursery grown at three sites in the Philippines are listed in Table 3. Some of these lines were earlier identified as drought tolerant in the vegetative phase in the DS nursery at IRRI.

Pedigree lines from the F_3 were screened for submergence tolerance in tanks. Surviving plants were transplanted in the field and the following generation was again tested. Crosses which produced a high proportion of submergence-tolerant F_3 progeny are listed in Table 4. Breeding lines tested at several Philippine flood-prone sites were not subjected to flooding in 1983.

Medium-deep rainfed lowland conditions. A medium-deep water (25-50 cm) rainfed lowland site was simulated for a replicated yield trial in 3 fields using 24 entries and the IR42 check. Water depth was maintained between 30 and 40 cm from 3 WT until just before harvest.

Lodging was severe because of heavy rains during flowering and ripening. Yield levels were

Table 3. Breeding lines that performed well in drought screening during the vegetative phase in the DS drought nursery and the WS nurseries at Cebu, IRRI, and Santa Rosa, 1983.

Designation	Parentage	Duration (d)	Height (cm)	Drought nursery	
				WS[a]	DS[b]
IR26717-1-1-2-1-1	Goda Heenati/BR4//IR48	113	90	+	
IR26894-37-2-1-3	2526/IR2823-399-5-6//IR9129-209-2-2	107	80	+	+
IR28941-164-1-5	IR4227-28-3-2/Tilakchandan//IR48	118	100	+	+
IR29337-36-3	IR48/Mahsuri	128	160	+	
IR29341-85-3-1-3	IR52/IR46	114	100	+	
IR29385-2-30-3	Intan Chem. mut.	118	140	+	+
IR33353-2-2-1-3	IR52/IR36//IR52	125	85	+	
IR33353-64-1-2-1	IR52/IR36//IR52	121	85	+	
IR33353-88-3-2-1	IR52/IR36//IR52	127	90	+	
IR33356-14-3-1-3	IR52/IR48//52	127	105	+	+

[a]Cebu, Santa Rosa, and IRRI (Agronomy Department). [b]IRRI (Agronomy Department).

Table 4. Crosses which produced a high proportion of submergence-tolerant F_3 progeny. IRRI, 1983.

Cross	Parentage[a]
IR38759	Nam Sagui 19*/IR13146-179
IR40931	BKNFR76106-16-0-1-0*/ IR19661-131-1-2
IR41431	IR8234-OT-9-2*/IR19661-131-1-2
IR41468	IR17494-32-3-1-1-3/BKNFR76106-13-2*
IR42207	IR14632-22-3//IR19382-42-3-3-2// BKNFR76106-16-0-1-0*
IR42233	IR4563-52-1-3-6/Cafuringa-1*/ IR13146-45-2-3

[a] * = the submergence-tolerant parent.

low (Table 5). In fields 1 and 3, yields were negatively correlated with the degree of lodging, indicating that this may have caused the low yield. Varieties differed significantly in number of tillers, but this was not correlated with yield. The average tiller number per plant was about 11, much lower than for the shallow replicated yield trial. Water depth, which was about 5 cm deeper in the field where the third group (long duration) lines were grown, may account for reduced yields in this field.

Population improvement. The random mating population of IR38499 was carried through one cycle of selection. In 1983, 638 random S_1 lines were grown in the pedigree nursery and screened for resistance to BPH and GLH, translucent grains, and acceptable plant type for rainfed fields. Of those lines, 47 were identified as acceptable for all traits. Most of the S_1 lines were also screened for submergence tolerance. Only 16 could survive submergence for 10 d at the seedling stage. The rest of the S_1 seed from the selected lines formed the second selection cycle. The selected lines were also included in the pedigree breeding program.

S_1 lines of IR38499 were measured for seedling height in the seedbed at 20 DAS. The submergence-tolerant group contained short and tall lines, but more of the tall lines survived submergence. Lines with faster seedling growth seemed more able to survive submergence although this was not true in all cases.

Thai-IRRI Collaborative Breeding Project. In 1983 WS, 70 F_2 populations of Thai/IRRI crosses were sent to Thailand and grown at 5 research stations in the northeast. Thai and IRRI breeders made plant selections, and F_3 seed of 2,781 lines were brought to IRRI for generation advance. They will be screened for grain quality and resistance to BB, and F_4 seed of the best lines will be sent to Thailand for the 1984 WS.

The goal will be to identify photoperiod-sensitive lines with good plant type. When planted in December at IRRI, most photoperiod-sensitive

Table 5. Highest yielding breeding lines in the medium deepwater replicated yield trial. IRRI, 1983.

Designation	Parentage	Height (cm)	Duration (d)	Yield (t/ha)
	Group I (medium)			
IR13149-71-3-2-3	BG90-2/IR46//IR4417-177-1-4	121	118	2.7*
IR9217-58-2-2	IR2071-588-6/IR2061-213-2//IR2058-78-1-3-3	122	119	2.6*
IR31916-1-3-3	2196/IR4570-74-2-2-3-3//IR9129-209-2-2-2-1	110	119	2.4
IR54	Nam Sagui 19/IR2071-88//IR2061-214-3-6-20	126	115	2.4
IR42 (check)		112	125	1.9
	Group II (medium-late)			
IR33238-25-2-3-2	BR51-282-8/IR46//IR9764-45-2-2	147	127	2.5
IR19382-42-3-3-2	IR4409-76-1-3/IR44//IR4219-35-3-3	135	128	2.4
IR33209-22-1-1-1	BG367-7/IR4744-295-2-3//IR11248-131-3-2-2	153	127	2.3
IR19319-1-2-1-2-3	IR3372-44-1-2-1/IR4816-70-1//IR46	123	127	2.2
IR42 (check)		120	136	2.0
	Group III (late)			
IR26702-204-2-2-1-1-3	FR13A/IR48	130	138	2.1*
IR26760-27-1-3-2-1	Jaganath/IR2797-105-2-2-3//IR48	133	140	2.1*
IR24705-11-3-2-3-3	CSR1/IR52//IR5657-33-2	126	136	1.9
B4259-48-3-1-2	IR46/IR4422-98-3-6-1	136	145	1.9
IR42 (check)		118	135	1.4

Table 6. Parents utilized in at least 30 crosses for the deepwater program during 1983.

Parent	Crosses used (no.)	Major characteristics
Baisbish	36	Floating rice, elongation ability, resistance to RTV
BKNFR76106-13-2	64	Deepwater rice, submergence tolerance, medium height
BKNFR76106-16-0-1	85	Shallow-water rice, submergence tolerance, short height
Chenab 64-117	83	Deepwater rice, submergence tolerance, adaptation to Bihar
CN 540	57	Deepwater rice, submergence tolerance, adaptation to W. Bengal
DWCT156-1	147	Deepwater rice, elongation ability, semidwarf stature
IR11288-B-B-118-1	102	Floating rice, elongation ability, resistance to BPH
IR13423-10-2-3	88	MV, resistance to salinity, BPH, and GLH
IR14632-22-3	51	MV, resistance to salinity, alkalinity, BPH, and GLH, Zn efficiency
IR26702-52-3	114	MV, submergence tolerance and short height
IR31406-333	32	MV, submergence tolerance and short height
Nam Sagui 19	94	Rainfed rice, adaptation to rainfed environments, drought tolerance, Zn efficiency
RD19	155	Deepwater rice, elongation ability in a semidwarf plant type, adaptation to Thailand
Sail Kotha	38	Floating rice, elongation ability, adaptation to Bangladesh
TOX 896	131	Upland rice, excellent straw stiffness and good root system

lines flower within 3 mo. If planted after January, daylengths become too long and the sensitive lines do not flower. By planting at both times, seed can be harvested from photoperiod-sensitive lines planted in December, and lines from a smaller nursery planted in February can be classified for sensitivity.

Deepwater rice. In deep water, 464 single-cross and 794 multiple-cross F_1's were grown. Seventy percent of the single crosses, and 60% of the multiple crosses tested elongation ability as a survival strategy while the remaining crosses focused on submergence tolerance (Table 6). F_2 populations from 261 single crosses and 133 multiple crosses were grown for deepwater conditions. Other F_2 populations from 70 single crosses and 80 multiple crosses were grown for flash flood-prone deepwater areas.

In 1983, 19,154 pedigree nursery rows from 599 crosses were evaluated for stagnant-water situations, and 10,005 pedigree lines from 374 crosses were grown for flash flood-prone areas (Table 7, 8).

Screening for elongation ability. In a deepwater tank during DS, 260 F_3 families and 214 F_2 populations were screened for elongation ability using a standard field test and maximum water depth of 85 cm. Tillers of surviving plants were cut and transplanted into a normal rice field, and plant selections were subsequently made in WS. This accomplished selection for deepwater survival, photoperiod sensitivity, and insect and disease resistance in a single season. In WS, 46 single-cross F_2s and 6,429 F_2 families from 303 multiple crosses were subjected to a similar test, but the next generation came directly from the surviving plants in the deepwater tank.

Screening for submergence tolerance. In 3 screening tests in submergence tanks, seedlings at 30 DAS were subjected to 8-10 d submergence in water 83 cm deep. The study tested 239 F_2 populations and 431 pedigree lines. Surviving plants were transplanted into a regular field for further selection for plant type and insect and disease resistance. Table 9 compares submergence tolerance breeding values of the most frequently used donors from one of the tank experiments. Values are the aggregate percentages of surviving F_2 families from multiple crosses involving the

Table 7. Some promising breeding lines with survival ability in deepwater tests, good agronomic traits, and insect and disease resistance. IRRI, 1983.

Designation	Cross	Height (cm)	Elongation ability	Reaction[a] to								
				BI	BLB	GLH	BPH biotype			Salinity	Alkalinity	Zn deficiency
							1	2	3			
BKNFR76026-3-2-2-2	IR4427-70-4/ RD19	111	7			3	3	7	3			
GEU76050-0-19-4-1	IR2061-522-6-9/ LMN111// random el.	132	5			7	3	9	3			
HTAFR77043-2	LMN111*2/ PTB18	163	4	4	3	6	4	6	5	4	4	
IR11141-6-1-4	IR2061-465-1-5-5/ LMN111	118	7			6	4	7	4			
IR11288-B-B-118-1	IR36/LMN111	145	6	1	6	7	3	4	5			
IR11288-B-B-69-1	IR36/LMN111	122	7	2	7	3	2	4	3	7	6	6
IR31617-19-3-3-4	T1242/T442-57// IR42	105	6	1	7	5	5	7	9	5	3	4
SPR7411-7-2-1	LMN111/PTB18	165	5	4	4	5	2	3	3			

[a]By 1980 SES scale.

Table 8. Best deepwater rice lines with submergence tolerance in 1983. IRRI.

Designation	Cross	Height (cm)	Submergence tolerance	Reaction[a] to								
				BI	BLB	GLH	BPH biotype			Salinity	Alkalinity	Zn deficiency
							1	2	3			
IR21567-16-3	IR5857-4-1E-1/ KLG6986-133-4P//IR2071-586-5-6-3	106	5	2	6	3	2	6	3	5	5	4
IR21567-18-3	IR5857-4-1E-1/ KLG6986-133-40//IR2071-586-5-6-3	103	5	2	6	4	2	4	3	5	3	4
IR21567-9-2-2-2	IR5857-41E-1/ KLG6986-133-4P//IR2071-586-5-6-3	108	5	1	7	4	3	5	3	5	5	7
IR26708-2-2-3-1-1	FR13A/2*IR48	116	5	2	8	2	6	9	6	5	2	3
IR26721-135-2-6-1-1	Goda Heenati/ IR46//IR4219-35-3-3-2	113	6	1	4	4	9	7	9	5	3	4
IR26721-135-2-6-1-3	Goda Heenati/ IR46//IR4219-35-3-3-2	114	5	1	4	4	7	7	9	5	3	4
IR28884-26-3-505-1-1	Ratanagiri 9-5-3-2/FR13A// IR2863-38-2	118	3	4	5	8	4	7	3	6	5	2
IR28884-6-1-502-1-2	Ratanagiri 9-5-3-2/FR13A// IR2863-38-2	115	5	3	5	7	2	7	7	5	5	2
IR28905-10-1-3	IR3478-134-2-2-2-3/Goda Heenati/IR32	104	3	1	6	7				4	3	1
IR29012-4-1-3	Jagannath/ FR13A//IR42	113	1	1	5	3				5	3	4

Table 8 continued

Designation	Cross	Height (cm)	Submergence tolerance	Reaction[a] to								
				BI	BLB	GLH	BPH biotype			Salinity	Alkalinity	Zn deficiency
							1	2	3			
IR31142-14-1-1-3-2	Goda Heenati/ IR4563-52-1-3-6//IR13292-5-3	91	6	6	2	3	7	9	5	4	3	
IR31176-141-2-1-1-3	IR4658-86-1-3-2/ BKNFR76023// IR13415-9-3	S	6	1	3	3	3	6	8	4		
IR31406-333-1	Kurkaruppan/ CR1002// IR13415-9-3	99	4	5	6	6				3	3	5
IR31432-6-2-2-3	Kurkaruppan/ IR46//IR13168-143-1	99	5	1	6	5	4	4	3	4		
IR31442-1-503-1-2-1	Kurkaruppan/ IR4422-98-3-6-1//IR13419-113-1	158	3	1		6	3	7	1	6		
IR33167-1-501-1-2-3	B3897C-8/Goda Heenati// IR9764-45-2-2	151	6	1		4	9	9	9	6	5	
IR33279-1-501-1-1-2	FRG2/IR48// IR9764-45-2-2	187	5	1		3	3	5	9	6		
IR33279-1-501-1-2-1	FRG2/IR48// IR9764-45-2-2	171	5	1		3	7	7	9	6		
IR33284-4-503-1-1-2	FRG2/IR13426-19-2//IR9764-45-2	163	5	1		3	5	5	9	6		
IR33284-4-503-1-1-3	FRG2/IR13426-19-2//IR9764-45-2	162	5	1		3	5	5	9	5		

[a]By 1980 SES scale.

donor parents for submergence tolerance listed in the table.

Collaboration with Thailand to evaluate rices for elongation ability. At the Huntra Rice Research Station, Ayuthaya, Thailand, standard field tests with controlled water were used to screen 2,493 pedigree lines from 161 crosses for elongation ability. From IRRI's breeding program, 789 advanced lines were screened for submergence tolerance. Results were used to select pedigree lines.

Table 9. Submergence tolerance recovery from 4-parent multiple-cross F_2s when one of 4 parents is a submergence tolerance donor (combined from several crosses). IRRI, 1983.

Donor parent	Populations (no.)	Percentages of families with score of				Total
		1	3	5	7	
BKNFR76106-16-0-1	949		8	12	28	58
PKNFR76106-13-2	249		4	12	24	40
FR43B	648		1	5	14	20
Chenab 64-117	321			2	17	19
IR8234-OT-9-2	156				7	7

Evaluation of Thai breeding lines at IRRI. Several hundred promising lines from the deep-water rice breeding programs of Thailand were evaluated at IRRI. They were grown in the pedigree nurseries and tested for resistance or tolerance for diseases, insects, and soil problems (Table 10).

Rices for adverse soils. Donors of tolerance for salinity and efficient P use were used in 42 single-cross and 63 multiple-cross F_1s. F_2 populations came from 43 single crosses and 8 multiple crosses.

Table 10. Some promising breeding lines of deepwater rice from Thailand and their scores for other traits.[a] IRRI, 1983.

Designation	Elongation ability	Submergence tolerance	Reaction to							
			BI	BLB	GLH biotype			Salinity	Alkalinity	Deficiency
					1	2	3			
BKNFR76026-3-2-2-3-1					x					
BKNFR76035-136-0-1								x	x	x
BKNFR76035-140-1					x			x	x	x
BKNFR80073-1		x			x					
BKNFR80080-34			x		x					
BKNFR81017-20					x					
BKNFR81023-13		x			x					
HTAFR77012-3-1-1-2	x		x		x					
HTAFR77043-2				x	x					
HTAFR77054-3-5-FC162-1-1				x	x					
HTAFR77078-32-1-0-1-1			x		x					
SPR7216-RST42-1-2-5								x		
SPR7316-30-1-1								x		
SPR7411-7-2-3-3-1-1	x		x	x	x	x				
SPRLR76136-25-FC299-4-1			x	x						
SPRLR76138-1-1-7-1			x	x	x					
SPRLR76138-1-6-3-1			x	x						

[a]x = 5 or better for elongation and submergence tolerance, 3 or better for other traits.

Five hundred sixty-seven crosses were grown from 7,706 pedigree lines. Two hundred forty-two early generation lines and 563 advanced lines were planted in an artificially salinized field and one in which alkalinity was maintained. The best survivors (Table 11), based on adaptation to problem soils, plant type, and resistance to diseases and insects, were harvested as plant selections or in bulk.

Upland rice. During the year, 139 single crosses and 229 double crosses were made for upland nurseries. Fifty percent of the crosses during WS were planned to meet the needs of collaborators in Africa, Latin America, and Southeast Asia, and at IITA and WARDA.

In WS, about 600 F_2 bulk populations were grown at IRRI and in a farmer's field in Santo Tomas, Batangas. Of those, 315 populations were promising; plants were selected and bulked to be advanced to the F_3. Six plant breeders, from five countries participating in the first upland rice training program, identified several F_2 populations suited to their local conditions. F_3 seeds will be sent to their stations for evaluation and selection.

F_5 and F_6 breeding lines were grown in dry seedbeds and selected for deep and thick roots after seedlings were pulled at 25 DAS for transplanting. About 144 lines were selected and transplanted in 4-row plots under intermittent irrigation. From those, 867 plants were selected for their intermediate height, long and well-exserted panicles, heavy grains, and moderate tillering ability.

In a replicated yield trial during WS, 160 upland breeding lines were evaluated to determine their yield potential and stability and divided into three groups. Group A, the 40 most promising lines, was grown in expanded plots of 10 m^2. Groups B and C, 60 entries each, were mostly advanced lines from the upland observational yield trials and were grown in 5-m^2 plots. The trials were conducted in a farmer's field at Santo Tomas, Batangas, and at two IRRI sites.

Yield trials in Santo Tomas, Batangas. The crop grown in a farmer's field in Batangas received evenly distributed rainfall (1340 mm) from seeding to harvest with only short periods of water stress (Fig. 4). Average yield was 2.1 t/ha.

Group A yields ranged from 0.7 t/ha for IR5962-29-4 to 4.1 t/ha for IR3839-1. IR3839-1 continued high performance, outyielding local checks IR43, UPL Ri-7, and Kinandang Patong.

Group B yields ranged from 0.8 t/ha to 3.1 t/ha with IR5929-9-3 as top yielder. It is a progeny of Monolaya/IR1487-372-4//MRC 172-9, matures in 117 d, is resistant to drought, and has good recovery ability. The second highest yield was 3.0

Table 11. Some promising lines tolerant of problem soils evaluated in 1983, and scores for other traits. IRRI, 1983.

Designation	Cross	Height (cm)	Reaction[a] to								
			Bl	BLB	GLH	BPH biotype			Salinity	Alkalinity	Zinc deficiency
						1	2	3			
IR15948-4-2	N. Bokra/BF33-2//IR36					9	5		3	4	
IR21178-43-1-2-2-2	CR146-7055-225/ IR2061-465-1-5//IR52	130	3	4	3	1	2	5	7	3	
IR24705-116-2-1-5	CSR1/IR52// IR5657-33-2			6	3	9	3	5			3
IR24705-116-2-3-1	CSR1/IR52// IR5657-33-2			6	3	9	3	5			3
IR26916-13-1-1-2-1-1	Cheriviruppu/IR5657-33-2//IR42	100	1	6	4	3	5	7	2		
IR26916-13-1-1-2-3-1	Cheriviruppu/IR5657-33-2//IR42	102	1	6	3	3	5	5	3	3	5
IR26940-20-3-3-3	Obs.678/IR9129-393-2//IR4630-22-2-17		1		3				5		*
IR31375-3-3-1-1	Kuatik putih/IR4422-98-3-6-1//IR13415-9-3	117	1	7	3	3	5	2	3		
IR31375-3-3-2-2-2	Kuatik putih/IR4422-98-3-6-1//IR13415-9-3	125	1	7	3	3	5	2	3		
IR31375-3-3-4-2-1	Kuatik putih/IR4422-98-3-6-1//IR13415-9-3	110	1	7	3	3	5	2	3		
IR31375-5-2-1-3	Kuatik putih/IR4422-98-3-6-1//IR13415-9-3	134	1	7	3	5	5	3	2	5	3
IR31384-12-3-1-2	Kuatik putih/IR4422-480-2-3-3//IR13426-19-2	121	5	7	3	7	7	5	3	3	4
IR31476-71-1-2-3	Pinangkara/IR46// IR13426-19-2		1	8	7	7	8	5	2		
IR33451-12-1-1-1-1	IR13419-113-1/ IR9264-324-1// IR2307-247-2-2-3	123	1	8	3	1	7	3	4		

[a]Averages from varying numbers of observations.

t/ha from IR5982-7-6-1 compared to 1.4 t/ha from check variety IR45.

Group C yields ranged from 0.4 t/ha to 3.3 t/ha. IR13822-9 and UPL Ri-7 each yielded 3.3 t/ha, followed by IR10070-4-1 with 3.2 t/ha. IR13822-9 is a selection from Moroberekan/IR3273-P339-3 while IR10070-4-1 came from IR1750-F5B-3/ Maligaya 5//BPI 76*9/Dawn. Both lines mature in 117 d. Other promising lines include IR10120-7-2-1 with 3.1 t/ha, IR25816-12-1 with 2.6 t/ha, and IR12601-6-3-3 with 2.5 t/ha.

Yield trial at IRRI. At the wet and fertile site on the IRRI upland farm, yields were lower than from the farmer's field. This was caused by erratic rainfall distribution (Fig. 5) and prolonged drought stress during the reproductive phase. Glume Bl and ShB after a series of light showers also contributed to low yields.

Group A yields ranged from 1.2 t/ha for IR7950-2-4-2 to 2.6 t/ha for IR5929-12-3 and IRAT133 (from Ivory Coast). Because the latter two are early-maturing (110 d), they escaped moisture stress at the reproductive phase.

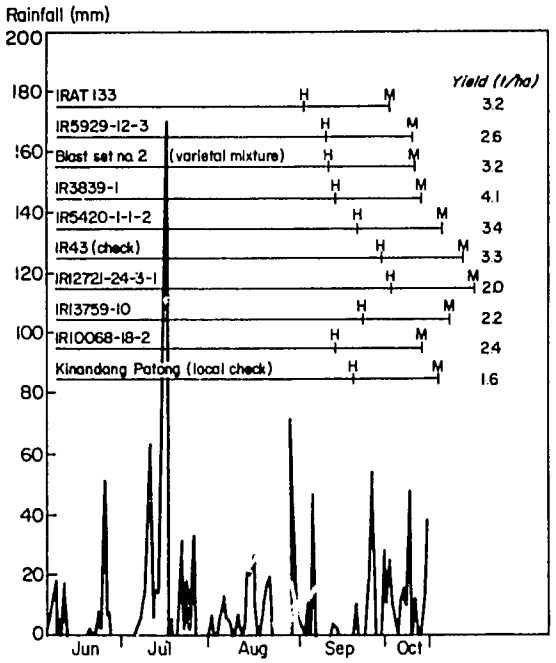
Group B yields ranged from 0.9 t/ha to 3.0 t/ha. IR9669 Sel. and IR12629-45-8-1, the highest yielders, performed well under intermittent stress. Check varieties UPL Ri-5 and IR45 yielded 2.6 and 1.9 t/ha.

Group C yields ranged from 0.5 t/ha for TOM 4-35 (from IITA) to 2.9 t/ha for UPL Ri-7 (a local check).

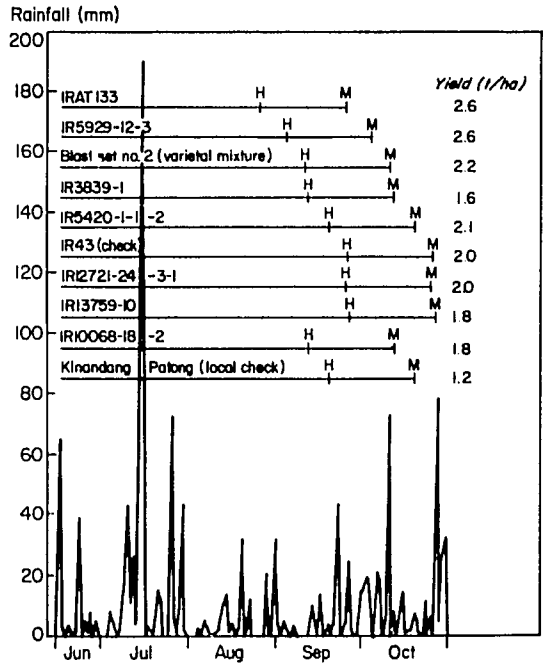
Only group A was grown at a poor, well-drained site on the IRRI farm. Yields ranged from 0.8 to 2.5 t/ha, with IRAT 133 as the highest yielder.

Yields from group A grown on a farmer's field in Batangas were compared with those from two IRRI sites (Table 12).

IRAT133 yielded highest at 2.7 t/ha. It matured



4. Rainfall distribution, growth duration, and yield of promising lines in a farmer's field at Santo Tomas, Batangas, Philippines, 1983 WS. H = heading, M = maturity.



5. Rainfall distribution, growth duration, and yield of promising lines on the IRRI upland farm, 1983 WS. H = heading, M = maturity.

in 106 d and was resistant to Bl but highly susceptible to ShB. The reduced yield of IR3839-1 at the IRRI railroad site was caused by moisture stress during the reproductive phase followed by glume Bl and ShB.

Two lines gave stable yield in the three locations. They were IR12721-24-3-1 (a selection from IR2735-F3B-6-2/IR9575//B541B-KN-19-3-4) and IR13759-10 (a progeny of IR3880-13/IR2823-179-5-4). Both lines matured rather late (136 d) with heights between 131 and 138 cm. They are resistant to drought and have good recovery ability.

Other promising lines were IR5929-12-3 at 2.0 t/ha and 112 d maturity and IR5420-1-1-2 at 1.8 t/ha and 120 d.

Collaborative breeding efforts. During the 1983 International Rice Research Conference, rice breeders from IRRI and 11 other institutions (Centro Nacional de Agricultura Tropical [CIAT], International Institute of Tropical Agriculture [IITA], West Africa Rice Development Association [WARDA], Instituto Nacional de Investigaciones

Table 12. Yield performance and maturity of promising group A lines grown under upland culture at 3 locations, 1983 WS.

Entry	Santo Tomas		Railroad site (IRRI)		IRRI upland		Mean yield (t/ha)
	Yield (t/ha)	Maturity (d)	Yield (t/ha)	Maturity (d)	Yield (t/ha)	Maturity (d)	
IRAT133	3.2	106	2.5	97	2.6	101	2.7
IR5929-12-3	2.6	114	0.7	111	2.6	110	2.0
IR3839-1	4.1	118	0.1	115	1.5	113	1.9
IR5420-1-1-2	3.4	125	0.1	133	2.1	126	1.8
IR12721-24-3-1	2.0	137	1.1	139	2.0	131	1.7
IR13759-10	2.2	128	1.1	146	1.8	133	1.7
IR10068-18-2	2.4	118	0.6	116	1.8	114	1.8
UPL Ri-7 (check)	2.8	117	1.1	111	2.6	111	2.2
IR43 (check)	3.3	133	0.1	141	2.0	132	1.8
Kinandang Patong (check)	1.6	124	–	–	1.2	126	1.4

Agrarias [INIA], Instituto Colombiano Agropecuario [ICA], Empresa Brasileira de Pesquisa Agropecuaria [EMBRAPA], and the national programs of Bangladesh, India, Indonesia, Thailand, and Venezuela) discussed collaborative efforts to strengthen upland rice improvement.

African and Latin American breeders emphasized the need to incorporate resistance or tolerance to Bl, LSc, *Helminthosporium* LS, glume discoloration, and Al toxicity into improved materials.

WARDA is particularly interested in long-duration (135 d) and tall phenotypes.

In Asia, Thai breeders prefer long panicles, early maturity, and glutinous endosperm.

Indonesian breeders requested F_2 populations that involve parents with Bl resistance, tolerance to Al toxicity, and the bulu plant type.

Indian breeders need adequate grain dormancy and tolerance to Fe and Zn deficiencies.

National program and regional center breeders have agreed to send locally adapted materials and breeding lines to IRRI for use as parents in the crosses. IRRI will make the crosses and send the F_2 bulk populations to the cooperators.

Control and management of rice pests

Diseases

Plant Pathology, Entomology, Agronomy, and Plant Breeding Departments

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MONITORING RICE DISEASES

Plant Pathology and Entomology Departments

Rice tungro monitoring in the Philippines (*Plant Pathology*). RTV monitoring continued in the Philippines as a joint project with the Bureau of Plant Industry, Ministry of Agriculture. A total of 56 Regional Crop Protection Center (RCPC) and Surveillance and Early Warning System personnel were trained to monitor for RTV at the Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, and at the RCPC Region 6 station, Iloilo. Two techniques for quick and efficient RTV identification in the field were introduced.

Monitoring covered 236 farmers' fields in 80 municipalities of 28 provinces. The fields were planted to 20 varieties and monitored at tillering stage. Major varieties were IR36 (29%) and IR42 (21%). The predominant RTV vector was adult GLH, averaging 8 insects/10 sweeps. RTV incidences, ranging from 0.5 to 95%, were observed in 76 fields. Overall incidence was about 10%, but 35 fields had more than 10% (Table 1), or an average of 57%. Most fields with RTV had a relatively high vector estimate: average of 30.3 GLH/10 sweeps.

Thirty-one percent of the diseased fields were planted to IR36, 23% to IR42, and 17% to other varieties such as Benkong, CI000, ARC2350, and IR46-9.

Light trapping of rice virus vectors (*Plant Pathology*). The weekly light trapping of rice virus

Table 1. Philippine areas covered by 1983 RTV monitoring with more than 10% tungro incidence.

Province	Municipality	Field no.	RTV incidence (%)	Variety	Growth stage[a]	No./10 sweeps[b]
Kalinga-Apayao	Rizal	1	30	IR42	L	41
	Balanau	1	80	IE36	E	21
		2	95	C1000	L	49
	Tabule	1	90	IR42	L	5
		2	35	IR42	L	4
Nueva Viscaya	Bambang	1	70	IR36	L	6
Camarines Sur	Libmanan	1	35	MRC2350	L	15
Albay	Oas	1	>80	Benkong	E	78
		2	>80	IR42	E	77
	Polangui	1	75	IR42	E	68
		2	<60	IR42	E	56
		3	90	IR42	E	143
		4	50	Benkong	E	43
		5	20	Unk	E	20
		6	85	IR36	S	63
		7	95	IR48	L	41
Iloilo	Barotac Nuevo	1	40	IR36	B	–
		2	10	IR36	L	4
Negros Oriental	Santa Catalina	1	60	IR56	L	8
		2	70	IR42	L	20
		3	90	IR36	L	9
		4	90	IR36	L	9
		5	90	IR36	L	6
Bukidnon	Maramag	1	80	IR36	B	–
Agusan del Norte	Aupagan	1	80	IR36	B	–
		2	80	IR36	L	0
Davao	Davao City	1	35	Unk	E	38
Davao del Norte	Santo Tomas	1	25	Unk	L	54
Davao del Sur	Magsaysay	1	40	Unk	B	–
	Bansalan	1	20	IR56	L	11
Sultan Kudarat	Isulan	1	10	Unk	E	11
		2	10	Unk	L	1
	Mariano Marcos	1	30	Unk	L	39
		2	45	IR46-9	R	45
		3	75	IR46-9	E	75

[a]E = early tillering, L = late tillering, B = booting, R = ratoon. [b]Dash (–) indicates no sweeping; plants were at booting stage.

Table 2. Average number of rice virus vectors collected by light trap[a] at IRRI and percentage of infective insects. 1983.

Month	Insects (no./trap)		Infective insects (%)		
	RTV vectors[b]	BPH	RTV	GSV	RSV
Jan	8	1	0	0	0
Feb	8	1	0	0	0
Mar	55	43	3.0	0.5	0
Apr	142	86	2.3	0	0
May	35	42	3.0	1.3	5.7
Jun	21	6	3.7	0	4.3
Jul	77	5	0.8	0	0
Aug	2026	322	0.1	0	0.4
Sep	598	398	0.3	0	0
Oct	131	119	1.3	0	0.8
Nov	151	244	2.7	0	2.7
Dec	8	1	0	0	0

[a]From 1700 to 2000 h after sunset. [b]*N. virescens, N. nigropictus,* and *R. dorsalis.* The ratio among the 3 species for the whole period was 46:40:14.

Table 3. Virus-carrying BPH caught by high beam trap as detected by ELISA, 1983.

Sample no.	Collection date	BPH				
		Tested (no.)	With GSV		With RSV	
			No.	%	No.	%
1	28 Jan-6 Feb	5	0	0	1	20.0
2	7-16 Feb	0	–	–	–	–
3	17-26 Feb	13	1	7.7	2	15.4
4	27 Feb-8 Mar	67	8	11.9	13	19.4
5	9-18 Mar	33	1	3.0	0	0
6	19-28 Mar	207	0	0	0	0
7	29 Mar-7 Apr	271	9	3.3	34	12.5
8	8-17 Apr	134	0	0	3	2.2
9	8-27 Apr	139	0	0	4	2.9
10	28 Apr-7 May	74	1	1.4	2	2.7
11	8-17 May	60	2	3.3	1	1.7
12	18-27 May	65	1	1.5	3	4.6
13	28 May-6 Jun	27	0	0	3	11.1
14	7-16 Jun	99	3	3.0	6	6.1
15	17-26 Jun	91	1	1.1	3	3.3
16	27 Jun-6 Jul	108	0	0	4	3.7
17	7-16 Jul	41	0	0	2	4.9
18	17-26 Jul	0	–	–	–	–
19	27 Jul-5 Aug	0	–	–	–	–
20	6-15 Aug	0	–	–	–	–
21	16-25 Aug	339	3	0.9	7	2.1
22	26 Aug-4 Sep	407	0	0	17	4.2
23	5-14 Sep	199	1	0.5	2	1.0
24	15-24 Sep	145	0	0	0	0
25	25 Sep-4 Oct	55	0	0	0	0
26	5-14 Oct	43	0	0	0	0
27	15-24 Oct	66	1	1.5	0	0
Total		2688	32	1.2	107	4.0

vectors continued at IRRI and serial transmission tests determined the infectivity of some of the trapped vectors.

As in previous years, few rice virus vectors were collected in December-February. The percentage of infective RTV vectors — *Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis* — ranged from 0.1 to 3.7% (Table 2), although RTV incidences were relatively high on the farm. The overall incidences of GSV and RSV were low; the percentage of infective BPH was also low.

Detection by ELISA of virus-carrying BPH caught by high beam trap (*Plant Pathology and Entomology*). The enzyme-linked immunosorbent assay (ELISA) was applied to detect GSV and RSV in individual migrating BPH caught daily by a high beam light trap. All BPH were tested if the daily number was less than 54.

Use of immunoglobulin gamma from antiserum for GSV and RSV showed 1.2% of 2,688 BPH tested were carriers of GSV and 4.0% RSV (Table 3). About 0.4% carried both viruses.

This study is significant for epidemiology of rice virus vectors. Similar studies are being conducted on BPH caught by sweep nets in Laguna.

Infectivity of field-collected green leafhopper (*Plant Pathology*). High RTV incidences in some IR varieties were observed in and around IRRI in 1983. Infectivity tests of *N. virescens* collected from fields with more than 80% RTV infection were conducted to determine whether the insects' transmissive ability increased.

GLH were collected in RTV-diseased fields planted to IR42 and Sinandomeng. They were immediately tested for their infectivity on RTV-susceptible TN1, IR42, and RTV-resistant IR54. The results are in Table 4.

Some insects were given 2-d feeding time on diseased plants from fields with more than 80% RTV and their infectivity was compared with that of a greenhouse colony. Infectivity of the field colony on IR42 was lower than that of the greenhouse colony (Table 5). There is no remarkable change in GLH's ability to transmit RTV to TN1, IR42, and IR54 even when the insects were obtained from severely infected fields planted with the same variety.

Incidence of RTV complex in the field. (*Plant Pathology*). Occurrence of the RTV complex in

Table 4. Infectivity of field-collected *N. virescens* tested immediately after collection on TN1, IR42, and IR54, 1983.

Collection site	Variety[a] planted	Test variety	*N. virescens* Tested (no.)	Infective No.	Infective %
Bay, Laguna	IR42	TN1	285	89	31.22
		IR42	301	70	23.26
		IR54	276	21	7.61
Maahas, Laguna	IR42	TN1	111	34	30.63
		IR42	116	19	16.38
		IR54	108	17	15.74
Calauan, Laguna	Sinandomeng	TN1	76	13	17.10
		IR42	76	8	10.52
		IR54	71	8	11.27

[a]RTV incidence of more than 80%.

Table 5. Comparative infectivity of field-collected and greenhouse-reared *N. virescens*. 1983.

Colony[a]	Collection site and variety planted	Test variety	*N. virescens*[b] Tested (no.)	Infective No.	Infective %
Field	IRRI, IR42	TN1	120	108	90.0
		IR42	119	107	89.9
Field	IRRI, UPRi-2	TN1	117	108	92.3
		IR42	118	92	77.9
Field	Bay, Laguna, IR42	TN1	90	64	71.1
		IR42	112	78	69.6
Green-house	IRRI, TN1	TN1	107	86	80.3
		IR42	108	85	78.7

[a]Except for greenhouse colony, insects were collected from fields with more than 80% RTV incidence. [b]Acquisition access time of 2 d on diseased plants obtained from site of collection.

naturally infected rice varieties was studied in 1982 WS when a high incidence of RTV occurred at IRRI. Leaves from diseased and healthy-looking plants were collected from infected fields and the latex test determined presence of RTV complex. Of 326 leaf samples with typical RTV symptoms, 325 were infected with both RTBV and RTSV, and 1 by RTBV alone. Plants showing typical RTV symptoms in the field were generally infected with both RTBV and RTSV. Of 195 leaves sampled from healthy-looking plants, 105 contained RTSV alone (Table 6).

Generally, greenhouse tests show low RTSV infection even when virus sources are infected with both RTBV and RTSV. Once RTSV is isolated, however, it is easily transmitted by leafhoppers. The unusually high incidence of RTSV in the field indicates that as an independent virus disease, RTSV is spreading at IRRI. This is the first report on the natural occurrence of RTSV in countries where RTV occurs except in Japan where it is called rice waika virus.

The field reaction of IR varieties (replicated yield trial - 1983 WS - unprotected) to RTV complex was determined using the same procedure. Leaf samples from all plants in each variety were tested. The incidence of RTV complex varied according to variety (Table 7).

CHEMICAL CONTROL OF FUNGAL DISEASES

Plant Pathology Department

An experiment at an upland rainfed field in Santo Tomas, Batangas, during 1983 WS tested four fungicides used to control BS, grain discoloration,

Table 6. Incidence of RTBV and RTSV on some varieties with and without RTV symptoms as detected by latex test. IRRI, 1983.

Variety	With RTV symptoms: Leaves tested (no.)	RTBV + RTSV	RTBV	RTSV	None	Without RTV symptoms: Leaves tested (no.)	RTBV + RTSV	RTBV	RTSV	None
IR8	50	50	0	0	0	50	0	0	17	33
IR22	75	75	0	0	0	75	3	0	53	19
IR36	71	71	0	0	0	29	2	0	23	4
IR42	61	60	1	0	0	10	2	0	6	2
UPL-Ri 2	69	69	0	0	0	31	6	2	6	17
Total	326	325	1	0	0	195	13	2	105	75

Table 7. Field reaction of IR varieties[a] to RTV complex. IRRI, 1983.

Variety	Plants tested (no.)	Plants (%) reacting to			
		RTBV + RTSV	RTBV	RTSV	None
IR5	42	50	5	43	2
8	25	96	0	4	0
20	45	20	60	67	13
22	33	20	60	21	3
24	43	0	58	2	40
26	36	6	19	0	75
28	49	43	14	20	23
29	48	21	13	10	56
30	49	18	29	8	45
32	48	56	11	25	8
34	53	73	0	19	8
36	40	45	0	40	15
38	50	40	28	14	18
40	49	12	53	4	31
42	45	91	0	9	0
43	42	71	10	2	17
44	41	71	0	17	12
45	36	86	0	14	0
46	50	96	2	2	0
48	43	88	0	12	0
50	49	19	14	22	45
52	31	19	10	42	29
54	50	18	10	36	36
56	44	14	11	11	64
58	30	20	0	43	37
60	52	13	13	27	47
TN1	63	95	0	3	2

[a]Replicated yield trials, 1983 WS (Block 400, unprotected).

and neck Bl on IR50. Captafol (50% WP), chlorothalonil (75% WP), mancozeb (80% WP), and edifenphos (50% EC) were applied three times at weekly intervals beginning at late booting stage.

Table 8. Effects of 4 fungicide treatments on BS, grain discoloration, neck Bl, and yield in IR50 at an upland rainfed site, 1983.

Treatment[a]	BS (%)[b]	Grain discoloration (%)	Neck Bl infection (%)	Yield (t/ha)
Captafol (50% WP)	37.7 bc	61.8 bc	46.2 b	2.3 bc
Chlorothalonil (75% WP)	36.7 bc	54.9 b	38.3 b	2.6 ab
Mancozeb (80% WP)	40.6 c	57.6 b	41.9 b	2.5 ab
Edifenphos (50% EC)	12.7 a	45.8 b	4.2 a	3.0 a
Unsprayed BS-inoculated check	55.2 d	82.5 c	68.2 c	2.0 c
Unsprayed uninoculated check	48.4 c	42.1 a	63.2 c	2.2 bc

[a]Fungicides were applied 3 times at 1.0 kg or litre of formulated product per ha. [b]Percentage flag leaf area with BS symptoms.

Three days after the first chemical spray, BS fungus was inoculated using a mixture of two virulent isolates. Bl occurred naturally with inoculum from an adjacent experiment.

Compared to the three other fungicides and the unsprayed inoculated check edifenphos significantly reduced BS infection on the flag leaves (Table 8). All treatments had less grain discoloration than the check. Edifenphos was best for neck Bl control although other chemical treatments were significantly better than the unsprayed checks. Edifenphos-treated plots yielded significantly higher than all other treatments.

Table 9. Effect of fungicide sprays on fungal diseases and yield of IR442-2-58 at an irrigated lowland site, 1983.

Treatment	Sprays[a]		Bl[b]		NBLS[c]	ShR	Yield (t/ha)
	Number	Rate	Lesions/ tiller	Neck infection (%)			
Edifenphos (50% EC)	6	1.0	22.8 a	0.9 a	0.1 a	0.7	3.8 ab
	6	0.5	35.2 b	2.8 abc	0.3 ab	0.9	3.5 ab
	6	0.25	38.2 bc	9.3 d	0.5 b	0.8	3.4 ab
	3	0.5	51.0 d	4.8 c	0.9 c	0.8	3.5 ab
Benomyl (50% WP)	6	1.0	35.5 b	1.8 ab	0.1 a	0.5	4.2 a
	6	0.5	41.1 bcd	3.4 bc	0.1 a	0.7	3.9 ab
	6	0.25	40.3 bcd	9.3 d	0.1 a	0.8	3.0 b
No chemical (check)			49.6 bc	24.4 e	2.8 d	1.5	2.9 b

[a]Rates in formulated product/ha. [b]Tillers assessed 1 wk after booting stage; neck infection assessed at harvest. [c]Rated on SES scale of 0 to 9: 0 = no incidence, 9 = 51 to 100% infection.

In a DS experiment in a lowland irrigated field in Calauan, Laguna, edifenphos and benomyl were tested at various rates for Bl control on IR442-2-58. Both reduced naturally occurring leaf and neck Bl compared to the check (Table 9). Benomyl at the highest rate produced yields statistically higher than those of the check (difference of 1.3 t/ha). The treatments reduced NBLS but had no significant effect on ShR. Neck Bl was controlled by the three-spray edifenphos treatment beginning at heading.

An IRRI field experiment evaluated IR42 yield loss from bakanae disease by using fungicide seed

Table 10. Effect of fungicide seed treatment on bakanae control and grain yield.[a]

Treatment	% with symptoms[b]			Yield (t/ha)
	Dapog bed seedlings	Field		
		Tillers	Hills	
Thiophanate methyl (70% WP)	0.3 a	0.06 a	0.6 a	6.2 a
Benomyl (50% WP)	0.4 a	0.04 a	0.4 a	5.8 ab
No chemical	16.5 b	7.87 b	33.3 b	4.7 b

[a]Mean of 4 replications. [b]Dapog bed reading taken 18 DAS; field readings taken 8 wk after transplanting.

Table 11. Viability of *R. solani* sclerotia collected after harvest from irrigated soil with different levels of ShB infection. IRRI, 1983.

Disease severity[a]	Sclerotia[b]			
	No.	Viable	Nonviable	
			With bacteria	Without bacteria
0-0.1	5	2	3	0
0-3	15	5	5	5
5-7	56	32	14	6

[a]Based on SES. [b]Per 0.0625 m^2 of soil; mean of 4 replications.

Table 12. Origin of groups of bacterial isolates antagonistic to the growth of *R. solani*. 1983.

Origin	Isolates (no.) with antagonistic activity[a]	% of total
Sclerotia	46	61.33
Rhizosphere soil of healthy rice plants	11	14.66
Partially decomposed healthy tissues	9	12
Paddy water	7	9.33
Rhizosphere soil of infected plants	2	2.66
Total	75	

[a]Based on inhibition zone.

Table 13. Effect of seed treatment with fluorescent and nonfluorescent bacteria on incidence and severity of ShB. 1983.

Treatment[a]	Incidence[b] (%)		Severity (lesion length, cm)	
	Trial 1	Trial 2	Trial 1	Trial 2
Pathogen alone	93.7	97.53	9.7	4.18
Pathogen + fluorescent type of bacteria				
Pathogen + In-b-4	81.4	79.34	5.3	3.09
Pathogen + In-b-20	84.7	72.44	4.1	3.28
Pathogen + In-b-22	86.5	70.92	2.6	3.57
Pathogen + In-b-27	87.0	83.28	4.8	3.91
Pathogen + In-b-23	89.2	85.29	3.6	2.66
Pathogen + In-b-24	91	77.88	2.8	3.20
Pathogen + nonfluorescent type of bacteria				
Pathogen + In-b-17	60.2	69.47	1.7	3.24
Pathogen + In-b-9	80.9	89.88	3.7	4.0
Pathogen + In-b-3	86.3	71.58	4.0	3.07

[a]Pathogen and autoclaved soil were mixed together then sown with IR36 seeds treated with antagonistic bacteria for 10 min (1 X 10^9 cells/ml). [b]Data were taken 26 DAS.

Table 14. Effect of seed treatment with fluorescent and nonfluorescent bacteria on sclerotia produced by ShB pathogen. 1983.

Treatment[a]	No. of sclerotia produced/40 plants[b]			
	I	II	III	IV
Pathogen alone	2	13	15	7
Pathogen + fluorescent type of bacteria				
Pathogen + In-b-4	8	0	0	0
Pathogen + In-b-27	0	0	0	0
Pathogen + In-b-22	0	0	17	0
Pathogen + In-b-24	2	0	0	0
Pathogen + In-b-20	0	0	21	8
Pathogen + In-b-23	3	11	34	16
Pathogen + nonfluorescent type of bacteria				
Pathogen + In-b-9	0	3	14	0
Pathogen + In-b-3	0	0	21	14
Pathogen + In-b-17	0	5	12	0

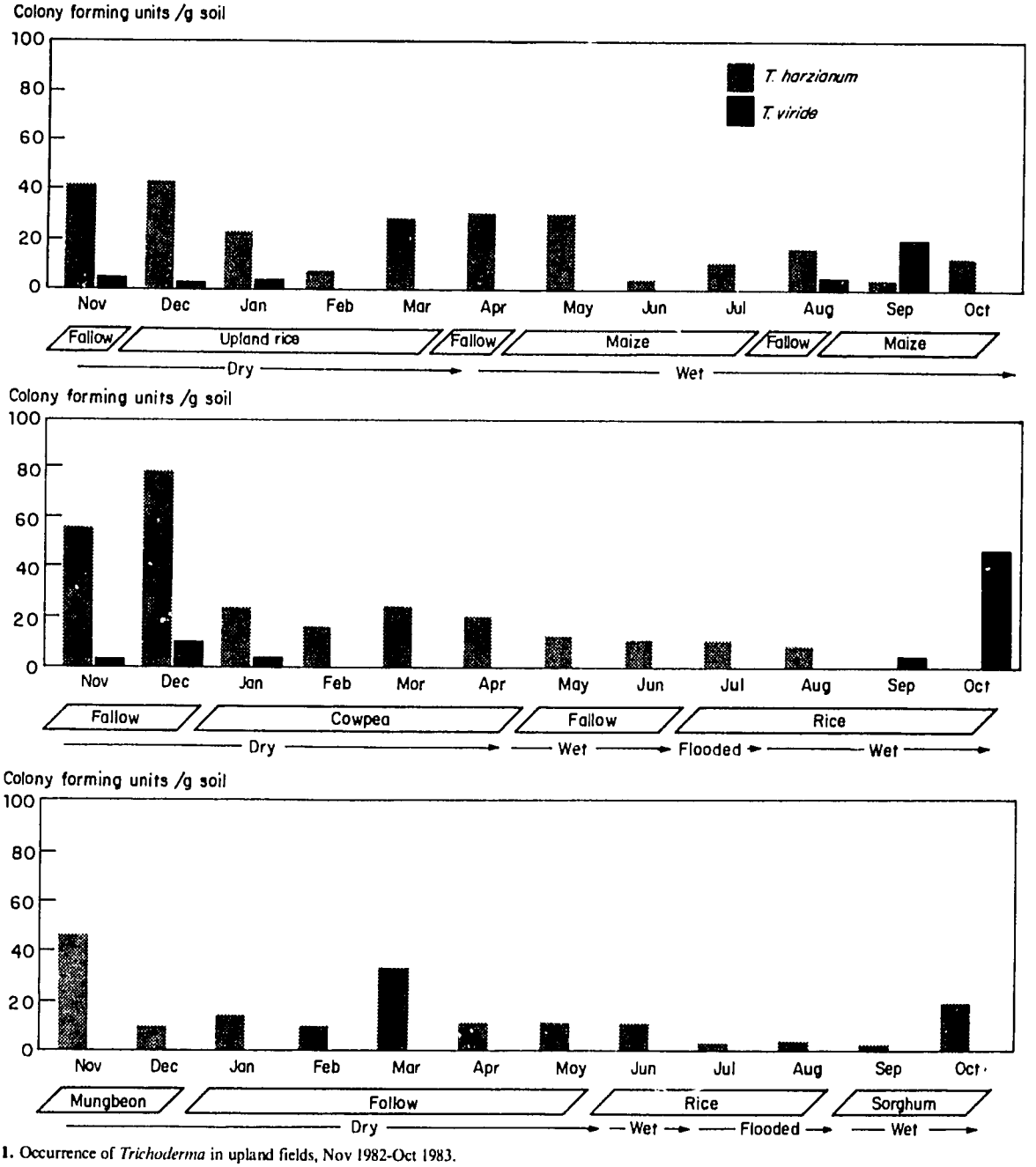
[a]Pathogen and autoclaved soil were mixed together then sown with IR36 seeds treated with antagonistic bacteria for 10 min (1 X 10^9 cells/ml). [b]Data were taken 2 DAS.

treatments and naturally infected seed. Treatments were benomyl (50% WP) at 1.5 g formulated product (fp)/1.5 litre suspension per kg seed, thiophanate methyl at 3.0 g fp, and an untreated check. Both fungicides controlled the disease and the thiophanate methyl treatment resulted in significantly higher yield (Table 10), presumably from bakanae control.

BIOLOGICAL CONTROL

Plant Pathology Department

Influence of antagonistic bacteria on sheath blight pathogen. Sclerotia were the primary source of inoculum for ShB infection. The population and viability of *Rhizoctonia solani* sclerotia collected after harvest from irrigated soil with different levels



1. Occurrence of *Trichoderma* in upland fields, Nov 1982-Oct 1983.

of ShB infection were determined by collecting sclerotia samples from the upper 3 cm of 25- × 25-cm surface soil. When the disease was severe, the number of sclerotia was also high (56/.0625 m^2) (Table 11). Sclerotia viability was 57.1%. Of the nonviable sclerotia, 50-100% were colonized by bacteria, most of which inhibited mycelial growth of the pathogen (Table 12). Of 75 isolates showing antagonistic activity, 61.33% were isolated from sclerotia.

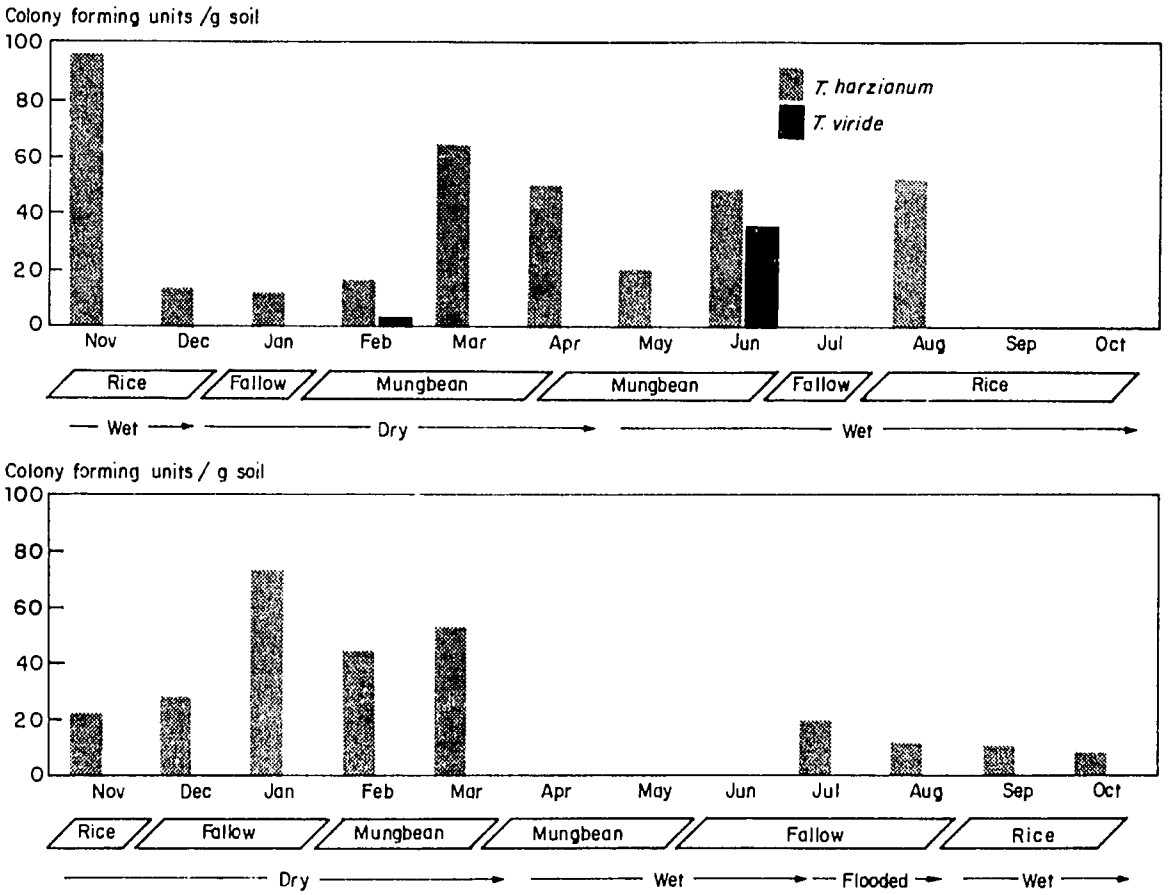
The influence of antagonistic bacteria on ShB development was further evaluated in the greenhouse. IR36 seeds were soaked in bacterial suspension (about 10^9 cells/ml) for 10 min before sowing in trays filled with a mixture of sterilized soil and 7-d-old inoculum of *R. solani* isolate LR-1. Disease incidence and severity were measured 26 DAS and the sclerotia attached to the plant were counted. Both nonfluorescent and fluorescent bacteria reduced disease incidence and severity compared with plants without bacteria (Table 13). Nonfluorescent bacteria appeared more effective than the fluorescent. Bacteria also affected sclerotia production of the pathogen (Table 14).

***Trichoderma* sp. in upland rice fields.** A survey determined the presence of *Trichoderma harzianum* and *T. viride* in soils representative of different rice culture types: upland, rainfed, and irrigated. The number of *Trichoderma* was highest in upland soil (Fig. 1). *Trichoderma* occurred more often in a rainfed lowland field when an upland crop was planted after rice (Fig. 2) than when only rice was planted (Fig. 3). *T. harzianum* was more abundant than *T. viride*.

INFLUENCE OF RICE INSECTS ON RICE DISEASES

Plant Pathology and Entomology Departments

Rice grain discoloration due to pests. *Identification of pest species.* Insect pests which cause grain

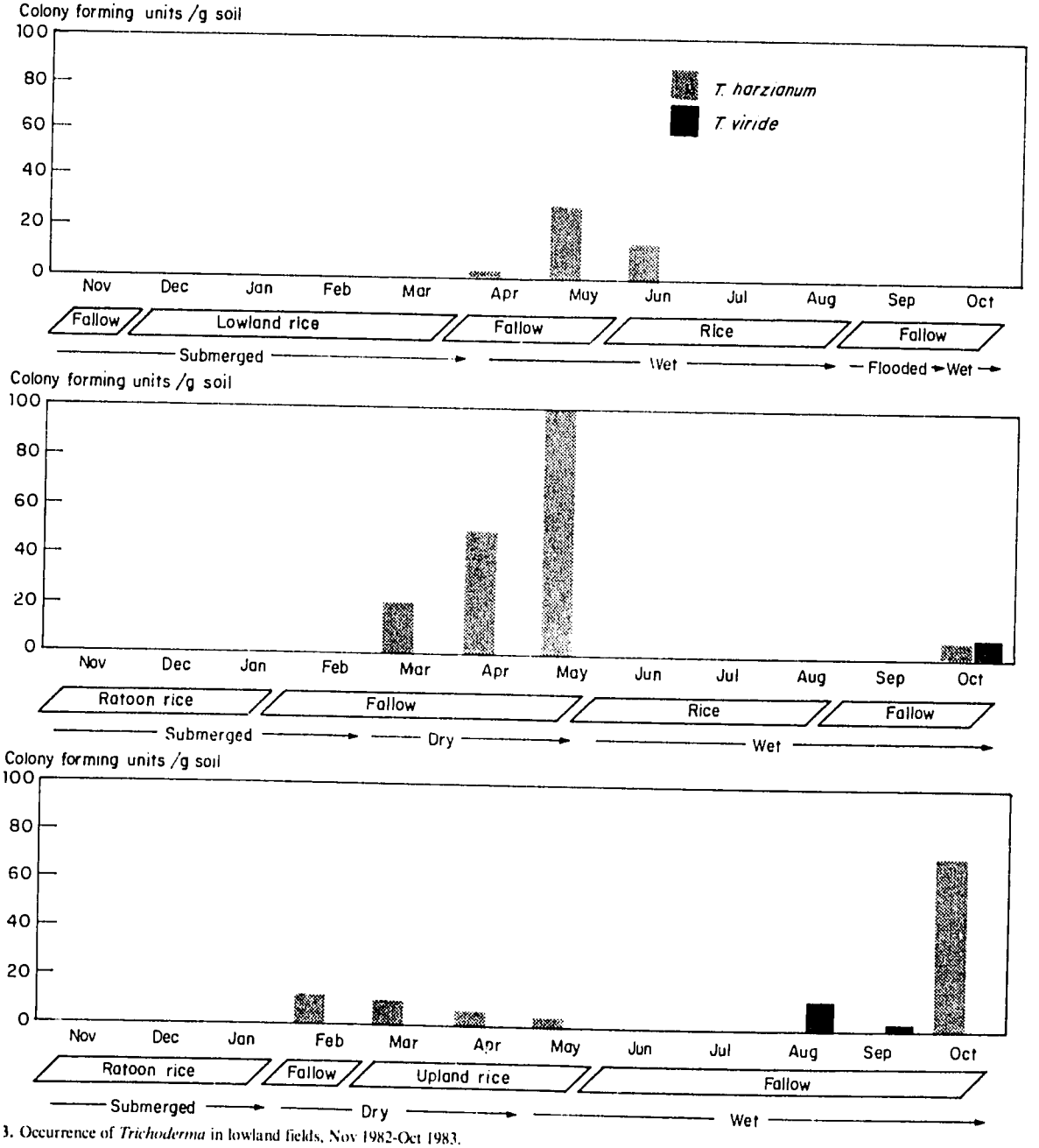


2. Occurrence of *Trichoderma* in rainfed fields, Nov 1982-Oct 1983.

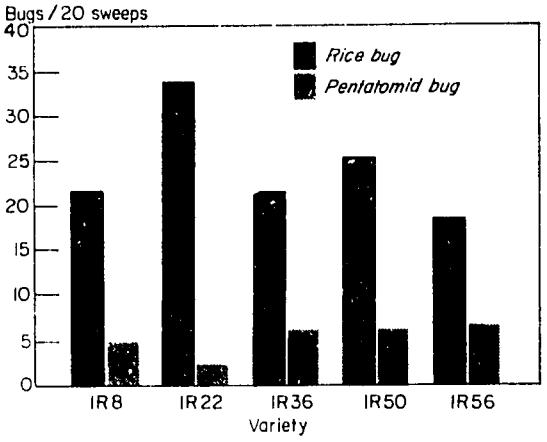
discoloration were collected with sweep nets at IRRI fields. Identified species were *Leptocorisa oratorius*, *Menida varipennis*, *Erysacoris ventralis*, and *Nezara viridula*. *L. oratorius* was the most abundant in December 1983 (Fig. 4).

IR56 was most severely discolored in WS (Table 15). The blotter method identified these fungi associated with rice grain discoloration: *Trichoconiella padwickii*, *Curvularia lunata*, *Drechslera oryzae*, *Fusarium* sp., *Phoma* sp., and *Sarocladium oryzae* (Table 16).

Pathogenicity test of associated organisms. To test the pathogenicity of organisms associated with rice grain discoloration, IR22 and IR36 were inoculated separately at the flowering stage with about 80,000 spores/ml of different pathogens.



3. Occurrence of *Trichoderma* in lowland fields, Nov 1982-Oct 1983.



4. Population density of RB and a pentatomid bug at milk stage of varieties at the new IRRI farm, 1983 DS.

Table 15. Discoloration of rice grains from IRRI field in 1983 WS.

Variety[a]	Grains (%)	
	Discolored	Healthy
IR56	60.0	40.0
IR8	27.0	73.0
IR54	15.4	84.6
IR36	13.0	87.0

[a]3,000 grains/variety.

Table 16. Average percentage of organisms associated with rice grain discoloration on 4 varieties. 1983 WS.

Organism	Percentage isolated[a]			
	IR36	IR54	IR8	IR56
Trichoconiella padwickii	26.0	40.0	15.0	17.8
Curvularia lunata	15.0	7.9	10.0	3.0
Drechslera oryzae	–	5.3	1.0	–
Fusarium solani	0.5	–	–	6.75
Fusarium equiseti	3.8	2.5	4.5	13.6
Fusarium semitectum	13.5	3.1	6.66	15.5
Fusarium moniliforme	–	–	–	0.5
Alternaria tenuis	–	–	1.0	0.5
Alternaria longissima	0.5	–	5.5	2.33
Phoma sp.	3.0	1.75	4.3	3.0
Sarocladium oryzae	–	0.5	4.5	0.83
Nigrospora sp.	–	0.5	–	0.66
Pithomyces	–	1.0	0.5	–
Gerlachia oryzae	–	1.0	1.0	–
Cladosporium sp.	–	0.83	0.5	0.5
Penicillium sp.	–	0.5	–	–
Aspergillus sp.	0.5	–	0.5	–
Nematode sp.	–	1.0	–	–

[a]Av of 3 replications. 200 seeds observed/variety.

Table 17. Degree of grain discoloration caused by different organisms inoculated on IR22 and IR36. 1983.

Organism	Discoloration[a]	
	IR22	IR36
Curvularia lunata	2.0	–
Phoma sp.	2.0	–
Drechslera oryzae	3.0	–
Fusarium solani	–	2.0
Trichoconiella padwickii	–	3.0
Sarocladium oryzae	–	2.3
Alternaria tenuis	–	2.0
Nigrospora oryzae	–	1.0
Control	–	0

[a]Av of 3 replications. Severity of discoloration: 0-3. – = not inoculated with organisms.

IR22 was inoculated with *D. oryzae*, *C. lunata*, and *Phoma* sp., and IR36 was inoculated with *Fusarium solani*, *T. padwickii*, *Alternaria tenuis*, and *Nigrospora oryzae*. The plants were incubated at 23° C for 30 h, and the severity of discoloration was recorded 3 WAI. Each pathogen produced a different degree of discoloration (Table 17).

Grains were inoculated with the organisms. When reisolated, the organisms were the same (Table 18).

Interaction between rice bugs and C. lunata. IR36 was infested at early milk stage with 5th-instar RB 2 d before spraying with *C. lunata*. Treatments were different combinations of RB and *C. lunata*. Yield loss data were gathered 30 DAI. A high percentage of unfilled grains accompanied RB infection with or without *C. lunata* infection. Grain

Table 18. Percentage of organisms isolated from those previously inoculated on IR22 and IR36.

Organism	%[a]	
	IR22	IR36
Curvularia lunata	50.0	–
Phoma sp.	68.0	–
Drechslera oryzae	68.0	–
Fusarium solani	–	98.0
Trichoconiella padwickii	–	88.0
Sarocladium oryzae	–	66.3
Alternaria tenuis	–	56.6
Nigrospora oryzae	–	37.3
Control	–	0

[a]300-400 seeds observed/treatment. – = not inoculated with organisms.

discoloration was significantly higher on treatments where both pests were present than when they occurred singly, but *C. lunata* infection contributed more to grain discoloration (Table 19).

Brown planthopper and sheath blight pathogen interaction. A study investigated the interaction between insect infestation and disease pathogen infection on rice plants. IR22 and TN1 at maximum tillering stage were infested with 100 4th-instar BPH per pot containing 1 hill of 10 tillers. They were inoculated with a culture of *R. solani*, the ShB pathogen, 7 DI.

Disease on both varieties was significantly more severe when both BPH and the ShB pathogen were present than when the ShB pathogen was alone (Table 20).

Degree of hopperburn on both varieties was significantly higher when BPH and ShB pathogen were combined than when BPH was alone (Table 21).

The apparent synergistic interaction between BPH and *R. solani* will be studied further.

Table 19. Effect of RB damage and *C. lunata* infection on grain discoloration and production of unfilled grains of IR36. 1983.

Treatment	Mean[a]	
	Discoloration incidence[b]	Unfilled grains (%)
20 RB + *Curvularia*	8.5 f	73.75 c
14 RB + *Curvularia*	6.5 ef	72.50 c
8 RB + *Curvularia*	5.0 de	70.00 c
Curvularia	4.0 cd	51.00 b
20 RB	4.5 c	74.75 c
14 RB	3.0 ab	75.00 c
8 RB	2.5 ab	55.00 b
Control	1.5 a	18.50 a

[a]Av of 4 replications. [b]Discoloration incidence scale: 0-9.

Table 20. Effect of BPH infestation and ShB infection on disease severity of IR22 and TN1. 1983.

Treatment	Av disease severity[a]	
	IR22	TN1
BPH + ShB[b]	5.33 c	7.00 d
BPH[c] + ShB[b]	4.00 c	4.25 c
BPH only	0.00 a	0.00 a
ShB only[b]	2.75 b	3.25 b
Control	0.00 a	0.00 a

[a]Disease severity: 1-9. Av of 4 replications. [b]Inoculation of *R. solani* 7 d after BPH infestation. [c]BPH was removed 7 DI, before inoculation of *R. solani*.

Table 21. Effect of BPH infestation and ShB infection on degree of hopperburn on IR22 and TN1. 1983.

Treatment	Av degree of hopperburn[a]	
	IR22	TN1
BPH + ShB[b]	7.83 c	7.19 c
BPH[c] + ShB[b]	0.00 a	0.25 a
BPH only	5.67 b	4.75 b
ShB only[b]	0.00 a	0.00 a
Control	0.00 a	0.00 a

[a]Degree of hopperburn: 1-9. Av of 4 replications. [b]Inoculation of *R. solani* 7 d after BPH infestation. [c]BPH were removed 7 DI, before inoculation of *R. solani*.

Table 22. Transmission of RTBV and RTSV by *N. virescens*[a] which were allowed sequential accesses to plants infected with RTBV or RTSV alone. 1983.

Acquisition access		Plants (no.) with viruses[b]			
1st for 1 d	2d for 8 h	RTBV + RTSV	RTBV	RTSV	None
RTSV	None	0	0	25	10
None	RTSV	0	0	7	8
RTSV	RTBV	31	11	2	6
RTBV	None	0	0	0	39
None	RTBV	0	0	0	14
RTBV	RTSV	0	0	24	20

[a]Three insects/seedling for overnight inoculation access. [b]Detected serologically by latex test.

VIRUS-VECTOR INTERACTIONS

Plant Pathology Department

Transmission of rice tungro virus complex by *N. virescens*. The GLH transmitted RTBV and RTSV singly or together from rice plants infected with both RTBV and RTSV. RTBV was not transmitted from plants infected with RTBV alone, but RTSV was transmitted alone. RTBV transmission occurred when GLH fed previously on RTSV-infected plants (Table 22). The minimum acquisition feeding period for RTSV or hypothetical "helper component" for RTBV transmission was about 1 h. RTBV was acquired after 15 min access. The leafhopper retained the transmitted RTSV for 1 d. But when the same leafhoppers which failed to transmit RTSV had access to RTBV-infected

plants, RTBV transmission occurred for 7 d. The "helper component" was retained by the leafhopper long after it stopped transmitting RTSV. It was not clear whether the "helper component" was RTSV itself or a substance produced in the plant as a result of RTSV infection.

Determination of RTBV and RTSV infection. Serological tests are used to determine infection by RTBV, RTSV, or both viruses in RTV-infected plants. Insect transmission and disease symptoms were used to determine whether plants were infected by the RTV complex.

Seven-d-old TN1 seedlings were inoculated by *N. virescens* after feeding on plants infected with both RTBV and RTSV. One mo after inoculation, plants showing symptoms were separated from the healthy-looking plants. Ten GLH fed on each diseased plant for 1 d and then were individually tested for their infectivity to healthy TN1 seedlings. Source plants that transmitted disease were designated as RTBV- and RTSV-infected and those that did not, as RTBV-infected.

Each healthy-looking plant separated earlier was also used as a virus source for 1 d feeding by virus-free *N. virescens* followed by another 1-d feeding on plants designated as RTBV-infected. Source plants that infected TN1 test seedlings were designated as RTSV-infected and those that gave negative results, as healthy plants.

Of 68 inoculated plants, 31 were infected with RTBV and RTSV, 22 by RTBV alone, and 1 by RTSV alone. The 100% reliability of this detection method for RTV complex was verified by the latex test.

In another test using plants inoculated with RTSV alone, 12 out of 14 plants were identified as infected by RTSV by both methods.

DETECTION OF TUNGRO-ASSOCIATED VIRUSES BY ENZYME-LINKED IMMUNOSORBENT ASSAY

Plant Pathology Department

An experiment was set up to see if ELISA could detect RTSV and RTBV. IgG fraction was isolated from each antiserum by AS precipitation and diethylamino ethyl cellulose column chromatography. The IgG was tagged with the enzyme alkaline phosphatase. Plants infected with RTV were homogenized and the extracts were tested directly in ELISA. ELISA plate was coated with IgG against RTBV or RTSV, and the virus in the sample was selectively trapped. Enzyme-IgG conjugate was complexed with the trapped virus. The virus was detected visually or photometrically at 405 nm by the coloration of added substrate.

Healthy leaf extracts had low absorbance (0.00 to 0.09), while infected leaf extracts turned an intense yellow and had significantly higher absorbances (Table 23). ELISA can be used to differentiate healthy from RTV diseased rice plants. The absorbance of homogenates of plants infected with RTSV alone or with RTSV + RTBV were lower than those from RTBV-infected plants. This indicates that RTSV is more difficult to detect than RTBV.

PURIFICATION AND SEROLOGY OF RICE GRASSY STUNT VIRUS 2

Plant Pathology Department

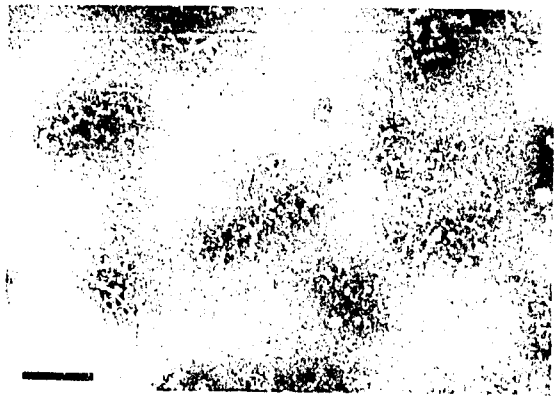
At the Institute of Plant Virus Research in Japan, rice grassy stunt virus 2 (GSV 2) was purified following the procedure for purifying RGSV. The purified virus fraction had a maximum absorbance of 260 nm and minimum at 246-247 nm, which is typical of a nucleoprotein. The average ratio of UV absorption at 260 nm and 280 nm (A 260/280) for purified virus was about 1.29. Virus yields from 300-400 g of infected plant tissue ranged from 0.85-2.0 OD260 units. Electron microscope examination of purified virus particles, negatively stained with uranyl acetate (1%), revealed filamentous particles of various lengths (Fig. 5).

Rabbits were immunized with purified virus and antisera with a titer of 1:640 were obtained.

Table 23. Reactions of RTSV-, RTBV-, or RTSV + RTBV-infected TN1 to IgG isolated from an antiserum for RTSV or RTBV. IRRI, 1983.

Sample	Reaction[a] to	
	RTSV-IgG	RTBV-IgG
Healthy (control)	- (0.00)	- (0.00)
RTSV-infected	++ (0.24)	- (0.00)
RTBV-infected	- (0.00)	+++ (2.14)
RTSV + RTBV-infected	++ (0.69)	+++ (1.87)

[a]Visual evaluation: - = colorless to faint yellow (background), ++ = yellow; +++ = dark yellow. Numbers in parentheses are absorbances at 405 nm.



5. Electron micrograph of purified GSV strain 2 stained with uranyl acetate. 1983. The bar represents 100 nm.

Serological tests were performed by precipitin ring interphase and double gel infusion tests. In the ring interphase test, antiserum against GSV 2 reacted strongly with GSV 1 and GSV in Japan. Reciprocal tests using antiserum to GSV produced similar results. In double diffusion tests, a single band was developed between antiserum to GSV and both GSV 2 and GSV in Japan. Reaction bands fused together (Fig. 6a). Reaction bands between the antiserum to GSV 2, and GSV 1 and GSV 2 also fused (Fig. 6b). GSV 2 is serologically very close to and indistinguishable from GSV 1 and GSV in Japan.

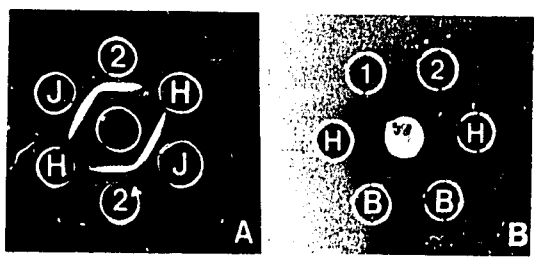
PHYSIOLOGY OF RICE PATHOGEN, NUTRITION OF HOST PLANT, AND DISEASE DEVELOPMENT

Plant Pathology Department

Pathogen physiology. Twelve isolates from different race groups of *Cercospora oryzae* (leaf spot) showed great variation in their use of C and N sources. Sucrose, fructose, and raffinose as C sources and glutamic acid, ornithine, arginine, aspartic acid, and NH_4Cl as N sources were utilized by at least six isolates. Sporulation of the isolates varied with light treatments and temperature, and only one isolate showed heavy sporulation. Continuous exposure to light and incubation at 25-28° C favored linear growth of the isolates.

Conidia began germination after 4 h at 15-35° C. No conidia germinated below 98.7% RH at 25-35° C. Growth was observed from pH 2.0 to 11.0 and sporulation from pH 3.0 to 11.0.

Effects of host mineral nutrition on disease. N form greatly influenced disease. Ammonium N favored disease development compared to nitrate N in IR42 and MI-273 plants grown in culture solutions with varying ratios of the two N forms (Table 24). Increasing Si reduced disease. Increasing N increased disease but only in treatments having ammonium N as the predominant N form. Increasing K and Ca concentrations decreased disease severity (Table 25). Mg had no effect.



6. Serological reactivity of GSV strain 1, strain 2, and the Japan isolate. 1983. A. The center well contains antiserum to Japan isolate and the peripheral wells contain Japan isolate (J), strain 2 (2), and clarified healthy sap (H). B. The center well contains antiserum to strain 2 and the peripheral wells contain isolate 1 (1), isolate 2 (2), clarified healthy sap (H), and buffer (B).

MANAGEMENT OF HOST RESISTANCE

Plant Pathology, Agronomy, and Plant Breeding Departments

Blast control using upland variety mixtures. Inoculation trials were conducted by the Plant Pathology Department of IRRI and in a farmer's upland field near Santo Tomas, Batangas, to evaluate three mixture sets, each composed of three varieties or breeding lines. The sets were also evaluated in the replicated upland yield trials

Table 24. Effect of N source and N-Si levels on development of Cercospora leaf spot. 1983.

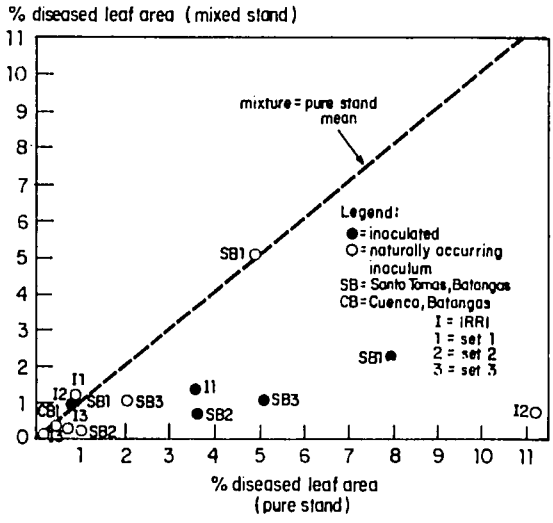
Variety	N level (ppm)	Leaf area infected (%)			
		80% NH_4:20% NO_3		20% NH_4:80% NO_3	
		30 ppm Si	60 ppm Si	30 ppm Si	60 ppm Si
MI-273	20	42.0	18.5	11.8	3.6
	60	44.1	27.9	9.4	3.2
	120	50.9	38.3	18.0	3.8
IR42	20	18.5	9.7	3.0	0.1
	60	38.3	11.2	4.3	0.4
	120	38.4	7.5	4.5	0.7

Table 25. Effect of K and Ca on Cercospora leaf spot. 1983.

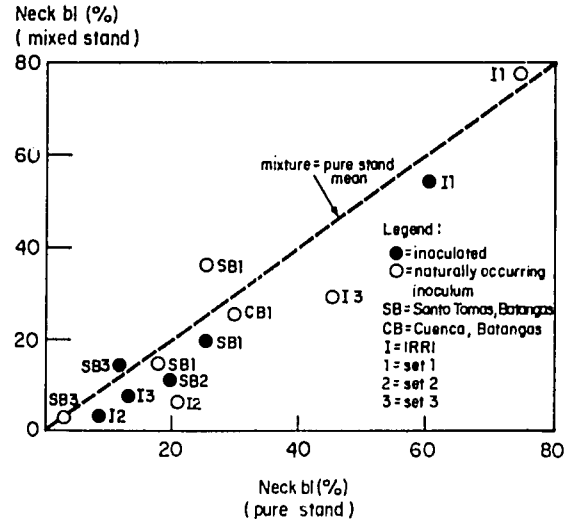
Mineral nutrient	Leaf area infected (%) at given concentration	
	20 ppm	60 ppm
Ca	71.2 a	35.7 b
K	31.1 a	16.3 b

carried out by Agronomy and Plant Breeding. Set 1 had varieties C22, UPLRi3, and UPLRi5; set 2, breeding lines IR3839-1, IR5931-110-1, and IR5929-12-1; and set 3, breeding lines IR6023-10-1-1, IR6115-1-1-1, and IR1001-16-3. The components of each set were sown in pure and randomly mixed stands. In the inoculation trials, dense bands of sorghum were sown between plots to reduce interplot inoculum drift.

In all of the 14 experiments, leaf Bl in the mixed stand was less than the pure stand mean (Fig. 7). But because of variation between plots, the decrease was statistically significant in only two cases. Similarly, in 9 of 13 experiments, neck Bl incidence was numerically less in the mixed stands (Fig. 8), and in 8 of 14 cases yield was higher in the mixed stands (Fig. 9). In general, mixed stands were more effective in reducing leaf Bl than neck Bl. Since neck Bl has a more direct effect on yield loss, mixtures that give better neck Bl control would be more likely to give higher yields. Two possible ways to increase disease control are to use varieties and lines with more dissimilar genetic background than those used in these experiments and to use more than three components in the mixture.



7. Mixed stand values versus pure mean values for leaf Bl (% diseased leaf area) in 14 field trials. 1983.

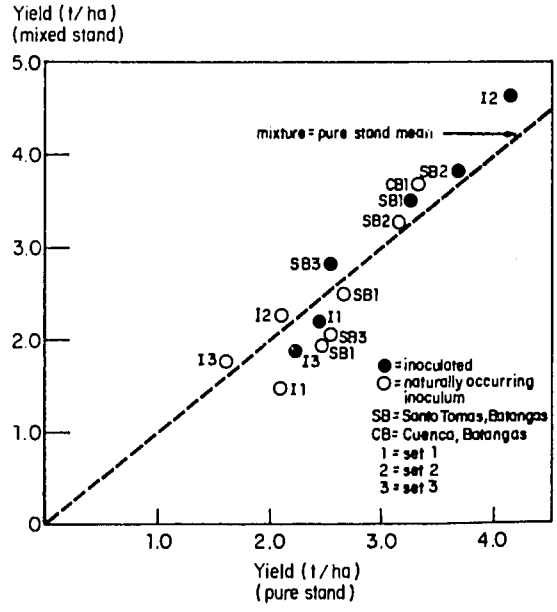


8. Mixed stand values versus pure stand mean values for neck Bl incidence in 13 field trials. 1983.

RICE ROOT NEMATODES IN RICE FIELDS

Plant Pathology Department

Little is known about the influence of nematodes



9. Mixed stand values versus pure stand mean values for yield in 14 field trials. 1983.

on rice production. A joint project was initiated with scientists from C.A.B. Tropical Plant Nematology, Commonwealth Institute of Parasitology, St. Albans, Herts., England, to investigate the occurrence of rice parasitic nematodes. A preliminary survey showed the presence of *Hirschmanniella* spp. in IRRI fields. Nematode population density was highest in the 3-rice cropping fields, than in 2-rice cropping and 1-rice cropping. No difference in nematode density was noted among IR46, IR9729, IR54, and Binato over the sampling period. In the rice garden, nematodes peaked during migration from soil to roots and from roots to soil.

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Control and management of rice pests

Insects

Entomology and Agronomy Departments

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ECOLOGY AND BIOLOGY

Entomology Department

Foodweb of the yellow stem borer. The foodweb of the YSB *Scirpophaga incertulas* in the Philippines comprises 118 species (Fig. 1). Predators (57) outnumbered parasites (38) and secondary natural enemies (23). Dominant predators were spiders and beetles. Principal egg parasites were scelionids *Telenomus rowani* and *T. dignus* and the eulophid *Tetrastichus schoenobii*. Dominant larval parasites were species in genera *Temelucha, Bracon,* and *Tropobracon,* while the main pupal parasite was the ichneumonid *Xanthopimpla stemmator*.

Five orthopterans of the genera *Metioche, Anaxipha*, and *Conocephalus* preyed on eggs. The fungi *Beauveria* and *Cordyceps* attacked the larvae. *Mermithidae*, *Agamermis*, and *Hexamermis* parasitized moths and larvae.

Twenty-three species of hyperparasites were recorded: 57% parasitized spiders, 19% preyed on orthopterans, 14% parasitized hymenopterans, and 5% preyed on mesoveliids. The fungus *Gibellula leiopus* was isolated from the micryphantid spider *Callitrichia formosana* Oi.

Brown planthopper migration. *Short distance.* IRRI collaborated with the UK Tropical Development and Research Institute (TDRI) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture in a program to learn what role migration plays in tropical populations of BPH. The long-term field study ended this year, and findings are summarized below.

- Despite the year-round availability of rice as a potential insect source, migrant activity is strongly seasonal. Flight activities peak during maturity of the WS and DS crops in August-September and March-April.
- Immigration varies between sites within a few kilometres, suggesting that many dispersal flights are highly localized. Activity is less at more isolated sites, and immigration during early crop growth is low. In extensively cultivated areas with more variable planting dates, high levels of immigration can occur during early crop growth.
- Since there is no correlation between immigration rate and population development, this cannot predict future control needs. Visual observation of population development is the only reliable method. Natural enemy action appears to be more significant in determining population size than the initial level of pest immigration. Immigration rates of pest and natural enemies are probably significant.
- Take-off activity peaks at dusk with a lesser occurrence at dawn. Active insects at dusk fly significantly longer. Distribution of their landing times is bimodal with most insects landing soon after take-off and another group before dawn. Second flights are common.
- Flight capacity is strongly affected by the host plant. Insects reared on a resistant rice variety can fly only 50% as long as those reared on a susceptible variety.

Long distance. Migrating BPH and other insects were monitored using 6 wind-propelled, revolving-type nylon nets (0.5 m diam, 2 m long) and 4 cross-shaped sticky traps (0.45 m × 0.45 m). The insects were collected during two interisland boat voyages along fixed commercial routes in 1983 DS and WS.

The DS voyage was 1-8 Mar (Manila-Zamboanga, Davao-Zamboanga-Manila), and the WS trip was 12-18 Oct (Manila-Tablas Is.-Zamboanga-Davao-Dadiangas-Zamboanga-Manila). The delphacids caught are listed in Table 1.

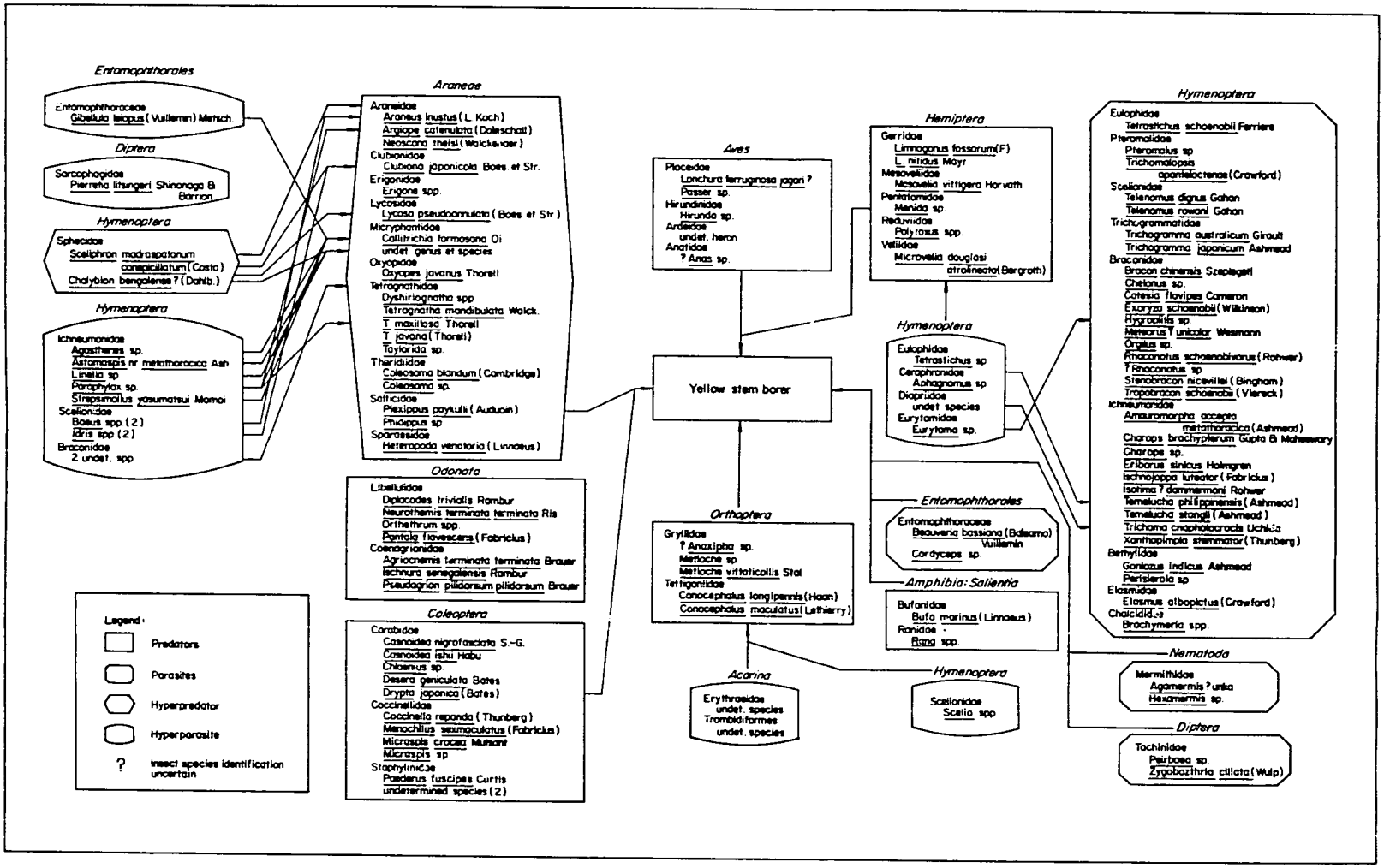
Wing morphism in whitebacked planthopper. Experiments investigated the influence of rice plant age, nymph density (crowding), and parents' wing type on the expression of wing morphism in WBPH *Sogatella furcifera*.

First-instar WBPH nymphs were caged in separate batches of 10, 20, 50, 100, and 150 nymphs each on potted TN1 plants aged 25, 45, 75, and 100 d. Emerging adults were counted according to wing morphs and sex. Each treatment was replicated four times.

For morphometric evaluation, 200 brachypterous females, 200 macropterous females, and 200 macropterous males were examined by calibrated microscopy for length and width of body, thorax, abdomen, and fore and hind wings.

Results showed that macroptery increased as infestation increased. The regression analysis of percent macroptery in relation to nymph density showed a highly significant increase during the plant vegetative phase.

Macroptery also increased significantly with



1. Food web of the YSB *Scirpophaga incertulas* (Walker) in the Philippines.

Table 1. Delphacids caught in nylon nets and sticky traps installed aboard on interisland vessel (M/V Manila City, William Lines) during DS and WS voyages in the Philippines, 1983.[a]

Delphacidae species	Delphacids (no.)	
	DS	WS
Nilaparvata lugens	2	55
Sogatella furcifera	29	46
Cemus sp.	0	1
Harmalia anacharsis	0	1
Necondan sp.	0	3
Nilaparvata bakeri	0	3
Paradelphacodes sp.	0	3
Sogatella longifurcifera	2	6
Sogatella sp.	0	1
Sogatodes geranor	0	2
Sogatodes pusanus	1	10
Stenocranus sp.	0	5
Toya sp.	1	7
Total	35	143

[a]During each voyage, 6 nylon nets and 4 sticky traps were used.

plant age, being twice as high on 100-d plants as on 25-d plants (Table 2).

Biology of black bug species. *Scotinophara latiuscula* Breddin and *S. tarsalis* Vollenhoven, relatives of the Malayan *S. coarctata* and Japanese *S. lurida* black bugs, occur in Laguna, Philippines. *S. tarsalis* is an upland insect that does not feed on rice and whose plant host is *Centrosema pubescens*. *S. tarsalis* is distinguished by its 6 mm size, brown body, light brown antennae, and yellow legs with black femora.

S. latiuscula, which feeds on rice, was studied in the IRRI greenhouse. It developed from egg to adult in 33-57 d. A female lays about 6 clusters of 2-14 eggs (av = 10) arranged in 2 to 3 rows which hatch in 2-7 d. Nymphs undergo 5 instars and complete development in 31-50 d. Adults live 65-150 d.

S. latiuscula is oligophagous as it was successfully reared on *Cyperus difformis*, *C. iria*, *Echinochloa crus-galli*, *Commelina benghalensis*, *Echinochloa colona*, *Echinochloa glabrescens*, *Fimbristylis miliacea*, and *Leptochloa chinensis* besides rice. Development stopped at the second nymphal instar on *Ischaemum rugosum*, *Imperata cylindrica*, *Leersia hexandra*, *Digitaria ciliaris*, *Eleusine indica*, *Monochoria vaginalis*, *Rottboellia exaltata*, *Saccharum spontaneum*, *Sorghum halepense*, and *Sphenoclea zeylanica*.

Populations of *S. latiuscula* are kept at low levels by natural enemies. A scelionid wasp, *Telenomus* sp. nr. *triptus* Nixon, parasitizes the eggs; two bugs — a pentatomid, *Zincrona caerulea* (L.), and a nabid, *Stenonabis tagalica* (Stal) — prey on nymphs.

Sex pheromone. *Trials to identify the yellow stem borer sex pheromones.* Cooperative work with TDRI confirmed that female YSB moths produced a sex pheromone. Further TDRI studies led to its identification and synthesis. Gas chromatography analyses showed peaks corresponding to Z11-16:aldehyde and Z9-16:aldehyde in a consistent 3:1 ratio. IRRI traps baited with a mixture of 750 μg Z11-16:aldehyde and 250 μg Z9-16: aldehyde caught more male moths than those baited with a virgin female moth (Table 3).

Third component of the striped stem borer sex pheromone. The female sex pheromone of the SSB was previously identified and synthesized as a mixture of Z-11-hexadecenal (Z-11-HDAL) and Z-13-octadecenal (Z-13-ODAL). Field trials showed that these two components are essential for male attraction. A third compound (Z-9-HDAL), which dramatically increased the number of males caught in traps, was recently confirmed in IRRI field tests using compounds supplied by Japanese scientists (Table 4).

Table 2. Influence of host plant age on wing morphism in *S. furcifera* at different nymph densities. IRRI, 1982.

Plant age (d)	Macroptery[a] (%) at different no. of nymphs/plant					Mean macroptery (%)
	10	20	50	100	150	
25	4 a	8 c	12 a	24 a	25 ab	14.6 b
45	10 a	12 bc	13 a	24 a	21 ab	16.0 b
75	7 a	21 ab	23 a	24 a	18 b	18.6 ab
100	10 a	32 a	25 a	35 a	38 a	28.0 a

[a]Remaining insects were brachypterous.

Table 3. Catches of male YSB moth in sticky board traps baited with sex pheromone. IRRI, 1983.

Treatment	Catch[a]
750 μg Z11-16 CHO + 250 μg Z9-16 CHO	58 a
750 μg Z11-16 CHO + 250 μg Z9-16 CHO + 50 μg Z11-16 OH	26 b
750 μg Z11-16 CHO + 250 μg Z9-16 CHO + 100 μg Z11-16 OH	10 c
750 μg Z11-16 CHO + 250 μg Z9-16 CHO + 200 μg Z11-16 OH	7 c
Virgin female	21 b
Blank (control)	0 d

[a]From 2 locations in 48 nights.

Mating disruption for striped stem borer control. Trials were conducted using a Hercon laminate formulation (pheromone impregnated in plastic) dosed at 42 mg/2.54 cm^2 to disrupt SSB mating. The laminates were cut into 0.63 × 0.63 cm and attached to rice plants at 2/3 plant height at a density of one piece/m^2. Clipped-wing virgin female moths exposed overnight in the field and then dissected to determine mating status showed that only 20% mated (Fig. 2).

Table 4. Three components of the rice SSB female pheromone. IRRI, 1983.

Components	Males caught[a] (no.)
Z-11-HDAL + Z-13-ODAL	40
Z-11-HDAL + Z-13-ODAL + Z-9-HDAL	959
Virgin female	156
Solvent control (ethyl acetate)	0

[a]From 3 locations at IRRI in Oct 1983 and 63 trap nights (21 nights at 3 locations) (21 X 3 = 63).

DAMAGE ASSESSMENT

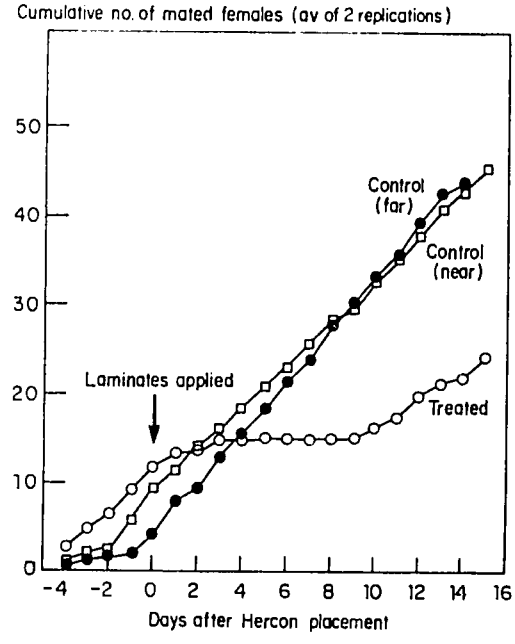
Entomology Department

Survey of rice pests in deepwater rice. The IRRI/Thai Department of Agriculture and Thai Divisions of Entomology/Zoology and Pathology monitored farmers' fields for deepwater rice pests from early seedling stage 1982 to harvest in 1982-83. A complex of leafeaters — flea beetle, leaffolder, hispa, thrips, and RWM — caused minor damage in many fields before flooding. Some BS and Bl infection also occurred. The gryllid *Euscyrtus concinnus* damaged 16% of the fields, a few severely. Gall midge was present at very low levels.

Nematodes were present in 21 of 51 fields before flooding, and 8 species were identified. The root-knot nematode *Meloidogyne graminicola* occurred in each field and was serious in three. Rats cut stems from tillering to harvest.

RSV appeared in flooded fields in August but was less serious than in 1981 (Table 5). Disease was less at the sequential sites and in all survey fields in 1982. BPH numbers in the 1982 preflood period were also lower. Less RSV was probably the main reason for higher 1982 yields in the Nakhon Nayok area.

YSB was the major pest causing widespread yield losses. Despite drier conditions and late flooding, the pattern and degree of stem damage closely resembled that of 1981. Thailand's 2-yr record is very similar to the 4-yr average in Bangladesh 1977-80. This shows that YSB is well adapted to deepwater rice and is a serious pest throughout the region. In the 1982 preflood period, YSB, and dark-headed and pink borers were present in low numbers. Dissections in 15 fields showed a mean of 1.6% damaged stems compared with 0.7% deadhearts in quadrat counts (ratio of 2:3:1). YSB was dominant in the main flooding period and by heading stage had attacked one-fifth



2. Cumulative number in open fields of mated SSB female moths treated with Hercon laminates. IRRI farm, 1982 WS.

Table 5. BPH and RSV incidence in deepwater rice fields, Thailand, 1981 and 1982.

	BPH before flooding[a]		RSV			
	Fields sampled (no.)	Adults/ 100 sweeps	Fields examined (no.)	Fields with symptoms (%)	Fields (%) with given symptom level	
					>15%	>8%
1981	35	12.5	48	91	21	29
1982	74	2.3	73	34	0	6

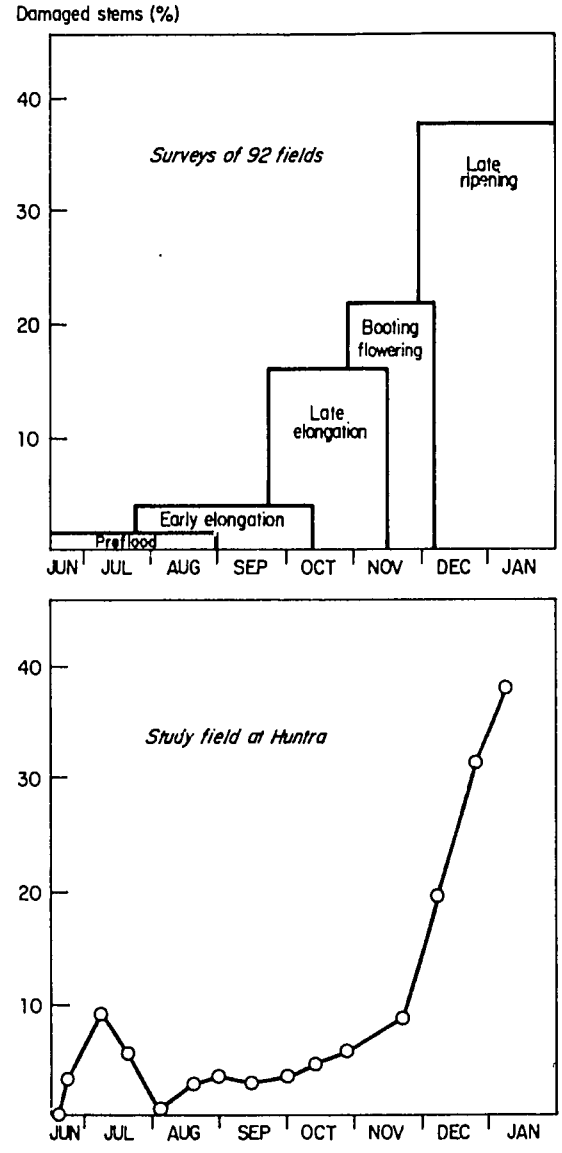
[a]Period of major virus transmission.

of the stems. Of the 37% stems damaged at harvest (Fig. 3), 2% were caused by pink borer, 15% by dark-headed borer, and 20% by YSB. The ratio of damaged stems to whitehead was 10.6:1 with a mean of 3.5% whiteheads in 35 quadrat counts. With an outbreak threshold of 20% damaged stems up to heading stage and 33% at maturity, 28% of the fields were at outbreak level by late elongation stage and >50% from booting stage to harvest.

Yield losses from yellow stem borer in deepwater rice. Cooperative work of the IRRI/Thai Department of Agriculture and Thai Entomology/Zoology Division involved growing four varieties in pots and exposing one set to YSB larvae. Infestation and yields were measured at maturity. Unfortunately, mealy bugs, RSV, and mechanical damage caused severe experimental error in some studies. Leb Mue Nahng 111 (LMN111) and Leuang Pratew 123 (LPT123) yields were reduced by about one-third with 85-89% damage at maturity (Table 6). Fewer bearing stems and reduced panicle weight (fewer filled grains) reduced yield. When exposed *after* flowering, Habiganj Aman II suffered a 19% yield loss from poor grain filling. Shulphan had the lowest damage rate and negligible yield loss.

In floating exclusion cages in a transplanted field of LPT123 flooded to 80-cm depth, YSB reduced yield by 48% because of moderate loss of bearing stems and reduced panicle weight from poor grain filling. There were 18 times more deadhearts and whiteheads, and 6 times more nodal tillers in the infested cages than in the checks.

Yield loss from ragged stunt virus in deepwater rice. In pot studies under simulated field conditions, the IRRI/Thai Department of Agriculture and

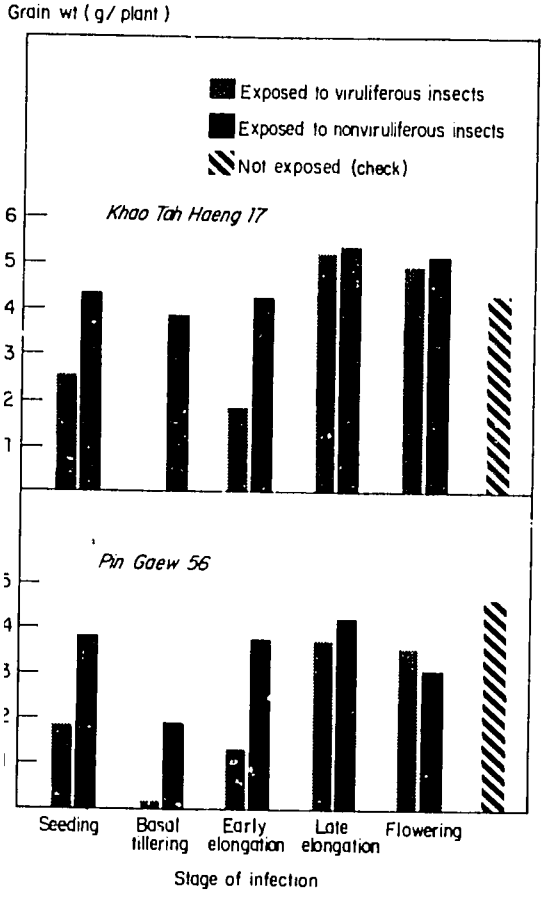


3. Stem damage by SB (predominantly YSB *Scirpophaga incertulas*) in surveys of deepwater rice fields in Thailand and in a study field at Huntra, Ayutthaya Province, Thailand, 1982.

Table 6. Crop loss from YSB in deepwater rice. Huntra, Thailand, 1982.

Variety	Damaged stems at maturity (%)		Reduction in		
	Check	Exposed	Yield (%)	Bearing stems (%)	Panicle wt (%)
Pot experiments					
LMN111 (i)	0	89	33 *	38	0
LMN111 (ii)	0	88	30 **	0	24
LPT123	0	85	28 **	26	16
Habiganj Aman II	0	88	19 *	0	19
Shulpan	5	16	4	–	–
Field cage exclusions					
LPT123	7	94	48 *	14	40

Thai Plant Pathology Division found that RSV, transmitted by BPH in seedling to early stem elongation stages, reduced yields of two deepwater varieties by 50-100% (Fig. 4). Yields were not affected by inoculation during the main flooding period (late stem elongation and flowering stages). Infection caused severe stunting (which led to plant mortality from rising water), distinct foliar symptoms, delayed flowering in one variety, and empty or partially filled panicles. Symptoms resembled those of lowland rice and were most severe during early infection. Symptoms were milder in the late-maturing Pin Gaew 56 than in the early Khao Tah Haeng 17. Field infection may be reduced by controlling vector populations before flooding. Resistance screening for both RSV and its vector can be done in the seedling stage.



1. Effects of time of RSV infection on grain yield of 2 deepwater rice varieties, Thailand, 1982. Yields based on mean/pot. ANOVA for plants exposed to viruliferous insects: Khao Tah Haeng 17: $P < 0.01$, $F = 5.41$, CV = 48.8%, LSD 1% = 1.21; Pin Gaew 56: $P < 0.01$, $F = 7.18$, CV = 13.0%, LSD 1% = 0.87.

Yield losses caused by multiple species infestations. Studies at IRRI in 1983 indicated that GHC and RWM did not cause significant yield losses, but in combination with the YSB, pests did reduce yield (Table 7). Combinations of YSB and GHC or RWM caused greater yield losses than YSB alone. Yield losses were caused by fewer productive tillers and more unfilled grains in YSB-infested plots. ShR infection was also highest in those plots.

CHEMICAL CONTROL

Entomology Department

Insecticide evaluation in the insectary. Coded or commercialized insecticides were evaluated in the laboratory against BPH, GLH, SSB, RB, and RWM.

Contact toxicity. Insecticides' effectiveness as a contact spray was evaluated using Potter's spray tower. Test insecticides were sprayed on BPH, GLH, and WBPH at concentrations of 0.15% except for WL 85871, which was at 0.01%. Mexacarbate 24EC, WL 85871 5WP, OK-135 30EC,

Table 7. Reactions of IR36 to single or combined infestations[a] of GHC, RWM, and YSB. IRRI, 1983 DS.

Insects[b]	Productive tillers (%)	Unfilled grain (%)	ShR infection (%)	Yield (g/m²)	Yield gain (+) or loss (–) from the protected control (%)
GHC	22.9 cde	18.6 c	1.9 cd	578.2 a	– 4.5
RWM	25.6 bc	15.5 c	1.5 d	569.1 a	– 6.0
YSB	19.0 e	31.8 b	2.2 bc	393.1 b	–35.1
GHC + RWM	28.9 ab	16.0 c	1.2 a	589.5 a	– 2.7
GHC + YSB	19.6 de	36.9 b	2.7 ab	350.8 bc	–42.1
RWM + YSB	18.9 e	50.8 a	3.3 a	230.0 d	–62.0
GHC + RWM + YSB	22.5 cde	40.4 b	2.8 ab	288.5 cd	–52.4
Control (unprotected)	29.9 a	20.8 c	1.5 d	557.2 a	– 8.0
Control (protected)	23.6 cd	16.9 c	1.3 d	605.7 a	–

[a]Av of 4 replications. [b]Infestation level of 30 pairs of adult GHC, 1000 RWM adults, and 400 1st-instar larvae of YSB per 36-hill (2.25 m²) plot.

OK-385 30EC, carbofuran 12F, diazinon 20EC, mexacarbate, and carbofuran caused 98 to 100% mortality at 48 HT. Mexacarbate killed 81% of GLH. Mexacarbate, carbamate, and diazinon killed 89 to 100% of WBPH.

Foliar spray. IR22 seedlings were sprayed with insecticides and infested with untreated insects 1 d after spraying. Rates were 0.75 kg ai/ha and spray volume was 500 litres/ha.

Of 11 chemicals tested against SSB, 9 were effective 1 DAT, but carbofuran, PP563, and WL 85871 showed residual effect to 10 DAT (Table 8).

Five of nine insecticides were effective against LF (Table 9).

Table 8. Laboratory evaluation of insecticides for SSB control by foliar sprays. IRRI, 1983.

Insecticides[a]	Mortality at indicated DAT[b]			
	1	3	5	10
Carbofuran 12 F	•	•	•	•
Fenitrothion + fenvalerate 40/1EC	•	•	•	
Mexacarbate 24 EC	•	•		
Oncol 40 EC	•			
BAS263 211 20 EC	•	•		
PP563 10 EC	•	•	•	•
SN72129 50 WP	•	•	•	
LAB137 3851 50 EC	•			
WL 85871 10 EC	•	•	•	•
XRD482 20 EC				
Ethoprop 72 EC				
Check				

[a]Applied at 0.75 kg ai/ha except for fenitrothion + fenvalerate and SN72129 at 0.50, and WL 85871 and PP563 at 0.05 kg ai/ha. Spray volume was 500 l/ha. [b]Av of 4 replications. • = > 80% mortality.

Table 9. Laboratory evaluation of insecticides for LF control by foliar sprays. IRRI, 1983.

Insecticides[a]	>80% mortality[b]
LAB137 385 I 50 WP	•
Ethoprop 72 EC	•
Fenitrothion 40 EC + fenvalerate 1 EC	•
PP563 10 EC	•
Monocrotophos 30 EC	•
WL 85871 5 WP	
SN72129 50 WP	
Mexacarbate 24 EC	
XRD482 20 EC	
Check	

[a]Applied at the rate of 0.75 kg ai/ha except for fenitrothion + fenvalerate and SN72129 at 0.50, and PP563 and WL 85871 at 0.05 kg ai/ha. Spray volume was 1000 l/ha.

[b]Percent mortality = $\frac{\text{dead larvae}}{\text{total no. of larvae released}} \times 100$

Three synthetic pyrethroids (PP563, WL 85871, and PP321), six conventional insecticides, and one mixture of a conventional insecticide and a synthetic pyrethroid (fenitrothion + fenvalerate) were tested on RB. All caused 100% mortality up to 15 DAT. BAS263 21 I, mexacarbate, monocrotophos, and XRD 482 showed more than 80% mortality up to 5 or 10 DAT (Table 10).

Granules. Carbofuran 3G and diazinon 5G broadcast or soil-incorporated were compared. Carbofuran was effective against RWM only when broadcast at 0.5-1.0 kg ai/ha (Table 11).

Insecticide evaluation in the field. Eight synthetic pyrethroids applied as foliar sprays against seven pest species in the field were studied in 1983 WS.

Table 10. Laboratory evaluation of new and coded insecticides for RB control by foliar sprays. IRRI, 1983.

Treatment[a]	Rate (kg ai/ha)	>80% mortality[b]			
		1 DAT	5 DAT	10 DAT	15 DAT
PP563 10EC	0.050	•	•	•	•
WL 85871 10EC	0.050	•	•	•	•
PP321 2.5EC	0.025	•	•	•	•
BAS263 1 I 20EC	0.750	•	•	•	
Mexacarbate 24EC	0.750	•			
Monocrotophos 30EC	0.750	•			
Fenitrothion 40EC + fenvalerate 1EC	0.500	•			
XRD482 20EC	0.750		•		
LAB137 385 I 50EC	0.750				
LAB131 594 I 25EC	0.750				
Ethoprop 72EC	0.750				
Check	–				

[a]Spray volume of 500 litres/ha. [b]Av of 3 replications.

Table 11. Laboratory evaluation of carbofuran 3G and diazinon 5G for RWM control by granule application. IRRI, 1983.

Treatments	Rate (kg ai/ha)	>80% mortality[a]				Damaged[b] (%)
		1 DAT	3 DAT	5 DAT	10 DAT	
Carbofuran 3G						
Broadcast	0.25					0
	0.50		•	•		0
	0.75		•			0
	1.00		•	•		0.3
Soil incorporated	0.25					1.3
	0.50					0.7
	0.75					2.0
	1.00					1.3
Diazinon 5G						
Broadcast	1.00					3.0
Soil incorporated	1.00					5 7
Check	–					6.3

[a]Av of 3 replications. Based on values transformed to arcsin x/100. [b]Based on 0 to 9 rating (0 = no damage, 9 = 100% damage).

MTI-11500 treatments had the lowest BPH populations. Deltamethrin, WL 85871, and FMC54800 had higher BPH populations than the check (Table 12).

Table 12. Number of BPH sampled by FARMCOP suction machine after each insecticide application on IR22. Masapang, Victoria, Laguna, 1983 WS.

Treatment[a]	Bi H nymphs/10 hills[b]																							
	2d application				3d application				4th application				5th application											
	A		B		A		B		A		B		A		B		C		D		E		F	
Cypermethrin 5EC[c] 25-50 g ai/ha	0.25	b	1.00	bc	0.75	b	3.00	c	3.00	bc	19.25	a	19.25	de	70.00	c	84.50	bcd	93.25	bc	2103.25	ab	605.25	ab
Cypermethrin 2.5EC[c] 25-50 g ai/ha	0.25	b	0.00	bc	0.75	b	0.75	c	1.00	de	8.50	ab	23.25	de	69.00	c	65.00	cd	65.25	c	519.00	bc	257.25	bc
Fenvalerate 3EC 30-60 g ai/ha	0.00	b	0.50	bc	1.50	b	8.75	bc	3.75	de	24.25	ab	38.00	cd	96.25	c	63.50	cd	105.00	bc	787.00	ab	663.25	ab
Deltamethrin 2.5EC 12.5 g ai/ha	1.25	a	0.50	bc	0.25	b	4.50	bc	13.25	abc	7.00	ab	751.50	a	387.75	ab	544.00	ab	1981.25	a	3386.75	a	2138.00	a
Permethrin 10EC 50-100 g ai/ha	0.25	b	0.25	c	0.50	b	3.50	bc	1.50	de	7.75	ab	29.25	cd	88.00	c	110.00	bc	121.75	bc	1191.50	bc	345.50	bc
MTI-11500 20EC 50 g ai/ha	0.00	b	0.00	c	0.00	b	1.75	c	0.50	e	0.25	b	3.50	e	11.75	c	27.75	d	4.50	d	101.50	c	33.50	c
WL 85871 5EC 25-50 g ai/ha	0.00	b	15.00	ab	2.00	b	48.50	c	19.00	ab	72.50	a	985.00	ab	1129.00	a	1714.00	a	1267.75	a	1326.75	ab	1611.75	a
FMC54800 45EC 25 g ai/ha	0.00	b	0.00	c	0.00	b	26.00	ab	28.50	c	65.75	ab	167.00	abc	428.25	a	776.50	ab	387.25	ab	2847.50	a	1714.00	a
Check	0.00	b	8.50	a	11.00	a	8.25	bc	6.25	bcd	8.75	ab	78.25	bcd	89.00	bc	52.50	cd	97.00	bc	826.25	ab	290.25	bc

[a]Insecticides were sprayed at 25 g ai/ha at 5, 10, and 25 DT, and at 50 g ai/ha at 40, 55, and 70 DT. [b]Data for the first application were omitted because no insect was found 1 and 2 wk after. A, B, C, D, E, and F indicate 1, 2, 3, 4, 5, and 6 wk after treatment. [c]5EC and 2.5EC came from different companies.

Table 13. Number of GLH sampled by FARMCOP suction machine 1 and 2 wk after each insecticide application on IR22. Masapang, Victoria, Laguna, 1983 WS.

Treatment[a]	GLH (adults + nymphs)/10 hills[b]											
	2d application		3d application		4th application		5th application					
	A	B	A	B	A	B	A	B	C	D	E	F
Cypermethrin 5EC[c] 25-50 g ai/ha	1.50 bcd	0.50 cd	0.25 b	2.75 bcd	1.25 c	1.25 bc	4.00 b	0.75 bc	0.25 cd	0.00 c	0.00 d	6.50 ab
Cypermethrin 2.5EC[c] 25-50 g ai/ha	0.00 d	0.50 cd	0.50 b	0.50 d	0.00 c	0.75 c	0.50 cd	0.50 bc	0.00 d	0.25 c	0.50 d	4.75 ab
Fenvalerate 3EC 30-60 g ai/ha	0.50 cd	2.75 bcd	0.25 b	3.25 bc	1.00 c	0.50 c	0.75 bcd	2.25 b	0.25 cd	0.25 c	5.25 ab	3.50 b
Deltamethrin 2.5EC 12.5 g ai/ha	0.00 d	1.50 bcd	0.00 b	3.75 bcd	0.25 c	0.50 c	0.25 d	0.00 c	0.25 cd	0.75 c	0.75 cd	5.75 ab
Permethrin 10EC 50-100 g ai/ha	0.25 cd	0.75 cd	0.25 b	2.25 bcd	0.50 c	2.00 bc	1.75 bcd	0.00 c	0.00 d	1.00 c	4.00 bcd	13.25 a
MTI-11500 20EC 50 g ai/ha	2.75 bc	3.50 b	0.00 b	4.50 bc	1.00 c	3.50 bc	1.75 bcd	2.75 bc	3.75 bc	5.00 b	6.50 ab	10.25 a
WL 85871 5EC 25-50 g ai/ha	0.00 d	0.25 d	0.00 b	1.25 cd	0.00 c	0.50 c	0.25 d	0.00 c	0.00 d	0.50 c	2.75 bcd	2.50 b
FMC54800 45EC 25 g ai/ha	4.75 b	3.75 bc	2.00 b	7.75 b	11.00 b	4.00 b	6.00 bc	3.00 b	4.75 b	11.50 a	5.75 abc	10.25 a
Check	25.50 a	29.75 a	34.00 a	57.25 a	62.50 a	17.75 a	26.00 a	23.50 a	41.75 a	23.25 a	14.75 a	11.75 a

[a]Insecticides were sprayed at 25 g ai/ha at 5, 10, and 25 DT, and at 50 g ai/ha at 40, 55, and 70 DT. [b]Data for the first application were omitted because no insect was found 1 and 2 wk after. A, B, C, D, E, and F indicate 1, 2, 3, 4, 5, and 6 wk after treatment. [c]5EC and 2.5EC came from different companies.

Table 14. Number of WBPH sampled by FARMCOP suction machine 1 and 2 wk after each insecticide application on IR22. Masapang, Victoria, Laguna, 1983 WS.

Treatment[a]	WBPH (adults + nymphs)/10 hills[b]											
	2d application		3d application		4th application		5th application					
	A	B	A	B	A	B	A	B	C	D	E	F
Cypermethrin 5EC[c] 25-50 g ai/ha	0.00	0.25 a	1.00 b	9.00 abcd	9.00 bc	33.00 b	43.24 bcd	25.50 b	128.75 a	45.75 b	125.50 ab	101.00 ab
Cypermethrin 2.5EC[c] 25-50 g ai/ha	0.00	0.00 a	1.00 b	5.25 abcde	5.50 cd	21.00 b	48.50 bcd	16.50 bc	52.00 ab	37.25 b	59.00 c	25.25 abc
Fenvalerate 3EC 30-60 g ai/ha	0.00	0.25 a	0.00 b	4.25 cde	4.50 cd	6.00 cd	15.00 def	6.00 d	10.25 c	10.25 c	29.75 c	21.75 bcd
Deltamethrin 2.5EC 12.5 g ai/ha	0.00	0.50 a	1.00 b	22.50 a	12.00 bc	18.50 b	88.75 ab	27.25 b	39.25 abc	133.75 a	222.25 a	196.50 a
Permethrin 10EC 50-100 g ai/ha	0.00	0.00 a	0.00 b	1.75 de	4.25 cd	13.75 bc	9.00 ef	3.50 d	15.50 bc	9.00 c	45.25 c	30.25 cd
MTI-11500 20EC 50 g ai/ha	0.00	0.25 a	0.00 b	1.75 e	1.25 d	3.25 d	4.25 f	0.75 e	1.50 d	0.75 d	5.75 d	3.75 d
WL 85871 5EC 25-50 g ai/ha	0.00	0.00 a	16.25 a	28.50 ab	63.25 a	128.00 a	453.00 a	92.00 a	145.75 a	134.50 a	154.50 abc	66.25 ab
FMC54800 45EC 25 g ai/ha	0.00	0.25 a	0.00 b	6.00 bcde	5.50 cd	1.75 d	55.50 bc	20.25 bc	90.75 ab	32.75 b	149.00 ab	83.25 ab
Check	0.00	0.00 a	12.00 a	10.00 abc	25.25 ab	26.00 b	23.00 cde	9.00 cd	16.75 bc	36.00 bc	57.00 bc	17.25 cd

[a]Insecticides were sprayed at 25 g ai/ha at 5, 10, and 25 DT and 50 g ai/ha at 40, 55, and 70 DT. [b]Data for the first application were omitted because no insect was found 1 and 2 wk after. A, B, C, D, E, and F indicate 1, 2, 3, 4, 5, and 6 wk after treatment. [c]5EC and 2.5EC came from different companies.

All chemicals were effective against GLH, especially deltamethrin, WL 85871, and cypermethrin (Table 13). Against WBPH, MTI-11500 was best, followed by fenvalerate (Table 14). Deltamethrin, cypermethrin, WL 85871, and FMC54800 treatments had more WBPH than the untreated check.

Table 15 shows the effects of the pyrethroids on some insect pests.

Twenty commercial insecticides including three synthetic pyrethroids were tested on the black bug *Scotinophara coarctata* in Maasin, Brooke's Point, Palawan. Two synthetic pyrethroids (deltamethrin and permethrin) and 4 conventional insecticides (monocrotophos, carbosulfan, endosulfan, and fenthion) killed 90-100% of the bugs 48 HT. Two conventional insecticides (triazophos and mexacarbate) killed 70-100%. Carbofuran 3G was also effective up to 43 DAT.

Resistance to insecticides. *LD_{50} values by topical application.* LD_{50} values were compared in brachypterous BPH collected from the IRRI greenhouse (insecticide-free population), a Calauan farmer's field, and the IRRI farm in August 1982. LD_{50} and estimated resistance ratio (ERR) values are given in Table 16.

In November, LD_{50}s of adult GLH of the F_2 at the IRRI farm were compared with LD_{50}s of a population kept in the greenhouse under insecticide-free conditions for several years. Populations at IRRI had low levels of resistance to all insecticides (Table 17).

Contact toxicity. The same populations used for LD_{50} values were evaluated for contact toxicity by Potter's spray tower. All insecticides, except a mixture of BPMC + chlorpyrifos, produced significantly higher BPH mortality in the greenhouse than in the field population (Table 18). Similar greenhouse results were obtained for GLH.

Residual toxicity of foliar sprays. Insecticides used in Potter's spray tower were also applied as foliar sprays (Table 19). BPH mortality was significantly lower in the field than in greenhouse populations. GLH mortality in the field population was significantly lower only with carbofuran and isoprocarb.

Neem oil formulations for insect control. *Rice ear-cutting caterpillar.* The weight of dried excreta of *M. separata* was significantly less when larvae were fed leafcuts sprayed with ≤12.5% neem oil than when fed untreated leafcuts. However, larval

Table 15. Effect of foliar spray application of synthetic pyrethroids on RWM, SB, LF, RB, and grain yield of rice variety IR22.[a] IRRI, 1983.

Treatment[b]	RWM 25 and 35 DT	Deadhearts from SB 40 DT	LF 80 DT	RB 75 DT	Whiteheads from SB 5 DBH	Yield (t/ha)
Cypermethrin 5EC[c] 25-50 g ai/ha	√	√	√			3.50 a
Cypermethrin 2.5EC[c] 25-50 g ai/ha	√	√	√			3.30 ab
Fenvalerate 3EC 30-60 g ai/ha	√	√				2.75 c
Deltamethrin 2.5EC 12.5 g ai/ha	√	√	√	√		2.79 abc
Permethrin 10EC 50-100 g ai/ha	√	√	√			3.16 abc
MTI 11500 20EC 50 g ai/ha	√	√				3.08 abc
WL 8571 5EC 25-50 g ai/ha	√	√	√			2.75 abc
FMC54800 45EC 25 g ai/ha	√	√	√			2.68 bc
Check						2.66 bc

[a]√ = significantly less than the control at 5% level. [b]Insecticides were sprayed at 25 g ai/ha at 5, 10, and 25 DT and at 50 g ai/ha at 40, 55, and 70 DT. [c]5EC and 2.5EC came from different companies.

Table 16. LD_{50} and estimated resistance ratio (ERR) values for brachypterous females of BPH from an IRRI field, an IRRI greenhouse, and a farmer's field, Aug 1982.

Insecticide	LD_{50} (µg/g)			ERR	
	Greenhouse (A)	Calauan (B)	IRRI field (C)	B/A	C/A
BPMC	1.85 a	2.21 a	10.38 a	1.19	5.61
Carbaryl	2.64 a	1.81 a	2.36 a	0.69	0.89
Carbofuran	0.29 a	0.80 a	0.85 a	2.75	2.93
Diazinon	6.34 a	6.45 a	14.21 a	1.02	2.24
Malathion	44.58 a	46.57 a	60.78 a	1.04	1.36
MTMC	3.32 a	2.51 a	2.79 a	0.76	0.84

Table 17. LD_{50} values for GLH in IRRI field and a greenhouse, Nov to Dec 1983.

Insecticide	LD_{50} (µg/g)		ERR[a]
	Field population	Greenhouse population	
BPMC EC	4.56	2.62	1.74
Carbaryl WP	7.19	5.25	1.37
Carbofuran F	2.69	0.87	3.09
Diazinon EC	15.00	8.75	1.71
Monocrotophos EC	9.69	7.19	1.35

[a]Estimated resistance ratio = LD_{50} for field population ÷ LD_{50} for greenhouse population.

feeding activity was almost identical on treated and control plants exposed to sunlight for 2 to 4 d (Table 20). Sunlight degraded the antifeedant property of neem oil.

Armyworm. Larvae of *Spodoptera m. acronyctoides* excreted markedly less when fed leafcuts sprayed with ≤1.56% neem oil, indicating reduced feeding (Table 21). Larvae also fed significantly less on leafcuts from treated plants exposed to sunlight for 2 d.

Neem oil and extracts on hemipterous rice pests. To determine how much newly emerged BPH, WBPH, and GLH females ate, they were enclosed individually in parafilm sachets on neem oil-treated and control plants. The amount eaten was the sum of the insect's fresh weight of excreta, the insect's weight gain or loss, and the insect's loss of water in 24 h. The hoppers ate significantly lesser amounts of neem oil-treated plants at even the lowest (1%) concentration than they ate of the control. Food intake became progressively less with increasing oil concentration, indicating that it has an antifeedant effect.

Growth and development of hopper nymphs were greatly retarded on plants sprayed with neem

Table 18. Contact toxicity of 7 insecticides to greenhouse and field populations at IRRI, Nov-Dec 1983.

Treatment[a]	Mortality[b] (%) at 48 HT					
	BPH			GLH		
	Greenhouse	Field	Difference	Greenhouse	Field	Difference
Carbofuran 12F	97.5	12.5	85.0**	77.5	20.0	57.5**
Monocrotophos 30EC	97.5	45.0	52.5**	97.5	32.5	65.0**
BPMC 50EC	82.5	20.0	62.5**	100.00	87.5	12.5*
BPMC + chlorpyrifos 10.5 + 21EC	65.0	47.5	17.5 ns	70.0	60.0	10.0 ns
Acephate 75WP	52.5	15.0	37.5**	7.5	25.0	−17.5*
Isoprocarb 50WP	50.0	7.5	42.5**	65.0	22.5	42.5**
Carbaryl 85WP	25.0	5.0	20.0**	45.0	15.0	30.0**
Untreated check	7.5	10.0	−2.5 ns	0.0	7.5	− 7.5 ns

[a]Insecticides were applied at 0.25% concentration, except carbofuran at 0.15%. [b]Av of 4 replications. Based on values transformed to $\arcsin\sqrt{x/100}$.

Table 19. Mortality from foliar sprays of 7 insecticides applied to greenhouse and field populations at IRRI, Nov-Dec 1983.

Treatment[a]	Mortality[b] (%) at 1 DAT					
	BPH			GLH		
	Greenhouse	Field	Difference	Greenhouse	Field	Difference
Monocrotophos 30EC	82.5	2.5	80.0**	87.5	90.0	-2.5 ns
Carbofuran 12F	80.0	2.5	77.5**	87.5	52.5	35.0**
Carbaryl 85 WPM	75.0	5.0	70.0**	92.5	80.0	12.4 ns
Acephate 75WP	75.0	7.5	67.5**	95.0	92.5	2.5 ns
BPMC + chlorpyrifos 10.5 + 21EC	60.0	7.5	52.5**	65.0	57.5	7.5 ns
Isoprocarb 50WP	52.5	2.5	50.0**	92.5	67.5	25.0**
Carbaryl 85WP	35.0	7.5	27.5**	60.0	45.0	15.0 ns
Check	5.0	2.5	2.5 ns	2.5	7.5	-5.0 ns

[a]Insecticides were applied at 0.75 kg ai/ha, except carbofuran at 0.50 kg ai/ha. Spray volume was 500 litres/ha. [b]Av of 4 replications. Based on values transformed to arcsin $\sqrt{x/100}$.

Table 20. Degradation of neem oil's antifeedant property by sunlight.[a] IRRI, 1983.

Neem oil concn (%)	Excreta (μg)/10 larvae kept 24 h on leafcuts from plants exposed to sunlight for		
	0 d	2 d	4 d
0 (1.66% detergent)	307 a	181 a	216 a
1.56	310 a	170 a	187 a
3.125	274 a	149 ab	186 a
6.25	263 a	180 a	205 a
12.5	156 b	163 a	223 a
25.0	86 b	105 b	200 a

[a]Based on dry weight of 24-h oven-dried excreta of first-instar ear-cutting caterpillar larvae on leafcuts of TN1 rice plants sprayed with neem oil and held outdoors.

Table 21. Degradation of neem oil's antifeedant property by sunlight.[a] IRRI, 1983.

Neem oil concn (%)	Excreta (μg)/10 larvae kept 24 h on leafcuts from plants exposed to sunlight for	
	0 d	2 d
0 (1.66% detergent)	373 a	341 a
1.56	169 b	354 a
3.125	135 b	309 ab
6.25	117 b	232 b
12.4	28 c	250 b
25.0	8 c	91 c

[a]Based on dry weight of 24-h oven-dried excreta of first-instar armyworm larvae on leafcuts of TN1 rice plants sprayed with neem oil and held outdoors.

Table 22. Growth of BPH, WBPH, and GLH on TN1 rice plants sprayed with neem oil or neem seed extracts.[a] IRRI, 1982-83.

Neem derivative	Nymphs (%) that became adults		
	BPH	WBPH	GLH
Neem oil (%)			
0 (control)	100 a	96 a	80 a
0.5	62 b	52 b	54 b
1	36 c	28 c	22 c
3	8 d	12 d	2 d
6	–[b] e	–[b] e	–[b] e
NE II (mg/kg)			
0 (control)	94 a	82 a	94 a
20	78 b	72 b	74 b
50	40 c	60 c	50 c
100	12 d	46 d	14 d
200	8 d	22 e	4 e
MTB (mg/kg)			
0 (control)	92 a	92 a	92 a
10	84 b	80 b	62 b
20	76 b	60 c	54 b
50	26 c	52 cd	26 c
100	6 d	40 d	14 d
AZT-VR/K (mg/kg)			
0 (control)	80 a	84 a	92 a
10	62 b	56 b	50 b
20	48 b	42 b	36 c
50	16 c	18 c	16 d
100	–[b] d	8 d	–[b] e

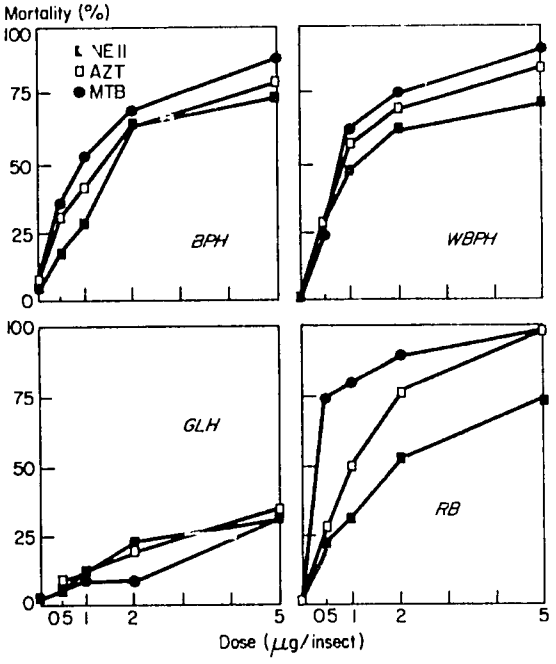
[a]First-instar nymphs were caged on 30-d rice plants. Av of 5 replications, 10 nymphs/replication. [b]Nymphs died.

oil (Table 22). Neem extracts were even more effective: less than 50% nymphs reached adult stage on plants sprayed with extracts of ≤50 mg/kg.

At 100 mg/kg, AZT-VR/K almost completely prevented nymph growth, making it the most potent of the 3 neem extracts. Abnormalities

during BPH, WBPH, and GLH development also occurred when nymphs were confined to extract-treated plants.

Growth was affected even when neem extracts were topically applied. Topical application caused premature death of late-instar BPH, WBPH, and rice bug *L. oratorius* nymphs (Fig. 5). Body malformations and different degrees of molting failures were recorded in *L. oratorius*. Neem extract doses of 2 μg killed more than 50% of BPH, WBPH, and rice bug nymphs. No extract was effective against late instar of GLH. MTB extract was more toxic than NE II or AZT-VR/K, particularly to *L. oratorius*.



5. Effect of topical application of neem seed extracts coded NE II, AZT, and MTB on the development of 5th-instar BPH, WBPH, and GLH nymphs, and on 3d-instar RB nymphs. IRRI, 1982-83.

Hopper nymph growth and development was also affected when they were caged on seedlings the roots of which had been immersed for 24 h in aqueous solution of AZT-VR/K (Table 23). With a dilution of 5 mg extract/kg and a 5-d exposure to treated seedlings, only 50% of GLH nymphs became adults, while 92% of the control nymphs became adults. Some neem extracts exerted systemic action on hopper growth which persisted even when the nymphs were transferred to untreated plants.

Longevity and fecundity of BPH, WBPH, and GLH were markedly reduced when newly emerged males and females were caged in pairs on neem oil-treated plants (Table 24). Even 3% neem oil decreased fecundity to 65% of the normal number of viable eggs produced per female. At higher concentrations, neem oil prolonged the preoviposition period from 2 to 8 d.

Table 23. Systemic action of neem extract AZT-VR/K on growth of BPH, WBPH, and GLH nymphs exposed for 5 d to rice seedlings, the roots of which had been immersed in aqueous solution of the extract for 24 h.[a] IRRI, 1983.

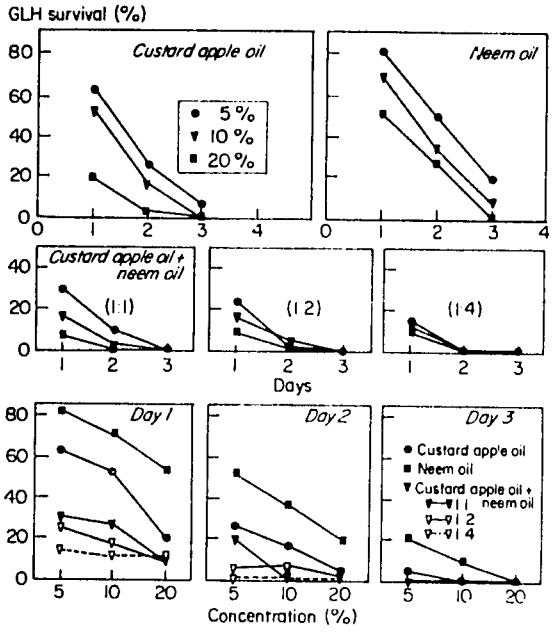
Concn (mg/kg)	Nymphs that became adults (%)		
	BPH	WBPH	GLH
0 (control)	88 a	98 a	92 a
5	58 b	72 b	50 b
10	50 c	48 c	36 c
20	12 cd	44 d	16 d
50	–[b] d	16 e	–[b] e

[a]First-instar nymphs were transferred to 30-d-old untreated rice plants after 5 d exposure to treated plants. Av of 5 replications, 10 nymphs/replication. [b]Nymphs died.

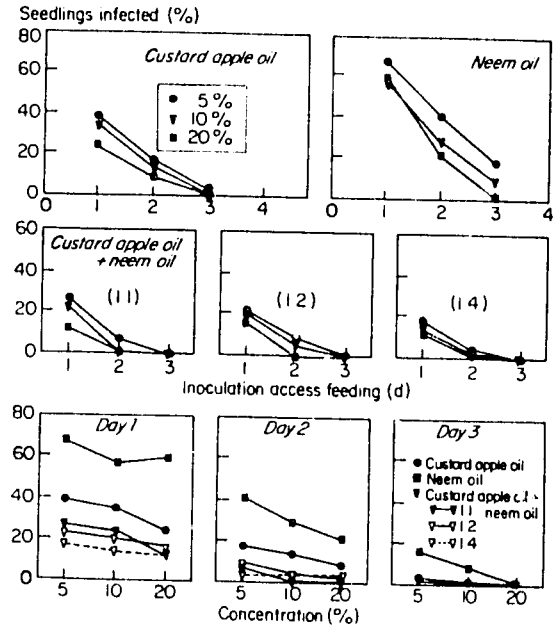
Table 24. Longevity and fecundity of BPH, WBPH, and GLH females on rice plants[a] sprayed with neem oil.[b] IRRI, 1982.

Concn (%)	Longevity (d)			Fecundity (viable eggs/female)		
	BPH	WBPH	GLH	BPH	WBPH	GLH
0 (control)	16 a	13 a	14 a	242 a	180 a	122 a
3	15 a	13 a	15 a	164 a	93 b	65 a
6	9 b	11 ab	14 a	65 b	36 c	13 b
12	8 bc	8 bc	11 a	11 c	7 d	4 c
25	5 cd	5 cd	7 b	1 d	1 e	2 cd
50	4 d	3 d	4 b	–[c] d	–[c] e	–[c] d

[a]A single pair of male and female were caged on each 30-d-old rice plant. [b]Av of 15 replications, a single pair of hoppers per replication. [c]No visible eggs.



6. Average survival of GLH exposed for different periods on TN1 rice seedlings treated with emulsions of custard apple oil, neem oil, and their mixtures IRRI, 1982-83.



7. Average RTV infection on TN1 rice seedlings exposed to viruliferous GLH, then treated with emulsions of custard apple oil, neem oil, and their mixtures. IRRI, 1982-83.

Custard apple oil and neem oil mixtures. Custard apple oil, neem oil, and their mixtures reduced GLH survival and RTV transmission. More insects died on all oil-sprayed plants and the higher the concentration, the higher the death rate (Fig. 6). On the control seedlings, 97-100% of the insects were alive after 2 to 3 d. But on seedlings treated with 20% custard apple oil or oil mixtures, <7% survived 2 d after feeding. Few insects survived 3 d of feeding on oil-treated seedlings, except at low concentrations.

Insects with 1 d feeding on the control infected 69% of the seedlings with RTV. Infection of oil-sprayed seedlings was only 11-38% at all concentrations of custard apple or oil mixtures (Fig. 7). Infection of neem oil-treated seedlings was significantly reduced only at 10 and 20% concentrations. Oil mixtures were significantly more effective than individual oils in killing insects and reducing virus transmission. Even at the lowest concentration (5%), the 1:4 mixture of custard-apple oil and neem oil was as effective as 20% custard apple oil.

Neem kernel powder on WBPH. Neem kernel powder-urea mixture in 1:10, 2:10, and 3:10 proportions (wt/wt) was applied at the rate of 120 kg N/ha to 30- to 45-d-old TN1 rice plants. Plants treated with SCU 21 or urea alone were controls. Nymphal growth was determined as the ratio of percentage of nymphs that became adults to the development period required. Significantly fewer WBPH nymphs became adults on plants treated with neem kernel powder than on control plants (Table 25).

BIOLOGICAL CONTROL

Entomology Department

Rice field spider fauna of the Philippines. A survey of 17 Philippine upland, rainfed lowland, and

Table 25. Growth and development of WBPH on TN1 rice plants treated with neem kernel powder-urea mixture. IRRI, 1983.

Treatment	Nymphs becoming adults[a] (%)	Developmental period (d)	Growth index[b]
Neem kernel powder:urea			
1:10 parts	57 b	12.9	4.4 b
2:10 parts	57 b	12.8	4.4 b
3:10 parts	51 b	13.3	3.8 b
SCU 21	83 a	12.8	6.5 a
Urea	92 a	12.6	7.3 a

[a]Av of 6 replications, 10 first-instar nymphs/replication.
[b]Calculated as the ratio of percent nymphs becoming adults to the developmental period in days.

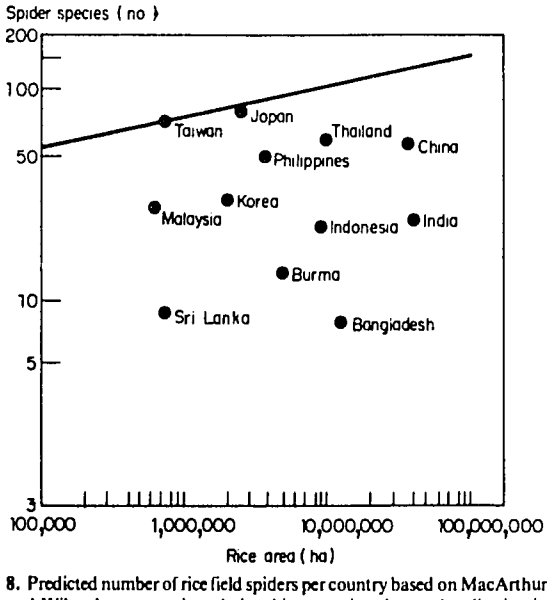
irrigated lowland rice fields showed 16 families, 34 genera, and 51 spider species. Of these, 42 species belonging to 33 genera and 16 families were new records for Philippine rice ecosystems and 17 species, 15 genera, and 1 family were new to the Asian checklist. Twenty species could not be identified and are presumed to be new species.

Based on the area-species relationship, spider numbers for each country can be estimated from the slope of a line drawn through the totals from Japan and Taiwan which have more extensive spider collections.

The Philippines with a larger rice area than Taiwan or Japan should support over 90 species (Fig. 8). India and China, which have the largest rice areas, should eventually record more than 130 species.

Countries sharing the same species with the Philippines are Thailand (20), Taiwan (17), and Malaysia (16). Countries with fewest overlapping species are Korea (3), Bangladesh (4), Burma and Sri Lanka (6 each). Commonality of Philippine spider species between countries bears no apparent relationship to proximity, climate (temperate vs tropical), rice area, or zoogeography (insular vs continental landmass).

Philippine rice field ecosystems are dominated by orb-web spiders, which represent 45% of all species and 66% of the individuals collected in 17 locations. Space-web spiders represent 15% of species and 19% of individuals collected, and

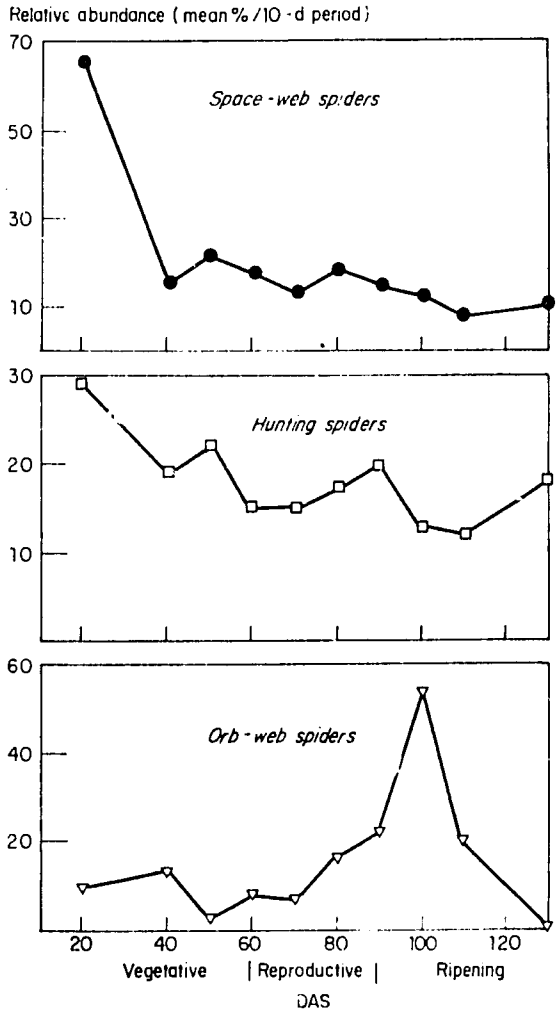


8. Predicted number of rice field spiders per country based on MacArthur and Wilson's area-species relationship assuming thorough collection in Taiwan and Japan. 1983.

Table 26. Overlap index values (Cjk)[a] for spiders collected from rice fields in several environments. IRRI, 1983.

Environments	Overlap index (Cjk)
Upland vs irrigated lowland	0.20
Upland vs rainfed lowland	0.33
Irrigated lowland vs rainfed lowland	0.56

[a] $Cjk = 1 - 0.5\ [Pij - Pjk]$. [$Pij$ and Pik are the proportions of species i in j and k environments.] For each environment 14 fields were sampled by D-Vac. For each field, a 1.4-m^2 area for was sampled at midgrowth.



9. Relative abundance of 3 spider guilds by crop age, IRRI, 1983. Spiders were collected by D-Vac suction sampler in 14 fields in each of upland, rainfed lowland, and irrigated lowland environments. Relative abundance percentages total 100% for each of the guilds.

hunting spiders represent 39% of species but only 16% of individuals.

Irrigated lowlands had the greatest spider species diversity (H′ = 2.72), followed by rainfed lowland (H′ = 2.22) and upland environments (H′ = 1.89). The species diversity data show that lowlands have more insects in common than either lowland-upland combination (Table 26).

Space-web and hunting spider guilds rapidly colonize fields and their numbers decline with crop age (Fig. 9). Spiderlings in seedbeds are numerous during the 40 DAS. Hunting and space-web spiders find shelter in grassy rice bunds and border areas between rice crops. They inhabit the base of plants and are less affected by rice harvest than orb-weavers which require tall foliage on which to suspend their webs. Hunting and space-web spiders can readily recolonize rice fields, but orb-web weavers peak after the crop reaches maximum growth.

Of the 10 most prevalent spider species, 7 are orb-weavers, dominated by *Tetragnatha javana* (Thorell), *T. maxillosa* Thorell, *Araneus inustus* (L. Koch), and *Argiope catenulata* (Doleschall). *Neoscona theisi* (Walckenaer) and *T. mandibulata* Walckenaer are widespread but not abundant. *Leucauge decorata* (Blackwall) is less widespread but abundant.

Callitrichia formosana Oi was the most dominant space-web spider and the most abundant species. It inhabits the base of plants, seeks shelter in grassy border areas, and is a rapid recolonizer of rice fields.

Among hunting spiders, the most prevalent were *Lycosa pseudoannulata* and *Oxyopes javanus* Thorell, found in 14 locations. *L. pseudoannulata* was numerous, representing 10.0% of the collections compared to 3.3% for *O. javanus*. *Lycosa*, a wolf spider, hunts at the base of plants while *Oxyopes* hunts in the crop canopy.

Good predators are those that colonize the rice crop early to reduce insect populations before they build up. *Lycosa* and *Callitrichia*, both early colonizers, make an excellent team. *Lycosa* is large and aggressive and can prey on colonizing pests to curtail egg laying. *Callitrichia* is small and preys on first generation immatures.

Of the 10 most prevalent species, *Oxyopes* is most abundant during the reproductive rice phase, and is important to the crop.

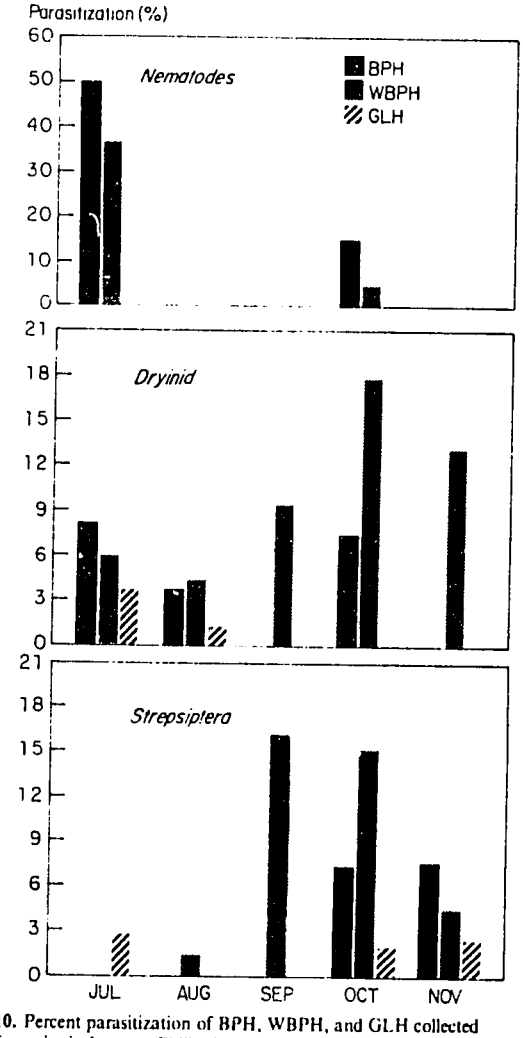
Parasitization of leafhoppers and planthoppers. A weekly survey in Laguna Province from July to November determined the extent of BPH, WBPH, and GLH parasitization.

Figure 10 shows BPH and WBPH parasitization by nematodes was high in July. Dryinids and strepsipterans were highest on WBPH in September to November. Parasitization of GLH was low on all collection dates.

CULTURAL CONTROL

Entomology Department

Synchronous planting. Drought prevented planting during the first half of 1983 in the Marbel Rice Diversion Irrigation System in Koronadal, South Cotabato. But villages with spring-fed communal



10. Percent parasitization of BPH, WBPH, and GLH collected from rice in Laguna, Philippines, Jul-Nov 1983.

Table 27. Insect abundance, yield loss, and chemical insect control in 2 villages with asynchronous (AS) planting practices[a] and 2 with synchronous (S) planting practices[b] on irrigated TPR IR60[c], Koronadal, South Cotabato, Jun-Sep 1983.

RWM[d] (% damaged leaves) 35 DT		Green semilooper[e] (% damaged leaves) 35 DT		SB[f] (%) Deadhearts 35 DT		SB[f] (%) Whiteheads		LF[g] (% damaged leaves) 63 DT		Yield[h] (t/ha)	
S	AS	S	AS	S	AS	S	AS	S	AS	S	AS
Complete protection: vegetative stage - 0.75 kg ai monocrotophos EC/ha 5, 15, 25 DT; reproductive stage: 0.75 kg ai chlorpyrifos EC/ha 35, 45, 55 DT; ripening stage: 0.75 kg ai monocrotophos EC/ha soft, hard dough											
3.8 ab	7.8 b	1.5 a	1.8 a	0.5 a	0.8 a	0.1 d	1.1 ab	0.3 ab	3.2 bc	5.84 ab	4.84 bc
No vegetative stage protection											
5.5 ab	13.4 c	2.0 a	4.0 b	3.5 c	1.9 ab	0.3 cd	1.2 ab	0.2 ab	3.6 bc	5.51 ab	4.50 c
No reproductive stage protection											
4.3 ab	7.0 ab	1.3 a	1.8 a	1.0 ab	0.9 a	1.1 bcd	2.6 ab	2.0 c	5.4 cd	6.28 a	4.99 bc
No ripening stage protection											
3.3 a	8.6 bc	1.5 a	2.2 a	0.9 a	0.9 a	0.5 cd	1.3 ab	0.1 a	1.7 ab	5.71 ab	5.12 bc
Untreated											
4.2 ab	12.6 bc	2.5 a	4.4 b	4.8 c	2.6 b	2.8 a	2.6 ab	2.0 c	8.6 e	5.47 abc	4.81 bc

[a]Morales and Barrio 3. [b]Caloocan and Barrio 1. [c]Av of 4 and 5 fields in each of synchronous and asynchronous planting areas. [d]*Hydrellia philippina*: 20-hill sample. [e]*Naranga aenescens*: 20-hill sample. [f]*Scirpophaga incertulas* and *Chilo suppressalis*: 20-hill sample. [g]*Cnaphalocrocis medinalis*: 20-hill sample. [h]25-m² sample.

irrigation systems continued year-round planting. Rains in the second half of 1983 allowed farmers to plant rice in a highly synchronized manner. Communal system farmers continued to stagger their plantings.

Field trials were carried out in two villages each of the synchronous and asynchronous plantings with transplanted IR60. Results showed significantly more RWM, green semilooper, and LF in the asynchronous fields than in synchronous fields (Table 27). YSB and SSB were unexpectedly more abundant in the synchronous area, perhaps because their natural enemies were slow to recolonize after the 6-mo rice-free period.

No significant yield loss (difference between complete insect control and untreated check plots) occurred in either the synchronous or asynchronous areas (Table 27). Lower yields in the asynchronous area are from Zn deficiency and other soil problems that result from continuous flooding.

Direct seeded rice. In DS in Nueva Ecija, fields are established by direct seeding with pregerminated rice. Timely planting is important because farmers need irrigation water to do fieldwork. During WS, rainfall supplements irrigation water and farmers can take longer to establish transplanted crops.

Direct seeding by hand is often uneven because some farmers are inexperienced in the technique. In 1983 DS, 11 direct-seeded fields in different locations were sampled. Plants ranged from less than 50 to more than 900 plants/0.25 m². Green semilooper was unaffected by plant density ($R^2 = 0.28$ ns), but RWM infestation progressively declined as plant density increased. The weak correlation was probably a result of border effects from the small sample area.

Factors affecting rice whorl maggot oviposition. N levels of 0 to 160 kg/ha had no effect on the number of RWM eggs on plants. Plants in flooded plots had three to six times as many eggs as in saturated plots. When *Azolla pinnata* floated on the water surface, the number of eggs laid on plants was significantly reduced as was the percentage of damaged leaves. Wide spacing (40 × 40 cm) in transplanted rice and low direct-seeding rate (80 kg/ha) produced fewer eggs per m². There were

Table 28. Toxicity of foliar spray insecticides to adults of *Anagrus* sp., a parasite of stem borer eggs. IRRI, 1983.

Treatment[a]	Mortality[b] (%) of *Anagrus* 24 HT
Carbofuran 12 F	99 a
Chlorpyrifos 21 + BPMC 10.5 EC	100 a
Diazinon 20 EC	99 a
Endosulfan 35 EC	97 a
Cypermethrin 5 EC	97 a
Check	45 b

[a]Insecticides were applied at 0.75 kg ai/ha, except cypermethrin at 0.05 kg ai/ha. Spray volume was 500 litres/ha. [b]Av of 5 replications. Mortality data were accumulated for each HT.

Table 29. Toxicity of insecticides to *Anagrus* sp., a parasite of stem borer eggs, when sprayed on plants infested with parasitized BPH eggs. IRRI, 1983.

Treatment[a]	Survival[b] (%)
Azinphos ethyl 40 EC	0.0 a
Carbofuran 12 F	0.7 a
Chlorpyrifos 21 + BPMC 10.5 EC	2.3 ab
Cypermethrin 5 EC	4.0 abc
Monocrotophos 30 EC	7.3 bcd
Diazinon 20 EC	13.3 cde
BPMC 50 EC	24.0 def
Endosulfan 35 EC	43.0 ef
Buprofezin 50 WP	50.3 f
Check	35.0 ef

[a]Insecticides were applied at 0.75 kg ai/ha, except cypermethrin at 0.05 and buprofezin at 0.25 kg ai/ha. Spray volume was 500 litres/ha. [b]*Anagrus* coming out of the BPH eggs in the plants sprayed with insecticide.

also less eggs per plant, resulting in a lower percentage of damaged leaves.

INTEGRATED PEST MANAGEMENT

Entomology Department

Effect of insecticides on natural enemies. When 5 foliar spray insecticides were tested on *Anagrus* sp., a parasite of stem borer eggs, all killed more than 97% of parasite adults (Table 28).

Eight insecticides and a molting inhibitor (buprofezin) were tested for their effect on the hatchability of *Anagrus*. Five insecticides were toxic to *Anagrus*. Survival in the buprofezin, endosulfan, BPMC, and diazinon treatments was not significantly different from that of the untreated check (Table 29).

In a Potter's spray tower test some insecticides were selectively more toxic to BPH than to its natural enemies (Table 30). Of the insecticides tested, acephate, BPMC, ethylan, and monocrotophos were least toxic to *Lycosa* spider; ethylan to *C. lividipennis*; and acephate, BPMC, carbofuran, endosulfan, ethylan, and monocrotophos were least toxic to *M. d. atrolineata*. Two synthetic pyrethroids, cypermethrin and deltamethrin, are highly toxic to the three predators.

Inhibitory effects of insecticides on entomogenous fungi. *Metarrhizium anisopliae* and *Beauveria bassiana* are the entomogenous fungi most commonly isolated from BPH in the Philippines. A promising aspect of microbial insect control is its combination with other measures, particularly insecticides. Some insecticides enhance the activity or virulence of the fungi, but others cause partial or complete inhibition of growth.

Two methods to determine the effect of insecticides on spore germination of two fungi were tested twice. Each test used four insecticides.

In method 1, insecticides were mixed with the culture media at 40-45° C before it was poured on sterile petri dishes. The spore suspension was then spread on top. In method 2, the insecticides and the spores were mixed in suspension and then spread on top of the media.

Table 30. Toxicity of 8 insecticides to the BPH and its 3 predators in the laboratory. IRRI, 1983.

Treatment[a]	Rate[b] (%)	Predator mortality[c] (%)		
		Lycosa pseudoannulata	*Cyrtorhinus lividipennis*	*Microvelia atrolineata*
Acephate	0.040	6.7 de	56.7 b	0.0 d
BPMC	0.116	0.0 e	53.0 bc	16.7 b
Carbofuran	0.022	66.7 b	96.7 a	13.3 bc
Cypermethrin	0.003	93.3 a	100.0 a	100.0 a
Deltamethrin	0.016	100.0 a	100.0 a	100.0 a
Endosulfan	0.048	36.7 c	46.7 bc	3.3 cd
Ethylan	0.024	20.0 d	20.0 d	16.7 b
Monocrotophos	0.031	6.7 de	100.0 a	13.3 bc
Check	–	0.0 e	3.3 f	0.0 d

[a]Insecticides were applied by Potter's spray tower. [b]Rate of insecticide applied on the predators in 7-cm-diam petri dishes. Mortality readings taken 48 h after both BPH and predators were treated. [c]Treatments with >50% mortality are more toxic to the predator than to the BPH. Those with <50% mortality are selectively less toxic to the predator than to the BPH.

Table 31. Effect of insecticides on spore germination of *Metarrhizium anisopliae* and *Beauveria bassiana*. IRRI, 1983.

Treatment	Spore germination (%)			
	Method I		Method II	
	M. anisopliae	*B. bassiana*	*M. anisopliae*	*B. bassiana*
		Test 1[a]		
Monocrotophos	0 c	32 b	72 b	95 b
BPMC	1 b	2 c	36 d	36 d
Carbosulfan	0 c	0 d	66 c	68 c
Azinphos ethyl + BPMC	0 c	0 d	28 e	68 c
Untreated	99 a	100 a	99 a	100 a
		Test 2[b]		
Azinphos ethyl	20 d	71 c	16 d	77 c
Deltamethrin	56 c	90 b	81 b	89 d
Methyl parathion	0 e	6 e	15 d	72 d
MIPC	66 b	38 d	75 c	67 e
Untreated	99 a	100 a	99 a	100 a

[a]Insecticide rate was 0.75 kg ai/ha. [b]Insecticide rate was 0.50 kg ai/ha, except deltamethrin (0.025 kg ai/ha).

Table 32. Development of a chemical insect control practice on irrigated TPR IR56 using the yield loss method.[a] Zaragoza, Nueva Ecija, Feb-May, 1983 DS.

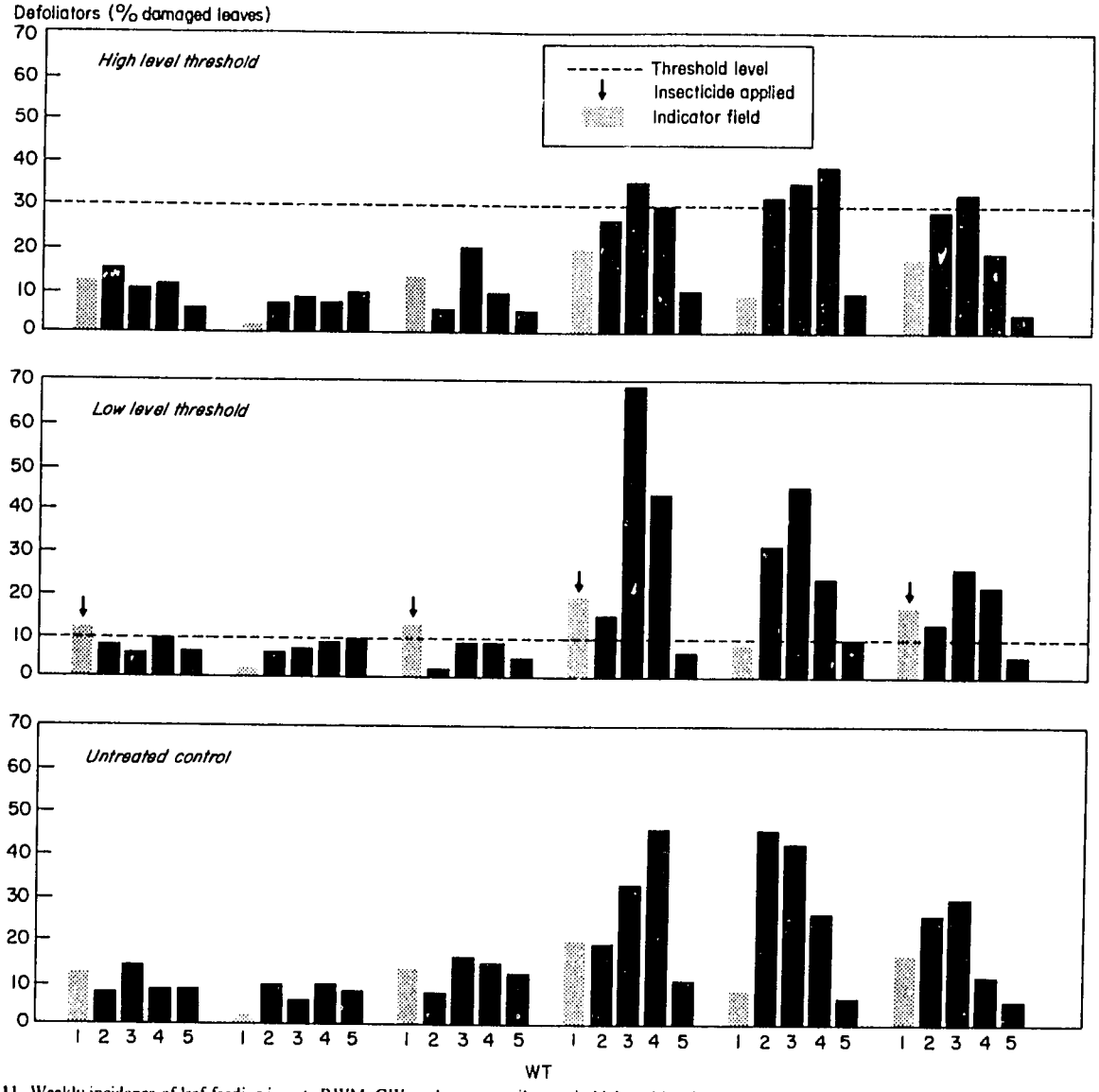
RWM[b] (% damaged leaves) 3 WT	GHC[c] (% damaged leaves) 3 WT	SB[d] (%) Deadhearts 8 WT	SB[d] (%) Whiteheads	LF[e] (% damaged leaves) 3 WT	Yield[f] (t/ha)
Complete control: vegetative – 0.75 kg ai monocrotophos EC/ha 2, 3, 4 WT; reproductive – 0.75 kg ai chlorpyrifos/ha 5, 6, 7, 8 WT; ripening – 0.75 kg ai monocrotophos EC/ha milk and soft dough					
11 ab	4.1 a	0.3 a	0.3 a	0 a	5.61 a
No vegetative protection					
25 e	7.1 c	1.0 ab	0.3 a	0.5 ab	5.03 bc
No reproductive protection					
12 abc	4.8 a	2.3 cd	1.9 b	2.5 bc	5.39 ab
No ripening protection					
9 a	4.5 a	0.3 a	0.3 a	0 a	5.41 ab
Untreated					
25 e	7.6 c	3.3 d	2.9 b	5.0 d	4.70 c
Economic threshold (high values)[g]					
20 de	6.5 bc	2.3 cd	2.1 b	3.3 cd	4.98 bc
Economic threshold (low values)[h]					
17 cd	5.5 ab	2.3 cd	2.3 b	2.3 c	4.89 bc
Farmers' practice: 0.2 kg ai monocrotophos/ha 2, 4 WT; 0.2 kg ai MIPC EC/ha 6 WT; 0.2 kg ai azinphos-ethyl EC/ha 9 WT					
16 bcd	6.0 ab	1.8 bc	1.2 ab	1.8 bc	5.02 bc

[a]Av of 6 fields (replications). [b]*H. philippina:* 20-hill sample. [c]*R. atimeta:* 20-hill sample. [d]*S. incertulas:* 20-hill sample. [e]*C. medinalis:* 20-hill sample. [f]30 m², two fields suffered drought stress from reproductive stage to harvest. [g]Action threshold for combined leaf pests, (30% damaged leaves from a 100-leaf sample) exceeded in all 6 fields; 0.75 kg ai diazinon G was broadcast in paddy water 1-3 WT in 5 fields, 0.4 kg ai monocrotophos EC/ha was sprayed in 3 fields 3-5 WT. [h]Action threshold for combined leaf pests (10% damaged leaves from a 100-leaf sample) exceeded in all 6 fields; 0.75 kg ai diazinon G was broadcast in paddy water 1-2 WT in 6 fields, 0.4 kg ai monocrotophos EC/ha was sprayed in 6 fields 3-5 WT

Mixing the insecticides with the culture media greatly reduced spore germination (Table 31). High temperature did not affect their inhibitory effect. All insecticides, except monocrotophos on *B. bassiana*, completely inhibited spore germination in test 1.

Spore germination was high when the insecticides were applied to the media surface. The insecticide mixture azinphos ethyl+BPMC was most toxic to *M. anisopliae*, while BPMC was most toxic to *B. bassiana*. Monocrotophos was the least toxic to both fungi.

Use of economic thresholds. The economic threshold value for a pest can vary because of environmental and site characteristics. The 1983 DS field trial in Nueva Ecija with transplanted IR56 tested two treatments using high and low economic threshold values for each pest. By contrasting the treatments for several years the yield loss method can determine an optimal value for each pest or pest group in the site. Significant yield loss from multiple species attack of leaf-feeding insects, RWM, and hairy caterpillar *Rivula atimeta* occurred in the first season only during the vege-



11. Weekly incidence of leaf-feeding insects RWM, CW, and green semilooper in high and low level economic threshold plots. Santa Rosa, Laguna, Philippines, 1983 WS.

Table 33. Crop stand and GLH mortality in direct seeded lowland rice as affected by insect and weed control treatments on IR36. Victoria, Laguna, 1983.

Treatment[a]	Crop stand (plants/m²) 16 DAS	GLH mortality[b] (%) 14 DAS
CGA73102 ST + butachlor 5 DBS	85 cd	8.3 ab
CGA73102 ST + butachlor 3 DBS	118 abc	3.3 b
CGA73102 ST + butachlor 5 DAS	52 d	13.3 ab
CGA73102 ST[c]	49 d	5.0 b
Carbosulfan ST + butachlor 5 DBS	55 cd	28.3 a
Carbosulfan ST + butachlor 3 DBS	78 cd	30.0 a
Carbosulfan ST + butachlor 5 DAS	84 cd	21.7 a
Carbosulfan ST	162 ab	28.3 a
Butachlor 5 DBS	92 cd	5.0 b
Butachlor 3 DBS	109 bcd	1.7 b
Butachlor 5 DAS	83 cd	5.0 b
Untreated control	172 a	1.7 b

[a]ST = seed treatment. [b]Bioassays based on 20 newly emerged GLH adults placed on plants in one cylindrical mylar film cage. Mortality readings taken 48 h after caging. [c]Hand weeded at 26 d, after data in this table were recorded.

tative phase. Neither the farmers' practice of 4 prophylactic sprays nor the 1.5 or 2 sprays per field in response to high or low economic threshold values improved yield over the untreated check (Table 32).

The main problem in applying economic thresholds is the timing of insecticide application to control leaf-feeding pests which attack soon after transplanting. Insecticide granules broadcast in the paddy water or foliar sprays 1-3 WT have been too late to prevent damage. Leaf-feeding pest symptoms are not visible the first WT, the optimal time for insecticide application.

To overcome this, the leaf-feeding insect abundance was determined using the nearest existing field (transplanted 1-2 wk earlier) as an indicator field. An economic threshold, based on the combined damage of RWM, CW, green semilooper, GHC, and other early vegetative phase pests, was a necessary simplification since farmers cannot read-

Table 34. Effect of herbicide and insecticide treatments on plants of different weed species in direct seeded IR36 lowland rice. Victoria, Laguna, 1983 WS.

Treatment[a]	Weed wt (g/m²)					
	Cyperus difformis	*Ludwigia octovalvis*	*Scirpus supinos*	*Sphenoclea zeylanica*	Others[c]	Total
CGA73102 ST + butachlor 5 DBS	0.0 a	2.0 ab	0.0 a	16.0 abc	0.0	18.0 ab
CGA73102 ST + butachlor 3 DBS	0.0 a	0.7 a	0.0 a	6.7 ab	0.0	7.4 a
CGA73102 ST + butachlor 5 DAS	18.0 a	5.3 abc	0.0 a	26.7 abc	6.7	56.7 bc
CGA73102 ST + 1 hand weeding 25 DAS	7.3 a	14.0 bc	14.0 c	19.3 abc	10.0	64.7 bc
Carbosulfan ST + butachlor 5 DBS	0.0 a	0.0 a	0.7 a	7.3 abc	0.7	8.7 a
Carbosulfan ST + butachlor 3 DBS	0.0 a	2.7 ab	0.7 a	16.7 abc	0.0	20.1 abc
Carbosulfan ST + butachlor 5 DAS	8.0 a	6.7 abc	0.7 a	50.7 ab	1.4	67.5 c
Carbosulfan ST + 1 hand weeding	2.3 a	10.7 abc	2.7 a	18.7 abc	0.7	35.1 bc
ET[b] + butachlor 5 DBS	0.0 a	0.7 a	0.0 a	4.7 a	0.0	5.4 a
ET + butachlor 3 DBS	0.0 a	1.3 a	0.0 a	13.3 abc	0.0	14.6 abc
ET + butachlor 5 DAS	0.7 a	5.3 abc	0.0 a	61.3 c	0.0	67.3 c
ET + 1 hand weeding	4.0 a	3.3 ab	3.3 ab	26.7 abc	12.0	49.3 c
Untreated control	0.0 a	14.7 c	3.3 ab	30.7 abc	8.7	57.4 c

[a]ST = seed treatment, ET = economic threshold. [b]ET for defoliation was exceeded at 35 DAS and monocrotophos foliar spray was applied at 0.75 kg ai/ha. [c]*Cyperus iria, Echinochloa colona, E. glabrescens, Eclipta alba, Fimbristylis littoralis, Lindernia* sp., and *Ludwigia octovalvis.*

Table 35. Grain yield and economics (per hectare basis) of direct seeded lowland rice as affected by insect and weed control treatments on IR36. Victoria, Laguna, 1983 WS.

Treatment[a]	Yield[b] (t/ha)	Gross profit[c] ($)	Pesticide cost[d] application ($)	Hand weeding and pesticide labor cost[e] ($)	Net gain[f] ($)	Gain from pesticide[g] ($)	Benefit cost ratio[h]
CGA73102 ST[i] + butachlor 5 DBS	3.94 abc	619	25	2	592	100	3.7
CGA73102 ST + butachlor 3 DBS	4.63 ab	727	25	2	700	208	7.7
CGA73102 ST + butachlor 5 DAS	3.48 bc	457	25	2	520	28	1.0
CGA73102 ST + 1 hand weeding 26 DAS	3.27 c	514	15	55	444	–48	<1
Carbosulfan ST[j] + butachlor 5 DBS	3.96 abc	622	25	2	595	103	3.8
Carbosulfan ST + butachlor 3 DBS	4.28 abc	673	25	2	646	154	5.7
Carbosulfan ST + butachlor 5 DAS	3.12 c	490	25	2	463	–29	<1
Carbosulfan ST + 1 hand weeding	4.65 ab	731	15	55	661	169	2.4
ET[k] butachlor 5 DBS	4.51 ab	709	26	3	680	188	6.5
ET + butachlor 3 DBS	4.89 a	768	26	3	739	247	8.5
ET + butachlor 5 DAS	3.20 c	503	26	3	474	–18	<1
ET + hand weeding	3.72 abc	585	70	56	459	–33	<1
Untreated control	3.13 c	492	0	0	492	–	–

[a]ST = seed treatment, ET = economic threshold. [b]Grain yield was from a 10-m² area in the center of each plot. [c]Based on rough rice price of US$ 157/t. Exchange rate was ₱14 = $1. [d]CGA73102 ST and carbosulfan at $11.00/litre; monocrotophos at $3.46/litre; butachlor at $10.36/20 kg formulation. [e]Cost of labor for pesticide application and hand weeding = $2.00/8 h. Cost of labor for seed treatment = $1.00; broadcasting of herbicide = $1.00/ha; monocrotophos spray = $2.00; and hand weeding = $54.00/ha. [f]Gross profit minus (pesticide cost + pesticide treatment). [g]Net gain of treatment minus net gain of untreated control. [h]Gain from pesticide divided by (pesticide + pesticide application cost). [i]ST: 3 g ai CGA731-02/ha of pregerminated seed. [j]ST: 3 g ai carbosulfan/ha of pregerminated seed. [k]ET for defoliation was exceeded at 35 DAS and monocrotophos foliar spray was applied at 0.75 kg ai/ha.

ily distinguish the damage from each species. Diazinon granules were applied 3 DT if the insect numbers in the indicator field exceeded the high economic threshold value, and 5 DT if numbers exceeded the low value. The assumption is that insect pest numbers progressively increase from the earliest to the latest planted fields. An indicator field 50-100 m away was used for each replication.

The indicator field correctly predicted the increase in leaf-feeder population in four of six low threshold fields but only in three of six high threshold plots (Fig. 11). All four "wrong decisions" underestimated the infestation and insecticide was not applied.

Indicator fields can predict some insect infestations, but limitations need to be set on their maximum distance from the test fields. Several indicator fields can predict better than one field can.

INTERACTION OF GREEN LEAFHOPPER AND WEED CONTROL IN DIRECT SEEDED LOWLAND RICE

Entomology and Agronomy Departments

In a study conducted in a farmer's field in Victoria, Laguna, seeds were treated with insecticides and butachlor granules were broadcast at 5 DBS, 3 DBS, and 5 DAS. GLH mortality did not exceed 30% when the insects were caged over plants treated with CGA73102 or carbosulfan (Table 33).

Weeds were fewer when butachlor was applied before sowing than when granules were broadcast 5 DAS (Table 34). Benefit-cost ratios for pesticide use ranged from 4 to 8 in treatments receiving herbicide before sowing. Net gain was highest in treatments where butachlor was applied at 3 DBS (Table 35).

Control and management of rice pests

Weeds

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HERBICIDE SCREENING

Research to identify herbicides that would complement other direct methods of weed control continued at IRRI and at the Maligaya, Bicol, and Visayas research stations of the Philippine Bureau of Plant Industry (BPI). Screening trials and studies on the control of specific weeds were conducted at IRRI.

Echinochloa crus-galli ssp. *hispidula, E. glabrescens, Monochoria vaginalis,* and *Cyperus difformis* were common at all sites.

Irrigated transplanted rice. *Preliminary screening.* All herbicide treatments on irrigated TPR had yields similar to those in the HW and thiobencarb - 2,4-D checks (Table 1). Only MY93, A6754, MY93E, and X-52B yielded significantly higher (about 1 t/ha) than the untreated check. Herbicide treatments were safe for rice and produced yield increases of 0.7 to 1.2 t/ha.

Secondary screening. Regardless of rate, DPX 5384 reduced weed growth significantly compared to the untreated check (Table 2). Propanil - MCPA - oxyfluorfen and fluazifop-butyl - 2,4-D did not significantly reduce weed weights. Except for fluazifop-butyl - 2,4-D at 0.05-0.6 kg/ha, all herbicide treatments had significantly higher yields than the untreated check.

Advanced trials, IRRI and BPI. In DS, all herbicide-treated plots at IRRI and Maligaya produced significantly higher yields than the untreated check (Table 3). Plots treated with bifenox - 2,4-D and oxyfluorfen yielded significantly less than the HW check at IRRI but significantly more at Maligaya. At Bicol, only naproanilide - thiobencarb, pendimethalin, and bifenox - 2,4-D had yields significantly higher than the untreated control.

In WS, all herbicide-treated plots, except those treated with molinate - simetryn - MCPB at Bicol, produced significantly higher yields than the untreated check (Table 4). At Bicol, yields from all herbicide-treated plots were significantly less than that of the HW check.

Methods of herbicide application. An IRRI experiment in DS tested the effectiveness of preemergence applied butachlor, thiobencarb, and oxadiazon using the micronherbi (an ultralow-volume sprayer) at 15 litres/ha and the conventional knapsack sprayer at 300 litres/ha.

Regardless of application method, all herbicides and HW significantly reduced total weed weight at 51 DT and at harvest, resulting in significant yield increases (up to 3.5 t/ha) over the untreated check.

Spray equipment. An IRRI experiment conducted during the 1983 WS compared the performance of the micronherbi, single nozzle, birky, boom, and VLV-50 sprayers in applying butachlor and its combination with 2,4-D.

Butachlor followed by 2,4-D sprayed with the micronherbi, birky, and boom sprayers significantly reduced the dry weight of broadleaf weeds at 60 DT. At harvest, all herbicide and sprayer treatments significantly reduced weed infestation.

Table 1. Effect of herbicides on weed control, crop tolerance, and yield of irrigated TPR IR36. IRRI, 1983 WS.

Treatment[a]	Application		Weed wt[b] (g/m²)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Broadleaf weeds	Grasses	Sedges		
HW check	Twice	15 & 30	6 ab	0 a	0 a	0	3.6 a
A6754 G	0.4	4	6 ab	0 a	21 ab	0	3.4 a
MY93 EC	2.0	4	48 b	4 a	26 b	0	3.3 a
Thiobencarb – 2,4-D IPE G	1.5	4	4 a	18 ab	32 b	0	3.3 a
MY93E G	2.0	4	38 b	28 ab	20 ab	0	3.2 a
X-52B G	0.5	4	18 b	14 ab	22 ab	0	3.2 a
A6728 EC	0.8	4	0 a	0 a	24 b	0	3.1 ab
PPG 1013 EC	0.1	4	30 b	14 ab	38 b	1	3.1 ab
MY71 G	2.0	4	20 b	72 b	26 b	0	3.0 ab
A6728 G	0.8	4	6 ab	58 b	32 b	0	2.9 ab
Untreated check	–	–	36 b	59 b	18 ab	0	2.2 b

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. [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 2. Effect of promising granular herbicides on weed control and yield of TPR IR36.[a] IRRI, 1983 DS.

Treatment[b]	Application		Weed wt (g/m²)	Yield (t/ha)
	Rate (kg ai/ha)	Time (DT)		
HW check	–	15 & 35	13 a	5.8 a
DPX 5384	0.025	5	24 ab	5.6 a
DPX 5384	0.050	5	40 ab	5.6 a
Propanil – MCPA – oxyfluorfen	1.4 - 0.4 - 0.05	15	46 abc	5.2 a
Propanil – MCPA – oxyfluorfen	1.8 - 0.5 - 0.07	15	34 abc	5.0 a
Fluazifop-butyl – 2,4-D	0.05 - 0.6	15	57 abc	4.7 ab
Untreated check	–	–	123 c	3.7 b

[a]Av of 3 replications. [b]The hand-weeded check was weeded 16 and 30 DT. A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture.

Table 3. Effect of granular herbicides applied before weed emergence (4 DT) on TPR IR36 yield at 3 sites in the Philippines, 1983 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Bicol
HW check[c]	–	5.8 a	4.7 b	5.9 a
Naproanilide – thiobencarb	1.0 - 0.7	5.7 a	5.8 ab	4.3 b
Pendimethalin	0.75	4.2 ab	5.3 ab	6.2 a
Bifenox – 2,4-D EE	2.0 - 0.66	3.8 b	6.5 a	5.0 b
Butachlor	1.0	5.0 ab	6.3 a	3.4 c
Molinate – simetryn – MCPB	1.8 - 0.1 - 0.1	4.7 ab	5.6 ab	3.4 c
Piperophos – 2,4-D IPE	0.33 - 0.17	4.4 ab	5.6 ab	3.4 c
Oxyfluorfen	0.15	3.4 b	6.1 a	3.2 c
2,4-D IPE	0.8	3.7 b	5.6 ab	2.9 c
Untreated check	–	1.4 c	3.4 c	3.0 c

[a]A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture. [b]Av of 4 replications/site. [c]HW at 15 and 35 DT.

Butachlor alone applied with the micronherbi controlled broadleaf weeds better than the single nozzle but the other sprayers did not make a difference. All sprayers performed similarly when butachlor was followed by 2,4-D.

Weed weight at 60 DT did not differ among treatments. All herbicide treatments at harvest had more weeds than the plot HW twice. Most treatments did not differ in weed weight from the untreated, and grain yield did not differ among the treatments.

The type of sprayer did not influence herbicide performance in weed control.

Direct-seeded flooded rice. *Preliminary screening.* In 1983 WS, A6754, MY93E, MY71, X-52B, BAS514, and MY93 were compared with an untreated check and thiobencarb - 2-4,D for weed control on DSR. No significant differences were observed among treatments probably because of the low population of annual weeds and dominance of the perennial *Scirpus maritimus* which was tolerant of herbicides used. Nevertheless, A6754

Table 4. Effect of granular herbicides applied before weed emergence (4 DT) on TPR IR36 yield at 4 sites in the Philippines, 1983 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
HW check[c]	–	3.1 a	3.4 a	5.0 a	5.9 a
Molinate – 2,4-D	2.3 - 0.5	2.7 ab	3.1 a	4.2 b	5.5 ab
DPX 5384	0.025	1.6 bc	3.5 a	4.2 b	5.7 ab
2,4-D	0.8	2.1 ab	3.2 a	3.7 b	5.8 ab
Butachlor	1.0	2.5 ab	3.1 a	2.9 c	5.9 a
Piperophos – 2,4-D IPE	0.3 - 0.2	2.1 ab	3.2 a	2.6 c	5.8 ab
Naproanilide – thiobencarb	1.0 - 0.7	2.0 ab	3.3 a	2.7 c	5.5 ab
Pendimethalin	0.75	2.2 ab	2.9 a	2.8 c	5.4 ab
Molinate – simetryn – MCPB	0.83 - .05 - .05	1.5 bc	3.0 a	1.7 d	5.3 b
Untreated check	–	0.4 c	1.5 b	2.0 d	4.3 c

[a]A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture. [b]Av of 4 replications/site. [c]HW at 20 and 40 DT.

Table 5. Effect of promising granular herbicides on weed control and yield of direct-seeded, flooded IR36.[a] IRRI, 1983 DS.

Treatment[b]	Application		Weed wt (g/m^2)	Yield (t/ha)
	Rate (kg ai/ha)	Time (DAS)		
DPX 5384	0.025	6	45 ab	6.0 a
DPX 5384	0.050	6	16 a	4.8 ab
Propanil – MCPA – oxyfluorfen	1.8 - 0.5 - 0.07	15	34 ab	4.4 ab
Fluazifop-butyl – 2,4-D	0.05 - 0.4	15	34 ab	4.2 ab
Fluazifop-butyl – 2,4-D	0.075 - 0.6	15	90 b	3.9 b
Propanil – MCPA – oxyfluorfen	1.4 - 0.4 - 0.06	15	51 ab	3.7 b
Fluazifop-butyl – 2,4-D	0.05 - 0.4	15	48 ab	3.2 b
Untreated check	–	–	91 b	3.5 b

[a]Av of 3 replications. [b]A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture.

Table 6. Effect of early postemergence (6 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at 3 sites in the Philippines, 1983 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Visayas
Butachlor	1.0	4.8 a	4.4 a	7.2 a
Thiobencarb – 2,4-D IPE	1.0 - 0.5	5.5 a	4.2 ab	6.6 ab
Naproanilide – thiobencarb	1.0 - 0.7	5.8 a	4.2 ab	6.2 ab
Bifenox – 2,4-D EE	2.0 - 0.66	5.2 a	4.0 ab	6.6 ab
Pendimethalin	0.75	5.0 a	3.8 ab	6.3 ab
Oxyfluorfen	0.15	5.7 a	2.4 c	6.4 ab
Piperophos – 2,4-D IPE	0.33 - 0.17	5.5 a	2.3 c	5.9 b
Butachlor + 2,4-D IPE	0.75 + 0.5	5.5 a	4.2 ab	6.6 ab
Molinate – simetryn – MCPB	1.8 - 0.1 - 0.1	0 b	0 d	6.6 ab
Untreated check	–	5.0 a	0 d	6.1 b

[a]A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately. [b]Av of 4 replications/site.

and MY93E were safe for direct-seeded rice and yielded about 1 t/ha more than either the untreated check or thiobencarb - 2,4-D. BAS 514 was most toxic to rice.

Secondary screening. DPX 5384 gave significantly more weed control at 0.050 kg/ha and significantly more yield at 0.025 kg/ha than the untreated check (Table 5). Weed control and yield between the untreated check and the other herbicide treatments did not vary significantly.

Advanced trials, IRRI and BPI. In DS, all herbicide treatments at IRRI except molinate - simetryn - MCPB; those at Bicol, except butachlor; and the untreated check did not significantly differ in yield (Table 6). At Maligaya, yields of all treated plots, except those treated with molinate - simetryn - MCPB, were significantly higher than yields of untreated plots. Molinate - simetryn - MCPB was completely toxic and had zero yield at IRRI and Maligaya.

All herbicide treatments in WS at Maligaya and Bicol and most at Visayas yielded significantly higher than the untreated check (Table 7). At IRRI, only the naproanilide - thiobencarb treatment yielded significantly more than the untreated control. Yield differences among herbicide treatments at all sites were not pronounced.

Time of herbicide application. A WS experiment evaluated several herbicides applied 2 DBS for weed control and selectivity in direct-seeded flooded IR36.

All herbicides controlled more than 50% of the weeds, but, except for butachlor, the reduction was not significant. Thiobencarb - 2,4-D, piperophos - 2,4-D, and butachlor severely reduced the early crop stand, but the rice recovered easily. Panicle number at harvest did not differ greatly among treatments. Yields between treated and untreated plots did not differ much because of severe lodging at maturity.

During DS, two trials were conducted with broadcast-seeded flooded rice. Liquid oxadiazon at 0.4 kg ai/ha and butachlor at 1.0 kg ai/ha were applied using a sprinkler bottle at 6 and 3 DBS and 6 DAS. In the other experiment, granular butachlor at 0.75 and 1.0 and piperophos - 2,4-D at 0.3 and 0.5 kg ai/ha were broadcast at the same time. Untreated checks were maintained for comparison.

In the first trial, the perennial sedge *S. maritimus* became dominant, comprising 81% of total weed weight at harvest.

In some plots, standing water during seeding

Table 7. Effect of early postemergence (6 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at 4 sites in the Philippines, 1983 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
Molinate – 2,4-D	2.3 - 0.5	2.7 b	2.8 a	2.5 a	6.0 ab
Piperophos – 2,4-D IPE	0.3 - 0.2	3.7 ab	2.3 ab	1.8 b	6.1 ab
Thiobencarb – 2,4-D IPE	1.0 - 0.5	2.7 b	2.3 ab	2.7 a	6.2 ab
Naproanilide – thiobencarb	1.0 - 0.7	4.4 a	1.8 b	1.8 b	5.7 bc
Butachlor + 2,4-D IPE	0.75 + 0.5	2.9 ab	1.9 ab	1.7 b	6.6 a
DPX 5384	0.025	3.1 ab	2.1 ab	1.7 b	5.9 ab
Molinate – simetryn – MCPB	0.83 - .05 - .05	2.8 ab	1.8 b	1.9 b	5.6 bc
Butachlor	1.0	3.2 ab	1.9 b	1.5 b	5.1 c
Pendimethalin	0.75	2.7 b	2.4 ab	1.6 b	4.4 d
Untreated check	–	2.1 b	1.0 c	0.5 c	4.4 d

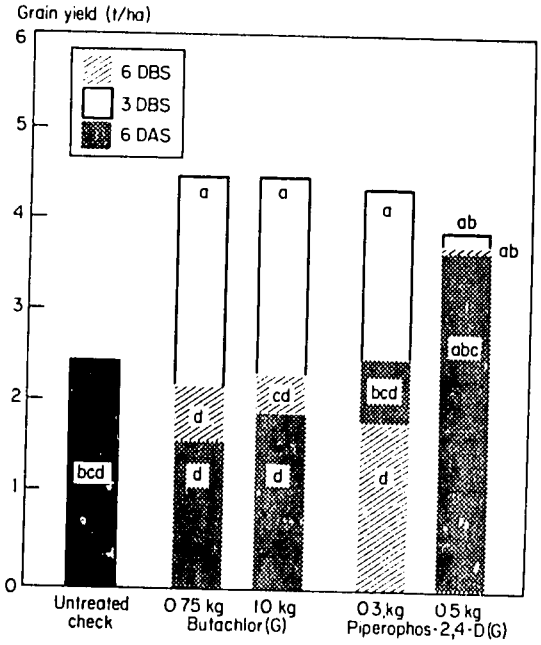
[a]A spaced dash (–) means 2 or more herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately. [b]Av of 4 replications/site.

aggravated initial toxicity of the preseeding herbicide treatments and resulted in a reduced stand at 30 DAS. Panicle number did not significantly differ among herbicides and application times, indicating the ability of IR36, a high tillering variety, to recover from herbicide damage. Grain yields were low because of high infestation of *S. maritimus* which is tolerant to the herbicides. Only oxadiazon applied at 6 DAS increased yield significantly over the untreated check. The margin of herbicide selectivity in broadcast-seeded rice seems to be very narrow and dependent on the water status in the field.

In the second trial, *E. crus-galli* ssp. *hispidula*/*E. glabrescens* comprised 63% of the weed population and *S. maritimus*, 29%. Other weeds were minor. Butachlor and piperophos - 2,4-D applied at 6 and 3 DBS reduced grass dry weight more than when applied at 6 DAS. However, application at 3 DBS produced higher yields than other application times and the untreated check (Fig. 1). Yields from 6 DBS treatments were lower, possibly because of early occurrence of *S. maritimus* which dominated those plots later. The 6 DAS treatments had poor grass control, resulting in low grain yields. Both herbicides were initially slightly toxic to rice but at 30 DAS, regardless of application time, the crop outgrew the injury.

Time and rate of herbicide application. Effect of application rate and time of three postemergence herbicides on weed control and the growth and development of WSR IR36 was studied at IRRI during 1983 DS. Propanil at 1.5 and 3.0 kg/ha, bentazon at 1.0 and 2.0 kg/ha, and fluazifop-butyl at 0.05 and 0.10 kg/ha were applied at the 2-3 and 5-7 leaf stages and the tillering stage.

At their higher rates, bentazon and propanil applied at 2-3 leaf stage did not affect the number of tillers at 60 DAS and were comparable to the HW crop which had the highest tiller count, 529/m^2 (Table 8). Tiller count of plants sprayed with fluazifop-butyl at 0.10 kg/ha was significantly lower than that of the untreated check. Fluazifop-butyl at 0.05 kg/ha and propanil at 1.5 kg/ha also had fewer tillers than the rest of the treatments.



1. Grain yield of broadcast-seeded flooded IR36 as affected by time of herbicide application (av of 4 replications). Bars having a common letter are not significantly different at the 5% level. IRRI, 1983 DS.

Table 8. Effect of time and rate of herbicide application on growth and development of WSR IR36[a] and weed control.[b] IRRI, 1983 DS.

Treatment[c]	Tiller count[d] (no./m²)				Weed weight[d] (g/m²)				Grain yield (t/ha)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Bentazon (1.0)	417 ab	426 abc	459 bc	434	56 bc	36 abc	34 b	42 b	2.3 a	0.4 b	2.4 a	1.7 a
Propanil (3.0)	500 ab	508 a	433 bcd	480	82 bc	25 ab	32 ab	46 b	1.9 ab	2.1 a	0.8 b	1.6 a
Bentazon (2.0)	475 abc	392 bc	492 ab	453	41 b	70 cd	21 ab	44 b	1.5 ab	1.8 ab	1.0 ab	1.4 ab
HW check	529 a	475 ab	466 abc	490	7 a	13 a	7 a	9 a	1.9 ab	1.8 ab	0.9 b	1.5 ab
Propanil (1.5)	388 cd	475 ab	433 bcd	432	82 bc	48 bcd	25 b	52 b	1.5 ab	1.2 ab	0.4 b	1.0 abc
Fluazifop-butyl (0.05)	383 cd	371 c	379 cd	378	146 cd	69 cd	131 c	115 c	1.1 ab	1.1 ab	0.5 b	0.9 abc
Fluazifop-butyl (0.10)	317 d	450 abc	554 a	440	216 d	78 cd	51 b	115 c	1.0 ab	0.5 b	0.7 b	0.7 bc
Untreated check	417 bc	429 abc	342 d	396	103 bcd	142 d	95 c	113 c	0.5 b	0.8 ab	0.4 b	0.6 c

[a]S_1 = 2-3 leaf stage of rice, S_2 = 5-7 leaf stage, S_3 = tillering stage. [b]Av of 3 replications. [c]Herbicide rate in kg/ha indicated in parentheses. HW check = weeded at 15, 30, and 45 DAS. [d]Sampled at 60 DAS.

Plants sprayed at 5-7 leaf stage had similar tiller numbers as the untreated. But at the tillering stage, those treated with propanil at both rates and fluazifop-butyl at 0.05 kg/ha had significantly fewer tillers than those treated with fluazifop-butyl at 0.10 kg/ha and were comparable with the untreated. Only bentazon at 2.0 kg/ha and HW treatments produced as many tillers as those with fluazifop-butyl at 0.10 kg/ha.

Propanil at 3 kg/ha appeared to reduce tiller number when applied toward the tillering stage. Fluazifop-butyl inhibited tillering more when applied at the early leaf stages. Time and rate of application of bentazon did not seem to affect tillering.

Most herbicides, applied at 2-3 leaf stage, controlled weeds (predominantly *S. maritimus* and *Cyperus iria*) but were not as effective as 3 HWs. Bentazon (1.0) and propanil (3.0) applied at 5-7 leaf stage were as effective. When sprayed at tillering stage at both rates, they significantly reduced weed weight. They are more effective when applied toward the tillering stage when weeds are older and have more top growth. Fluazifop-butyl had consistently poor weed control regardless of application time.

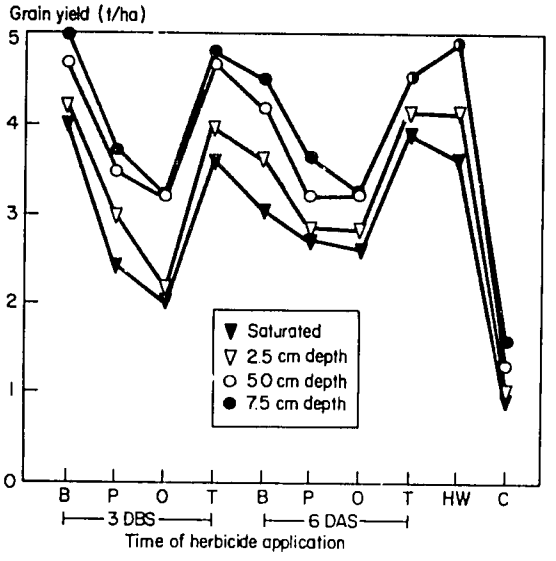
Bentazon at both rates and propanil at the higher rate yielded significantly higher than the untreated check. The highest yield of 1.7 t/ha obtained from bentazon-treated (1.0) plots was comparable with those of other treatments except fluazifop-butyl at 0.1 kg/ha which was significantly lower.

Butachlor application time and incorporation. Effects of application time and incorporation on the performance of butachlor were examined.

No significant differences were observed in crop stand and plant height when butachlor was applied 3 DBS or 1 DBS, or at 6 DAS. However, tiller counts were significantly higher and weed weights were significantly lower with preplanting applications. Differences between 3 and 1 DBS application and between soil incorporation and surface application before planting were not significant.

Yields were not significantly different between plots that were HW 14 and 28 DAS and those that received preplant herbicide applications. No yield was obtained from unweeded plots or from those to which butachlor was applied 6 DAS because of intense weed competition.

Butachlor rates. The effect of 5 butachlor rates (0.2 to 1.0 kg/ha) applied 3 DBS was compared with effects of 1 kg/ha 6 DAS and of weeding. Application of butachlor 6 DAS resulted in stand



2. Grain yield of direct-seeded lowland IR36 with different herbicide application times and water depths. B = butachlor, 1.0; P = pendimethalin, 0.75; O = oxyfluorfen, 0.2; T = thiobencarb, 1.5; HW = hand weeding, 15 and 35 DAS; C = unweeded control.

reduction, shorter plants, fewer tillers, and poorer weed control than application 3 DBS. Application of butachlor 3 DBS did not reduce stand, plant height, or tiller number compared to the HW check. Weed weights were significantly lower in HW plots. Herbicide rates had little effect on stand count, plant height, tiller counts, and weed weights.

No yield was obtained in the plots treated with butachlor 6 DAS because of heavy weed growth and high seedling mortality. Yields from plots treated with butachlor 3 DBS averaged only 1.6 t/ha because of competition from perennial weeds and rat damage. Those yields were not significantly different from each other or from the HW check.

Time of herbicide application under various moisture regimes. A field experiment with broadcast-seeded flooded IR36 rice in 1983 DS studied the effect of presowing incorporation (PSI) and early postemergence (EPE) application of herbicides under varying moisture levels (saturation, 2.5, 5.0, and 7.5 cm).

PSI of butachlor 3 DBS produced highest yields consistently at all moisture levels (Fig. 2) with weed control efficiency and grain yield comparable to those of HW.

Thiobencarb (PSI and EPE) was the next best treatment under all water depths. Whether the herbicide was applied as PSI or EPE, weed control efficiency and grain yield increased as the depth of irrigation water increased from saturation to 7.5 cm. Herbicide application was more beneficial at low than at high moisture.

PSI of butachlor/thiobencarb and EPE thiobencarb reduced weed biomass by 82-88% and increased panicle number with minimum toxicity to rice. PSI and EPE applications of oxyfluorfen were toxic to rice even though weed control was satisfactory (Table 9).

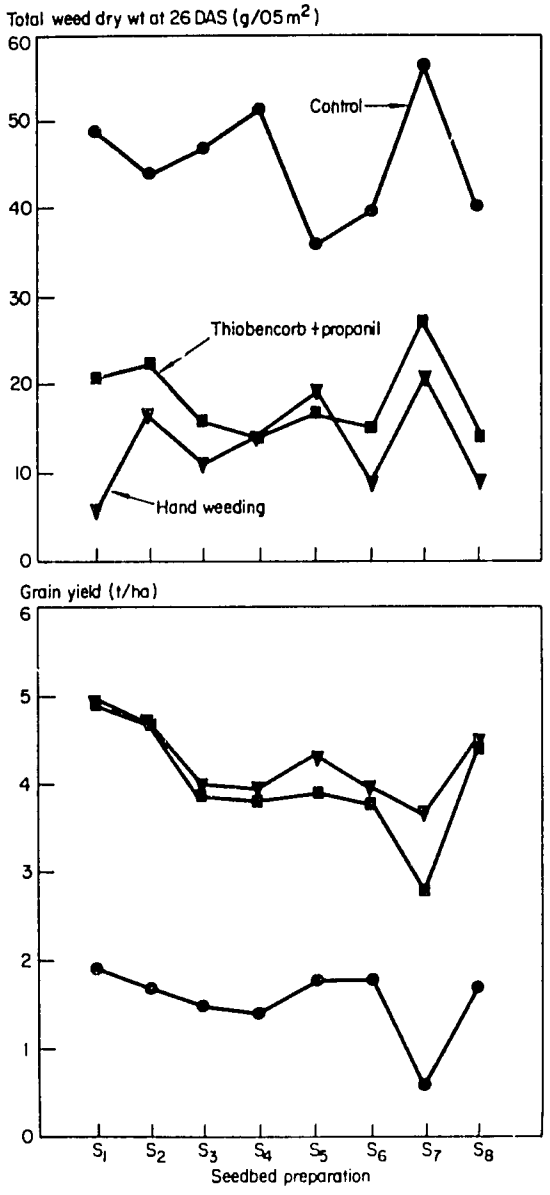
Seedbed preparation and weed control. Different methods of seedbed preparations and weed control were evaluated in WS to determine the best combination for high yield in direct-seeded flooded IR36.

Minimal tillage (one plowing fb one harrowing)

Table 9. Effect of presowing and early postemergence herbicide treatments on weed control, crop tolerance, panicle number, and grain yield of IR36. IRRI, 1983 DS.

Treatment	Application		Weed wt (g/m²) 45 DAS[a]	Panicle[a] (no./m²)	Visual toxicity rating[b] (15 DAS)	Yield[a] (t/ha)
	Rate (kg ai/ha)	Time				
Butachlor	1.0	3 DBS	36 ab	424 a	1	4.5 a
Pendimethalin	0.75	3 DBS	53 c	408 a	2	3.2 c
Oxyfluorfen	0.2	3 DBS	61 c	396 a	3	2.6 cd
Thiobencarb	1.5	3 DBS	48 bc	388 ab	2	4.3 a
Butachlor	1.0	8 DAS	45 abc	360 b	2	3.8 b
Pendimethalin	0.75	8 DAS	56 bc	348 b	2	3.1 c
Oxyfluorfen	0.2	8 DAS	58 c	316 c	3	3.0 c
Thiobencarb	1.5	8 DAS	33 ab	408 a	2	4.3 a
HW twice	–	20 fb 35 DAS	25 a	336 b	0	4.4 a
Unweeded check	–	–	267 d	204 d	0	1.2 e

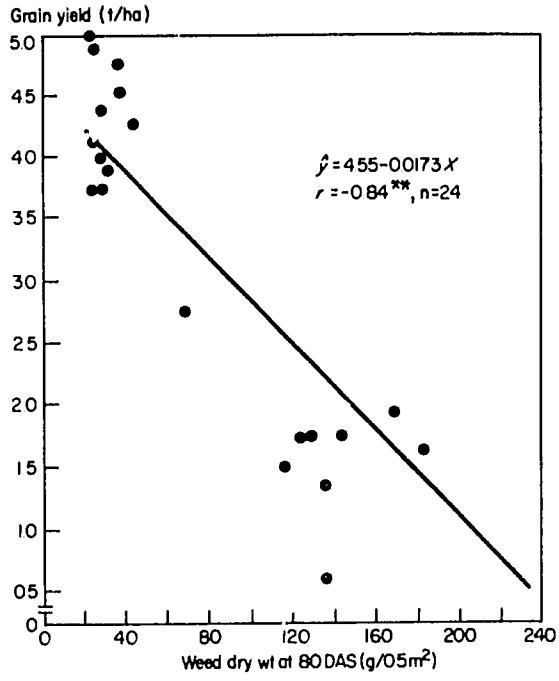
[a]Av of 3 replications. [b]Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity and 10 = complete kill.



3. Effect of seedbed preparation on total dry weight of weeds and grain yield in direct-seeded flooded IR36. IRRI, 1983 WS. S_1 = conventional tillage (1 plowing fb 3 harrowings), S_2 = minimal tillage (1 plowing fb 1 harrowing), S_3 = zero tillage (glyphosate, 1.5 kg/ha), S_4 = zero tillage (SC-0224, 1.5), S_5 = zero tillage (glyphosate 1.5 fb paraquat 0.75), S_6 = zero tillage (SC-0224 1.5 fb paraquat 0.75), S_7 = stale-seedbed (paraquat, 0.75), S_8 = stale-seedbed fb animal plowing once.

and a tank-mixed application of thiobencarb and propanil at EPE was highly effective. The yield was comparable to that of conventional seedbed preparation (2 plowings fb 3 harrowings) and 2 HWs at 15 and 35 DAS (Fig. 3).

When the field was infested with perennial weeds *Paspalum distichum* and *S. maritimus*, different



4. Relationship between grain yield and total dry weight of weeds at 80 DAS. IRRI, 1983 WS.

zero tillage techniques and seedbed methods had only limited benefit.

Stale-seedbed method (1 plowing 1 DBS) fb herbicide application ranked second in efficiency and yield (Fig. 3).

A strong relationship between weed dry weight and grain yield (r = -0.84**) reinforces evidence that weeding of direct-seeded flooded rice increases yields (Fig. 4).

Rainfed transplanted rice. *Preliminary screening*. All herbicide treatments on rainfed TPR had yields similar to those of the HW and thiobencarb - 2,4-D checks (Table 10). Only MY93 and X-52B yielded significantly higher than the untreated check and about 35% more than the thiobencarb - 2,4-D check. All herbicides were safe to rice.

Spray equipment. An IRRI experiment during WS compared the performance of five different types of herbicide sprayers using butachlor and 2,4-D. Butachlor was applied alone at 1.5 kg/ha or fb 2,4-D at 0.4 kg/ha on saturated plots. Delivery rates of the sprayers were calibrated.

Major weeds included *Paspalum* sp., *E. glabrescens*, *Leptochloa chinensis*, *M. vaginalis*, *Ludwigia octovalvis*, and *Fimbristylis littoralis*.

At 60 DT, total weed weight did not differ

Table 10. Effect of herbicides on weed control, crop tolerance, and yield of rainfed TPR IR36. IRRI, 1983 WS.

Treatment[a]	Application		Weed wt[b] (g/m²)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Broadleaf weeds	Grasses	Sedges		
MY93E G	1.0	4	28 a	110 ab	0 a	0	3.4 a
X-52B G	1.0	4	20 a	28 ab	2 a	0	3.2 a
HW check	Twice	15 & 30	16 a	18 ab	0 a	0	3.1 a
A6728 G	0.8	4	6 a	24 ab	0 a	2	3.0 ab
MY93 EC	1.0	4	20 a	20 ab	0 a	1	2.8 ab
A6728 EC	0.4	4	52 a	64 ab	0 a	0.3	2.8 ab
A6754 G	0.4	4	50 a	62 ab	4 a	0	2.7 ab
Thiobencarb – 2,4-D IPE G	1.5	4	20 a	0 a	4 a	0	2.3 ab
BAS 514 WP	0.2	4	36 a	114 ab	0 a	1	2.2 ab
PPG 1013 EC	0.2	4	82 a	110 ab	0 a	2	2.1 ab
Untreated check	–	–	26 a	142 b	0 a	0	1.5 b

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of 3 replications. [c]Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity and 10 = complete kill.

significantly among sprayers using butachlor alone and was comparable to that in the untreated check (Table 11). But when butachlor fb 2,4-D was applied, total weed weight was less than in the untreated.

All herbicide treatments were significantly inferior in weed control to the HW check at 60 DT (Table 11).

All treatments except butachlor applied with the single nozzle and VLV-50 sprayers yielded significantly more than the untreated check. The average weed weight of six herbicide treatments showed that the type of sprayer did not affect the effectiveness of herbicides.

Variety and nitrogen level. The effect of variety, N level, and weeding method on weed control in rainfed rice was evaluated during WS. Mahsuri (tall), IR42 (intermediate), and IR36 (semidwarf) were tested using 0, 50, and 100 kg N/ha, 1.5 kg butachlor/ha, 2 HWs (15 and 30 DT), and an untreated check.

Dry weight of weeds (mainly *P. distichum*, *L. chinensis*, *M. vaginalis*, *S. maritimus*, *F. littoralis*, and *C. iria*) at 60 DT did not differ among the varieties at 0 and 50 kg N/ha (Table 12). At the highest N level, however, weed weights in IR36 plots were lowest, significantly lower than in Mahsuri plots. Although weed weights in IR42 and Mahsuri plots appeared to increase with increasing N, the differences were not significant. IR42 consistently yielded highest.

At each N level, IR42 and IR36 had more tillers than Mahsuri (Table 13). Increasing N slightly increased tiller number of all varieties.

At each N level, IR42 and Mahsuri had similar LAI, which were significantly higher than that of

Table 11. Weed weight at 60 DT and grain yield of rainfed TPR IR36 as affected by herbicides applied with different spray equipment. IRRI, 1983 WS.

Type of sprayer	Herbicide[a] (kg ai/ha)	Weed wt (g/m²)	Grain yield (t/ha)
Micronherbi	Butachlor (1.5)	245 b	2.2 ab
Single nozzle	Butachlor (1.5)	229 b	1.9 bc
Birky	Butachlor (1.5)	265 b	2.2 ab
Boom	Butachlor (1.5)	172 b	2.2 ab
VLV-50	Butachlor (1.5)	165 b	1.9 bc
Micronherbi	Butachlor fb 2,4-D (1.5 fb 0.4)	178 b	2.4 ab
Single nozzle	Butachlor fb 2,4-D (1.5 fb 0.4)	162 b	2.4 ab
Birky	Butachlor fb 2,4-D (1.5 fb 0.4)	244 b	2.3 ab
Boom	Butachlor fb 2,4-D (1.5 fb 0.4)	227 b	2.7 ab
VLV-50	Butachlor fb 2,4-D (1.5 fb 0.4)	154 b	2.6 ab
HW twice	Butachlor fb 2,4-D (1.5 fb 0.4)	48 a	2.6 ab
Untreated check	Butachlor fb 2,4-D (1.5 fb 0.4)	284 b	1.2 c

[a]Herbicide rate indicated in parentheses.

Table 12. Effect of variety and N level on weed weight and grain yield of 3 rices grown in rainfed transplanted fields.[a] IRRI, 1983 WS.

N level (kg N/ha)	Weed wt[b] (g/m²)				Grain yield[c] (t/ha)			
	IR36	IR42	Mahsuri	N means	IR36	IR42	Mahsuri	N means
0	74 a	98 a	92 a	88	1.9	2.4	1.2	1.8
50	112 a	109 a	122 a	114	1.5	2.4	1.2	1.7
100	82 a	121 ab	154 b	119	1.9	2.4	1.1	1.8
Variety means	89	109	123	107	1.8	2.4	1.1	1.8

[a]Av of 3 replications and 3 weeding regimes. [b]Separation of means in a row by Duncan's multiple range test at the 5% level. Weeds were sampled 60 DT. [c]LSD between 2 V means = 0.8.

Table 13. Effect of N level on tiller count and leaf area index (LAI) at 60 DT of 3 rice varieties grown in rainfed conditions.[a] IRRI, 1983 WS.

N (kg/ha)	Tillers (no./m²)				LAI			
	IR36	IR42	Mahsuri	N means	IR36	IR42	Mahsuri	N means
0	317	324	244	295	1.39	2.51	3.16	2.35
50	319	351	249	306	1.63	3.43	3.21	2.76
100	344	393	271	336	1.79	4.18	4.16	3.38
Variety means	326	356	255	312	1.60	3.37	3.51	2.83
LSD (5%)	V means (at same or different N)			45 (60)				0.99 (1.11)
	N means (under same V)			28 (49)				0.36 (0.63)

[a]Av of 3 replications and 3 weeding regimes.

IR36. Addition of 50 kg N/ha did not significantly increase LAI of Mahsuri, but addition of 100 kg N/ha increased it over those at 0 and 50 kg N/ha. N fertilizer application did not affect LAI of IR36.

Tillering and LAI of IR42 were more responsive to N than those of IR36 and Mahsuri. N seemed to affect LAI more than tillering.

A correlation analysis showed that exeept for Mahsuri, there were no significant differences between varieties in weed weights at 60 DT and LAI or between tiller count at 60 DT and grain yield (r = -0.77).

Averages over N levels and weeding regimes show the rices had the same N absorbing ability as the weeds (0.88-1.15 vs 0.87-0.95%).

Rainfed direct-seeded rice. In a preliminary screening, most herbicides effectively controlled grassy weeds with rainfed direct-seeded rice and caused zero to slight toxicity to rice (Table 14). MY71, A6728, and PPG 1013 had yields similar to those with the other test herbicides but significantly higher than either the thiobencarb - 2,4-D or the untreated check.

Dry-seeded rainfed bunded rice. *Preliminary screening*. Fourteen herbicides were tested at 2 or 3 rates of application and compared with standard check plots with single rates of butachlor and propanil, and HW (14 and 28 DE) and unweeded treatments. Butachlor, pendimethalin, MY93E, and PPG 1013 were applied after a germinating rain following planting but before DSR emergence. Propanil, fluazifop-butyl, terbutryn, ametryn, and the commercial mixtures of fluazifop-butyl - 2,4-D, propanil - MCPA -oxyfluorfen, molinate, propanil, and propanil - MCPA were applied 9 DE. Plots treated with terbutryn and ametryn were HW at 45 DE.

Major weed species were *Melochia concatenata* and *Echinochloa colona*. None of the herbicides reduced the stand, but ametryn and terbutryn caused leaf burn early in crop growth.

At 30 DE, pendimethalin (1.5 and 2.0 kg ai/ha), molinate - propanil (1.9 - 1.9 and 2.35 - 2.35), bromoxynil - MCPA (1.0 - 1.0 and 1.23 - 1.27), propanil - MCPA - oxyfluorfen (1.56 - 0.43 - 0.006), fluazifop-butyl (0.08), fluazifop-butyl -

2,4-D (0.05 - 0.40), fluazifop-butyl fb 2,4-D (0.08 fb 0.5), and PPG 1013 (0.2) and the standard herbicide treatments controlled weeds as effectively as the HW check. Compared to the untreated check, 19 of the 30 herbicide treatments did not reduce weed weight. At 60 DE, weed weights in plots treated with pendimethalin (1.5), molinate - propanil (1.9 - 1.9), PPG 1013 (0.2), fluazifop-butyl fb 2,4-D (0.10 fb 0.5), and propanil (3.0) were significantly lower than that in the untreated check and were not significantly different from that of the HW check.

The HW check yielded highest at 2.8 t/ha. Herbicide treatments that yielded over 2.0 t/ha were terbutryn at all rates tested (0.25, 0.50, and 0.75 kg/ha) fb HW, ametryn at 0.5 kg/ha fb HW molinate - propanil at both rates tested, and pendimethalin at 1.5 kg/ha.

Adding HW to an herbicide treatment that did not effectively control weeds resulted in relatively high yields. Adequate weed control with fluazifop-butyl at 0.08 kg/ha early in crop growth did not lead to high yields because *E. colona* rapidly grew in the treated plots.

Yields from plots treated with any rate of fluazifop-butyl, fluazifop-butyl - 2,4-D, MY93E, and PPG 1013 at 0.1 kg/ha were significantly lower than yield from the HW check.

Advanced evaluation. Major weeds in order of decreasing importance were *E. colona, Paspalum* sp., and *C. iria.* At 35 DE weed weights in plots treated with butachlor fb propanil, pendimethalin fb 2,4-D, propanil - thiobencarb - fenoprop, butachlor and thiobencarb, and in HW plots were significantly lower than that in the untreated check. At 40 DE, plots were split and one-half was HW; the other half received no additional weed control. HW required from 228 to 683 labor h/ha (Table 15). Significantly less time was required for eight of the herbicide-treated plots compared to the untreated check.

Additional HW at 40 DE resulted in a significant yield increase for all treatments, averaging 1.7 t/ha.

Weed control combinations. Although flora varied between replications, the most common weeds were *E. colona, Chloris barbata, Commelina diffusa,* and *M. concatenata.*

Manual and mechanical weed control methods, alone or combined, were compared with herbicides alone, in mixtures, or combined with manual and mechanical weed control methods. Weed control methods were harrowing 1 DE; interrow cultivation or hoe weeding plus HW 8 DE; HW; rotary weeding 45 DE; application of butachlor or pendimethalin preemergence, 1 DE, or 8 DE; propanil 15 DE; and propanil + butachlor or pendimethalin 16 DE. Examples of combined treatments are harrowing 1 DE + interrow cultivation and HW 8 DE + butachlor or pendimethalin 8 DE, and harrowing 1 DE + hoe weeding and HW 8 DE + rotary weeding 45 DE. Additional treatments included HW 14 + 28 DE, application of a tank mixture of pendimethalin + oxadiazon preemergence, and application of pendimethalin preemergence fb 2,4-D at 15 DE.

For weed control and crop yield, the herbicide combinations were superior to combinations of

Table 14. Effect of herbicides on weed control, crop tolerance, and yield of rainfed WSR IR36. IRRI, 1983 WS.

Treatment[a]	Application		Weed wt[b] (g/m²)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Broadleaf weeds	Grasses	Sedges		
MY71 G	2.0	6	0 a	6 a	4 a	2	3.2 a
A6728 EC	0.4	6	0 a	0 a	12 a	0	2.9 a
PPG 1013 EC	0.15	6	58 b	10 a	8 a	3	2.9 a
X-52B G	1.0	6	40 b	0 a	12 a	2	2.6 ab
MY93 EC	2.0	6	8 b	0 a	12 a	0	2.6 ab
MY93E G	2.0	6	8 b	0 a	8 a	2	2.5 ab
BAS 514 WP	0.3	6	46 b	0 a	10 a	2	2.5 ab
Thiobencarb – 2,4-D IPE G	1.5	6	0 a	0 a	6 a	2	1.8 b
Untreated check	–	–	12 b	8 a	2 a	0	1.8 b

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of 3 replications. [c]Rated 2 wk after herbicide application on a scale of 0-10: 0 = no toxicity and 10 = complete kill.

Table 15. Effect of various weed control treatments on the time required for HW 40 DE and the effect of HW on yield. IRRI, 1983 WS.

Treatment[a]	Rate (kg ai/ha)	Time of application (DE)	Time required for weeding[b] (labor-h/ha)	Yield (t/ha)	
				Not HW	HW 40 DE
Butachlor fb propanil	1.5 fb 2.0	PE fb 9	228 ab	3.2 a	4.6 a
HW twice	–	14 + 28	108 a	3.0 ab	4.3 a
Pendimethalin fb 2,4-D	2.0 fb 0.5	PE fb 21	278 abc	2.8 ab	4.3 a
Propanil – thiobencarb – fenoprop	1.69 - 0.93 - 0.39	9	331 bcd	1.6 abc	3.6 ab
Butachlor	2.0	PE	322 bcd	1.6 abc	3.6 ab
Pendimethalin	2.0	PE	428 bcde	1.5 abc	3.3 abcd
Thiobencarb	3.0	PE	433 bcde	1.0 c	3.5 abc
Propanil	3.0	9	358 bcd	1.4 bc	2.9 abcde
Propanil – thiobencarb	1.93 - 1.07	9	450 cde	0.3 c	3.0 abcde
Pendimethalin + propanil	1.5 + 1.5	9	528 def	0.8 c	2.5 bcde
Dicamba + butachlor + propanil	0.25 + 1.0 + 1.0	9	503 def	0.9 c	2.5 bcde
Dicamba + propanil	0.25 + 2.0	9	683 f	0.4 c	2.2 bcde
Butachlor + propanil	1.5 + 1.5	9	617 ef	0.5 c	1.8 cde
Dicamba	0.5	9	653 f	0.0 c	1.7 de
Untreated check	–	–	694 f	0.0 c	1.4 e

[a]A dash (–) = proprietary mixture; + = tank mixed. [b]HW at 40 DE.

two or more manual or mechanical methods or the combination of manual or mechanical methods with herbicides.

Seedbed preparation techniques and herbicide mixtures. During 1983 WS, direct-seeded rainfed bunded IR36 was used to evaluate three seedbed preparation techniques combined with three EPE herbicide mixtures and HW and unweeded checks.

A tank-mixed EPE application of butachlor or pendimethalin with propanil reduced weed biomass by 84-87% and increased yield (Table 16) possibly by reducing weed dry weight and increasing panicle number (Fig. 5).

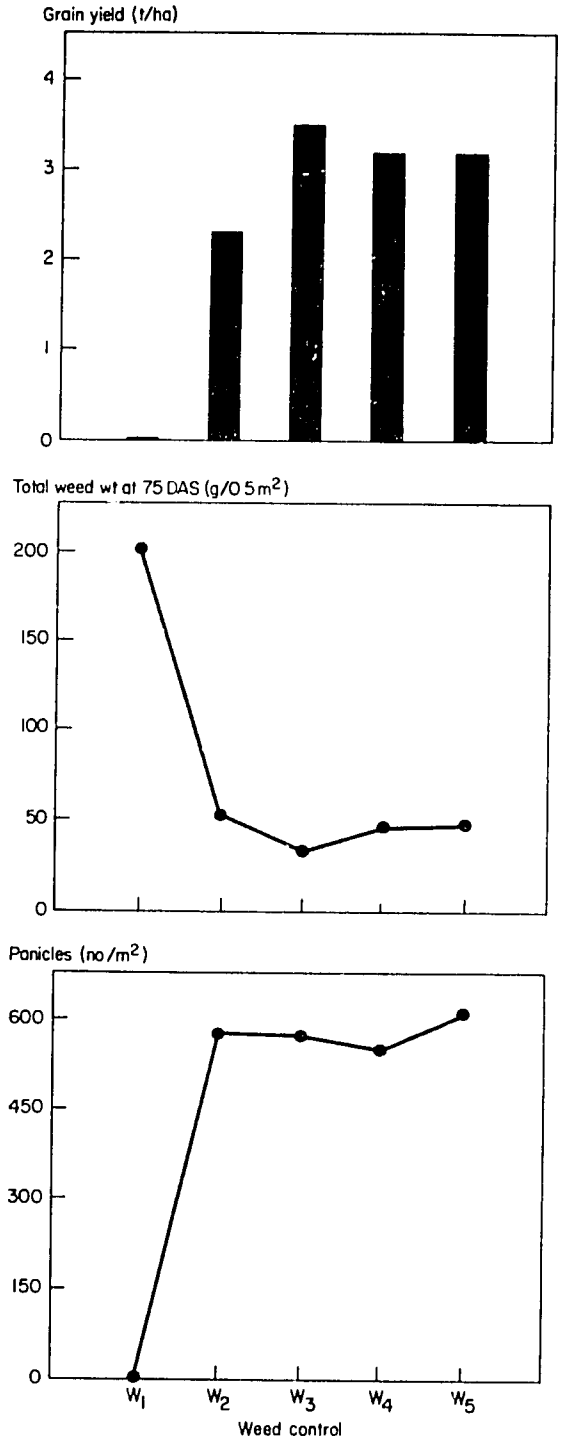
Upland rice. *Advanced trials, IRRI and Batangas.* Major weeds at IRRI included *Rottboellia exaltata, Digitaria* sp., *Eleusine indica, Amaranthus spinosus,* and *Ipomoea triloba.* All herbicides except propanil significantly reduced weed infestation but not as well as two HWs (Table 17).

The very low yields obtained could have been caused by a typhoon and heavy weed infestation particularly of *R. exaltata* during the reproductive

Table 16. Efficiency of herbicide mixtures in different seedbed preparations[a] for direct-seeded rainfed bunded IR36. IRRI, 1983 WS.

Treatment[b]	Application		Weed wt (g/m²)				Yield (t/ha)			
	Rate (kg ai/ha)	Time (DE)	CT	ZT	ST	Mean	CT	ZT	ST	Mean
Butachlor + propanil	1.5 + 1.5	8	48 a	58 a	92 a	66	3.9 a	3.6 a	3.2 a	3.5
Thiobencarb + propanil	1.5 + 1.5	8	48 a	82 b	130 b	86	3.5 b	3.2 b	2.8 b	3.2
Pendimethalin + propanil	1.5 + 1.5	8	78 b	114 c	92 a	94	3.2 b	3.2 b	3.3 a	3.2
HW	–	14, 35, 50	64 ab	78 ab	166 b	103	2.0 c	2.6 c	2.4 c	2.3
Untreated control	–	–	358 c	462 d	376 c	398	0.0 d	0.0 d	0.0 d	0.0

[a]CT = conventional tillage (2 plowings followed by 2 harrowings); ZT = zero tillage (preseeding application of glyphosate at 1.5 kg ai/ha); ST = stale-seedbed technique (application of paraquat at 0.75 kg ai/ha). [b]+ = tank mixture of 2 herbicides.



5. Effect of herbicide mixtures on total weed weight, number of panicles, and grain yield of direct-seeded rainfed bunded rice IR36. IRRI, 1983 WS. W_1 = control (untreated), W_2 = hand weeded (14, 35, and 50 DE), W_3 = butachlor + propanil (1.5 + 1.5 kg/ha DE), W_4 = thiobencarb + propanil (2.5 + 1.5 kg/ha DE), W_5 = pendimethalin + propanil (1.5 + 1.5 kg/ha DE). + indicates tank mixture.

phase. Although yields from herbicide-treated plots were not comparable with that from the HW check, yields from the dinitramine- and pendimethalin-treated plots were significantly higher than the untreated.

In Batangas, major weeds were *E. colona*, *Digitaria* sp., *Dactyloctenium aegyptium*, *Cyperus compressus*, *I. triloba*, and *Murdannia nudiflora*.

Oxadiazon was most effective and comparable to 2 HWs, oxyfluorfen, butralin, and dinitramine (Table 17). On the other hand, propanil, pendimethalin, butachlor, and thiobencarb did not control the weeds.

Only plots treated with oxyfluorfen, oxadiazon, pendimethalin, and dinitramine had yields comparable to that of the HW plot.

Sequential and tank-mixed herbicide applications. Four preemergence herbicides were tested in 1983 WS for weed control in upland IR36. Sequential and tank mixtures of preemergence herbicides with propanil were compared for effectiveness.

Grasses accounted for 91% of the weed flora. *R. exaltata* was the predominant weed.

Butachlor or pendimethalin fb propanil reduced weed dry weight by 89% (Fig. 6), and increased leaf area, panicle number, and grain filling which led to high yields (Table 18).

The total dry weight of weeds had a strong negative relationship ($r = -0.74^{**}$) with grain yield showing that effective weed control is necessary for high yields in upland rice.

Effect of spray equipment, IRRI and Batangas. Experiments at IRRI and a farmer's field in Cuenca, Batangas, during the 1983 WS compared the efficiency of 5 sprayers: micronherbi, single nozzle, birky, boom, and VLV-50. Butachlor, either alone at 1.0 or 2.0 kg/ha or fb 2,4-D at 0.4 or 0.8 kg/ha, was applied with each sprayer.

Most weeds at IRRI were *R. exaltata*, *Digitaria* sp., *I. triloba*, *Cleome rutidosperma*, *Calopogonium mucunoides*, *Centrosema pubescens*, and *Cyperus rotundus*.

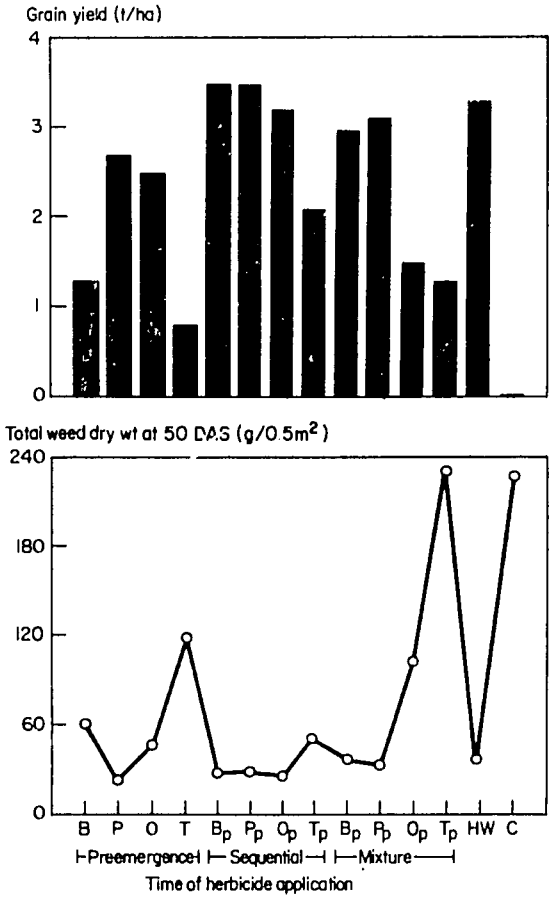
Total weed weight with the five sprayers did not differ (Table 19). Among the weed classes, only broadleaf weeds were affected by sprayer type with VLV-50 significantly less effective.

Averaged over five sprayers, a combination of butachlor and 2,4-D was more effective than butachlor alone. Increasing herbicide rate did not

Table 17. Total weed weight and grain yield of IR36 grown in upland fields at IRRI and Cuenca, Batangas, Philippines.[a] 1983 WS.

Treatment	Application		IRRI		Batangas	
	Rate (kg ai/ha)	Time (DAS)	Total weed wt[b] (g/m²)	Grain yield (t/ha)	Total weed wt[b] (g/m²)	Grain yield (t/ha)
HW twice	–	15 & 30 DE	17 a	1.1 a	148 ab	1.2 a
Pendimethalin	2.0	0-2	62 b	0.7 b	271 bcd	0.9 abc
Dinitramine	1.5	0-2	93 bc	0.6 bc	188 abc	0.8 abc
Oxyfluorfen	0.5	0-2	81 b	0.1 d	162 ab	1.1 ab
Oxadiazon	1.0	0-2	66 b	0.2 cd	133 a	0.9 abc
Butralin	2.0	0-2	105 bc	0.1 d	161 ab	0.5 bcd
Thiobencarb	3.0	0-2	139 bc	0.1 d	227 abcd	0.5 bcd
Propanil	2.0	10-15 DE	235 cd	0.1 d	329 cd	0.4 cd
Butachlor	2.0	0-2	99 bc	0.1 d	253 bcd	0.4 cd
Untreated check	–	–	357 d	0.0 d	364 d	0.1 d

[a]Av of 4 replications/site. [b]Weeds were sampled 70 DE.



6. Effect of preemergence and postemergence herbicides on weed dry weight and grain yield in IR36. IRRI, 1983 WS. B = butachlor, 2.0 kg/ha; P = pendimethalin, 2.0; O = oxadiazon, 0.5; T = thiobencarb, 2.5; Bp = butachlor fb propanil, 1.5; Pp = pendimethalin fb propanil, 1.5; Op = oxadiazon fb propanil, 0.4 fb 1.5; Tp = thiobencarb fb propanil, 2.0 fb 1.5; HW = hand weeding 14, 35, and 50 DE; C = unweeded control.

significantly reduce total weed weight or dry weight of broadleaf weeds.

The major weeds in Batangas were *E. colona, D. aegyptium, Paspalum dilatatum, Ischaemum rugosum, Aeschynomene indica, C. diffusa, I. triloba, M. nudiflora,* and *C. rotundus.*

Total weed weight was lowest in birky plots (Table 20), but boom, VLV-50, and single nozzle sprayers performed as well. Micronherbi plots had significantly higher weed weight.

Total weed weight was significantly lowest with higher rates of butachlor and 2,4-D. .This was comparable with butachlor (2.0) fb 2,4-D (0.4). A combination of the 2 herbicides except butachlor (1.0) fb 2,4-D (0.4 or 0.8) performed better than a single application of butachlor.

Grassy weeds were most effectively controlled by herbicides applied with the birky and boom sprayers and least effectively with the micronherbi and the single nozzle. Sprayer type did not affect control of sedges.

Grasses were effectively controlled with the higher rate of butachlor alone or followed by either rate of 2,4-D. A butachlor - 2,4-D combination controlled sedges better than butachlor alone. Increasing the butachlor rate in the combination did not improve sedge control. But increasing the rate of 2,4-D from 0.4 to 0.8 kg/ha without increasing butachlor significantly improved sedge control.

Butachlor applied alone at 1.0 kg/ha provided the best broadleaf weed control with the boom

Table 18. Preemergence and postemergence herbicide combinations for upland rice IR36. IRRI, 1983 WS.

Treatment[a]	Application		Weed wt 50 DAS (g/m²)	LAI at 60 DAS	Panicles (no./m²)	Filled grain (%)	Yield (t/ha)
	Rate (kg ai/ha)	Time					
Butachlor	2.0	PE	119 ab	0.714 bc	127 bc	56 ab	1.3 bc
Pendimethalin	2.0	PE	49 a	2.812 a	273 a	66 a	2.7 a
Oxadiazon	0.5	PE	88 a	2.516 b	245 ab	70 a	2.5 ab
Thiobencarb	2.5	PE	236 b	0.458 bc	73 c	53 b	0.8 c
Butachlor fb propanil	1.5 fb 1.5	PE fb 8 DE	51 a	3.558 a	355 a	72 a	3.5 a
Pendimethalin fb propanil	1.5 fb 1.5	PE fb 8 DE	52 a	3.711 a	328 a	71 a	3.5 a
Oxadiazon fb propanil	0.4 fb 1.5	PE fb 8 DE	45 a	2.752 ab	320 a	65 a	3.2 a
Thiobencarb fb propanil	2.0 fb 1.5	PE fb 8 DE	93 a	1.749 b	200 b	59 ab	2.1 b
Butachlor + propanil	1.5 + 1.5	8 DE	73 a	3.606 a	290 a	72 a	3.0 a
Pendimethalin + propanil	1.5 + 1.5	8 DE	64 a	4.004 a	312 a	68 a	3.1 a
Oxadiazon + propanil	0.4 + 1.5	8 DE	217 b	2.574 b	300 a	64 a	1.5 b
Thiobencarb + propanil	2.0 + 1.5	8 DE	269 b	1.741 b	181 b	61 a	1.3 bc
HW	–	14, 35, 50 DE	71 a	3.382 a	321 a	68 a	3.3 a
Unweeded check	–	–	455 c	0.382 c	0 d	0 c	0 d

[a]+ = tank mixture of 2 herbicides.

Table 19. Effect of spray equipment and herbicide rate on weed growth at 40 DE of IR36. IRRI, 1983 WS.

Factor	Dry weight (g/m²)			
	Broadleaf weeds	Grasses	Sedges	Total
Herbicide[a]				
Butachlor (1.0)	16 b	37 a	38 a	91 b
Butachlor (2.0)	17 b	27 a	37 a	81 b
Butachlor fb 2,4-D (1.0 fb 0.4)	3 a	36 a	27 a	66 ab
Butachlor fb 2,4-D (2.0 fb 0.4)	3 a	47 a	22 a	71 ab
Butachlor fb 2,4-D (1.0 fb 0.8)	2 a	34 a	25 a	61 a
Butachlor fb 2,4-D (2.0 fb 0.8)	2 a	26 a	26 a	54 a
Spray equipment[b]				
Micronherbi	7 a	31 a	27 a	63 b
Single nozzle	7 a	46 a	24 a	77 b
Birky	7 a	37 a	22 a	66 b
Boom	6 a	30 a	39 a	75 b
VLV-50	10 b	28 a	34 a	72 b

[a]Av of 3 replications and 5 spray equipment. Butachlor was applied 2 DAS and 2,4-D 15 d after rice emergence. [b]Av of 3 replications and 6 herbicide rates.

Table 20. Effect of sprayers and herbicide rate on weed growth at 60 DE of IR36. Cuence, Batangas, Philippines, 1983 WS.

Factor	Dry weight (g/m²)		
	Grasses	Sedges	Total
Herbicide[a]			
Butachlor (1.0)	144 bc	81 c	266 d
Butachlor (2.0)	108 a	81 c	225 cd
Butachlor fb 2,4-D (1.0 fb 0.4)	176 c	33 b	219 bcd
Butachlor fb 2,4-D (2.0 fb 0.4)	138 abc	29 b	176 ab
Butachlor fb 2,4-D (1.0 fb 0.4)	171 c	17 a	194 bc
Butachlor fb 2,4-D (2.0 fb 0.8)	121 ab	25 ab	152 a
Spray equipment[b]			
Micronherbi	213 d	43 a	282 b
Single nozzle	157 cd	37 a	206 a
Birky	95 a	43 a	168 a
Boom	112 a	55 a	173 a
VLV-50	139 bc	44 a	196 a

[a]Av of 3 replications and 5 sprayer types. Butachlor was applied at seeding time and 2,4-D 15 d after crop emergence. Herbicide rate in kg/ha is in parentheses. [b]Av of 3 replications and 6 herbicide rates.

sprayer (Table 21). At 2.0 kg/ha, butachlor provided good control with all sprayers except the birky. At lower butachlor and 2,4-D combination rates, all sprayers, except the VLV-50, had effective control. At the higher rates, control was unaffected by sprayer type. A butachlor and 2,4-D combination controlled broadleaf weeds better than a single butachlor application.

Neither location produced a harvest. At IRRI, drought and insects damaged the crop during the reproductive phase, resulting in sterile spikelets. In Batangas, heavy weed infestation, particularly

Table 21. Effect of type of sprayer and herbicide rate on the dry weight of broadleaf weeds in IR36 60 DE.[a] Cuenca, Batangas, Philippines, 1983 WS.

Sprayer	Dry weight of broadleaf weeds[b] (g/m²)					
	Butachlor (1.0)	Butachlor (2.0)	Butachlor fb 2,4-D (1.0 fb 0.4)	Butachlor fb 2,4-D (2.0 fb 0.4)	Butachlor fb 2,4-D (1.0 fb 0.8)	Butachlor fb 2,4-D (2.0 fb 0.8)
Micronherbi	65 a	52 ab	3 a	20 a	9 a	4 a
Single nozzle	36 a	14 a	10 ab	9 a	3 a	6 a
Birky	80 a	76 b	8 a	5 a	8 a	8 a
Boom	5 b	22 a	4 a	2 a	4 a	7 a
VLV-50	24 a	17 a	23 b	7 a	7 a	5 a
Means	42	36	10	9	6	6

[a]Av of 3 replications. [b]Butachlor and 2,4-D were applied after seeding and 20 d after rice emergence. Herbicide rates in kg/ha are in parentheses.

grasses, occurred during the reproductive phase.

Variety and nitrogen level. The performance of 3 upland rices [Kinandang Patong (tall), C171-136 (intermediate tall), IR43 (semidwarf)], 3 N levels (0, 50, and 100 kg/ha), and 3 weeding regimes [butachlor (2.0 kg/ha), 2 HWs at 15 and 30 DE, and untreated check] was evaluated for weed control.

Major weeds were *R. exaltata, E. indica, Paspalum* sp., *Digitaria* sp., *A. spinosus, C. rutidosperma, M. nudiflora,* and *C. rotundus.*

At 80 DE, total weed weight did not differ among rice varieties and N levels. However, dry weight of the predominant weed *R. exaltata*, at the highest N level, was significantly lower in C171-136 plots than in IR43 and Kinandang Patong plots. At 0 and 50 kg N/ha, dry weight of *R. exaltata* did not differ among the varieties. At 100 kg N/ha, C171-136 significantly reduced dry weight of *R. exaltata* compared to IR43. Averaged over the 3 N levels, C171-136 significantly reduced dry weight of *R. exaltata* and yielded significantly higher than IR43 and Kinandang Patong at all N levels. N rate, however, did not affect grain yield of each variety.

Plant height of all varieties significantly increased as N increased (Table 22). C171-136 and Kinandang Patong were similar in height without N and taller than IR43. LAI of IR43 and Kinandang Patong did not differ at all N levels; LAI of C171-136 was significantly higher at 100 kg N/ha than at zero N. Tiller number was similar among varieties regardless of N level.

Rices absorbed more and had higher percent total N at 60 DE than weeds at all weeding regimes (Table 23). Weeds in butachlor and untreated plots absorbed less N than those in the HW plots, possibly because of competition among themselves which favored more N uptake by the rice. When weed control was effective, as in HW plots, the remaining few weeds competed with rice for N uptake. This is shown by the lower percent total N of rice and the higher percent in weeds from HW plots compared to weeds of butachlor and untreated plots.

Table 22. Effect of N level on plant height, LAI, and tiller count of 3 varieties grown in upland fields.[a] IRRI, 1983 WS.

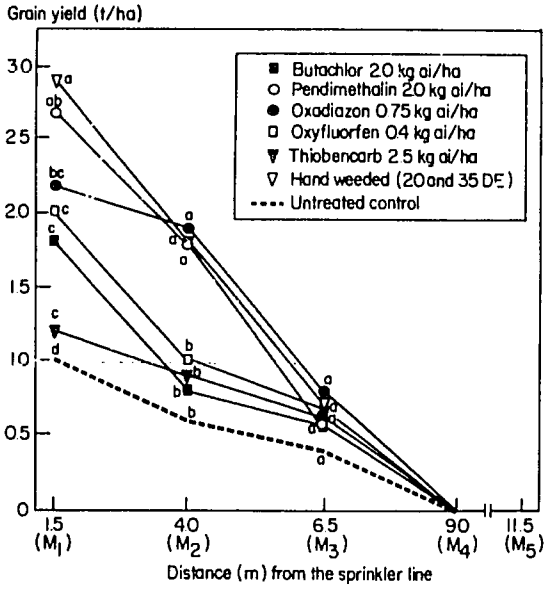
N level (kg/ha)	Plant height[b] (cm)				LAI				Tiller count (no./m²)			
	IR43	C171-136	Kinandang Patong	N means	IR43	C171-136	Kinandang Patong	N means	IR43	C171-136	Kinandang Patong	N means
0	88.3	122.7	135.2	115.4	4.96 a	5.04 b	4.77 a	4.92	457 a	419 a	332 a	403
50	92.0	124.3	152.0	122.8	4.69 a	5.74 ab	5.55 a	5.33	447 a	453 a	319 a	406
100	99.2	133.7	159.3	130.7	5.24 a	6.97 a	5.42 a	5.87	398 a	481 a	281 a	386
Variety means	93.2	126.9	148.8	123.0	4.97	5.92	5.25	5.37	434	451	311	399

[a]Av of 3 replications and 3 weeding regimes. [b]LSD (5%) = 21.9 between 2 V means.

Table 23. Percent total N of weeds and rice at 60 DE as affected by weeding regime, N level, and variety grown in upland fields.[a] IRRI, 1983 WS.

Weed control treatment	Total N (%)		
	Weeds	Rice	Difference
Butachlor (2.0 kg/ha)	0.87 b	1.37 a	-0.50**
HW check	1.01 a	1.19 b	-0.18*
Untreated check	0.83 b	1.28 ab	-0.45**

[a]Av of 3 replications, 3 N levels, and 3 varieties.



7. Effect of herbicides on IR36 yield under different upland soil moisture regimes. IRRI, 1983 DS. In a moisture regime, values marked by a common letter are not significantly different at the 5% level.

There was a correlation between total weed weight at 80 DE and yield of Kinandang Patong (r = -0.70*) and C171-136 (r = -0.89**), and total weed weight and plant height of C171-136 at 80 DE (r = -0.71*).

Soil moisture-herbicide relationship. A field experiment on soil moisture-herbicide relationship was conducted with upland IR36 during 1983 DS using a line-source sprinkler (LSS).

The cumulative amount of water applied including rainfall from day 0 to 100 in the plots nearest to or farthest from LSS was 811, 691, 525, 365, and 214 mm (M1 to M5 moisture regimes). These amounts compared to 668 mm recorded in the upland pan evaporation (UPE) during the same period. Thus, M1 and M2 were maintained above UPE at all stages of growth whereas M3 was more or less at UPE level; M4 and M5 were below UPE after initial crop establishment.

Five preemergence herbicides were compared with HW and unweeded checks for their effectiveness and selectivity.

At the highest moisture regime (M1), pendimethalin and HW provided significantly higher yields than the other regimes.

At M2, pendimethalin, the HW check, and oxadiazon yielded higher than the other weed treatments (Fig. 7). The pendimethalin and oxadiazon treatments had low weed weights, high panicle numbers, and high yield (Table 24). There were no perceptible differences in yield between the herbicide treatments and the unweeded control when the soil moisture was maintained at M3.

Table 24. Effect of herbicides on weed dry weight and panicle number under different soil moisture regimes in upland IR36.[a] IRRI, 1983 DS.

Treatment[b]	Application		Weed wt (g/m²) 45 DAS			Visual toxicity rating[c] (20 DS)	Panicles (no./m²)		
	Rate (kg ai/ha)	Time	M1	M3	M5		M1	M3	M5
Butachlor	2.0	PE	392 c	199 c	368 b	0	368 b	175 c	0
Pendimethalin	2.0	PE	122 b	121 b	46 b	0	473 a	252 b	0
Oxadiazon	0.75	PE	47 b	64 b	60 b	2	421 ab	235 bc	0
Oxyfluorfen	0.4	PE	61 b	79 b	54 b	3	319 c	251 b	0
Thiobencarb	2.5	PE	501 c	400 c	346 c	0	311 c	222 bc	0
HW check	–	20 & 35 DE	5 a	5 a	4 a	0	398 b	334 a	0
Untreated check	–	–	633 c	719 c	208 c	0	124 d	84 d	0

[a]Av of 4 replications. M1 = highest, M3 = middle, and M5 = lowest moisture regimes. [b]One late hand weeding was given at 50 DAS in all treatments. [c]Rated 3 wk after application on a scale of 0-10: 0 = no toxicity and 10 = complete kill.

Soil moisture above UPE at all stages of growth resulted in significant yield increases because of weed control (Fig. 7). Where soil moisture was inadequate (M3), all weed control treatments had yields as low as that of the unweeded check. No yield was obtained at M4 and M5 moisture levels despite effective weed control from herbicides or HW.

Control of Rottboellia exaltata. The effectiveness of pendimethalin and fluazifop-butyl and their combinations was tested in controlling *R. exaltata* in an IRRI upland field during 1983 WS. IR36 (short-statured, early-maturing) and Kinandang Patong (tall, late-maturing traditional) were used.

R. exaltata was the initial dominant weed. *I. triloba*, *Commelina benghalensis*, *C. iria*, and *C. rotundus* appeared later.

All herbicide treatments significantly reduced dry weight of *R. exaltata* over the untreated check in both varieties (Table 25). Tank-mixed pendimethalin and fluazifop-butyl had less weed weight than single application of either herbicide and the HW check in both varieties. The mixture produced significantly higher yields with IR36. Low yields of pendimethalin alone and in combination at 1.5 kg were caused by its toxicity to rice. Fluazifop-butyl

Table 25. Effect of pendimethalin and fluazifop-butyl and their combinations on control of *Rottboellia exaltata* in upland rice. IRRI, 1983 WS.

Treatment[a]	Application		Weed wt[b] (g/m²)		Yield[b] (t/ha)	Weed wt[b] (g/m²)		Yield[b] (t/ha)
	Rate (kg ai/ha)	Time	Grasses	Sedges		Grasses	Sedges	
				IR36			*Kinandang Patong*	
Pendimethalin	1.0	PE	110 c	18 b	1.4 c	64 bc	80 b	0.4 c
Pendimethalin	1.5	PE	110 c	16 b	0.2 e	36 b	64 b	0.4 c
Fluazifop-butyl	0.08	8 DE	220 c	60 b	0.2 e	40 bc	272 b	0.4 c
Fluazifop-butyl	0.08	12 DE	292 c	70 b	0.5 de	54 b	146 b	0.3 c
Pendimethalin + fluazifop-butyl	1.0 + 0.08	8 DE	20 a	32 b	2.2 a	0 a	236 b	1.0 ab
Pendimethalin + fluazifop-butyl	1.0 + 0.08	12 DE	10 a	36 b	2.0 ab	2 a	184 b	0.4 c
Pendimethalin + fluazifop-butyl	1.5 + 0.08	8 DE	30 ab	48 b	1.0 cd	4 a	98 b	1.3 a
Pendimethalin + fluazifop-butyl	1.5 + 0.08	12 DE	12 a	14 b	1.5 bc	24 ab	294 b	0.5 bc
HW check	Twice	15 & 30 DE	66 bc	0 a	1.2 c	162 c	88 b	1.2 a
Untreated check	–	–	946 d	0 a	0 e	760 d	0 a	0 c

[a]A plus (+) means that the 2 herbicides were tank-mixed and applied at the same time. A blanket application of 2,4-D amine was made 14 DE to control broadleaf weeds. [b]Av of 3 replications.

Table 26. Effect of tillage treatments on weed control and yield of the 19th and 20th crops.[a] IRRI, 1983 DS and WS.

Treatment	IR34			IR40			IR42		
	Weed wt[b] (g/m²)		Yield (t/ha)	Weed wt[b] (g/m²)		Yield (t/ha)	Weed wt[b] (g/m²)		Yield (t/ha)
	Annual	Perennial		Annual	Perennial		Annual	Perennial	
				19th crop, 1983 DS					
Conventional tillage	15 a	138 a	2.7 a	2 a	201 a	2.7 a	2 a	129 a	2.7 a
Minimum tillage	6 a	120 a	2.8 a	26 b	212 a	2.8 a	11 a	88 a	2.9 a
Zero tillage	18 a	185 a	2.5 a	4 ab	225 a	2.5 a	9 a	121 a	2.4 a
				20th crop, 1983 WS					
Conventional tillage	0 a	70 a	2.5 a	0 a	45 a	1.6 a	0 a	135 a	3.3 a
Minimum tillage	18 a	107 a	2.3 a	69 b	75 b	1.9 a	6 a	111 a	2.2 b
Zero tillage	4 a	328 b	0 b	8 ab	248 c	0 b	0 a	375 b	0.2 c

[a]Av of 4 replications/crop. [b]At rice harvest. Annuals were *Monochoria vaginalis* and *Echinochloa* spp.; perennials were *Scirpus maritimus* and *Paspalum distichum*.

alone had low yield because of competition from the second growth of *R. exaltata*, especially in IR36. Regardless of herbicide treatment, dry weight of *R. exaltata* was lower in the Kinandang Patong than in the IR36 plots. Kinandang Patong yields were relatively low because of lodging at maturity.

Results suggest that herbicide combinations such as pendimethalin + fluazifop-butyl are more effective against *R. exaltata* than single applications. Tall varieties such as Kinandang Patong seem to compete better with the weed.

PERENNIAL WEEDS AND THEIR CONTROL

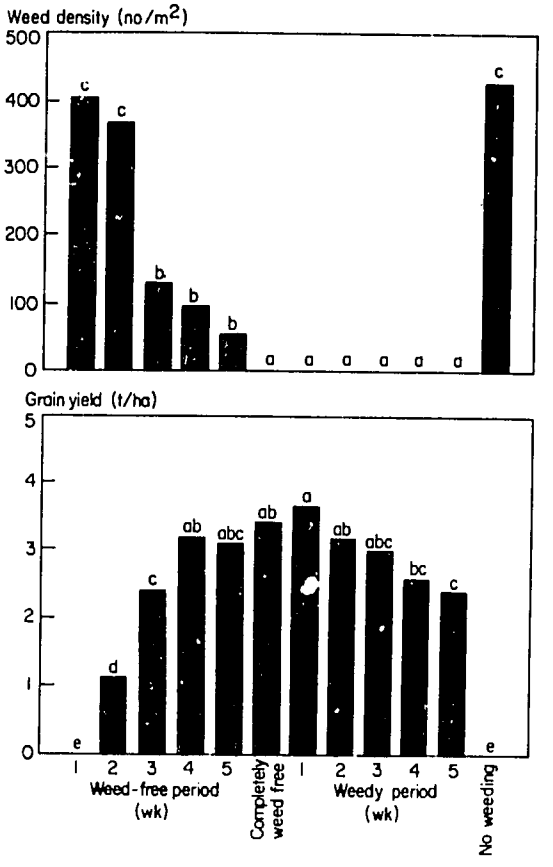
Long-term effects of reduced tillage. Long-term study on the effects of conventional tillage (one plowing + 2 harrowings), minimum tillage (one harrowing), and zero tillage in transplanted IR34, IR40, and IR42 rices continued during the 1983 DS (19th crop) and WS (20th crop). Zero tillage consisted of removing rice and weed debris from the previous crop, then applying 0.5 kg paraquat/ha.

In the 19th crop, the minimum and zero tillage plots were cultivated conventionally. Consequently, infestation of weeds, dominantly *Scirpus maritimus*, and grain yield (Table 26) did not vary with tillage treatment and variety.

In the 20th crop, an increase in *S. maritimus* stand, rather than a shift from annual to perennial weeds, occurred as tillage level changed from conventional to zero. The difference in weed stand and grain yield between conventional and minimum tillage was generally not significant (Table 26). But perennial weed stand increased and yield with all varieties decreased significantly as tillage was reduced to zero.

Time of weeding of *Scirpus maritimus*. An experiment with IR36 during 1983 WS examined effects of time of weeding *S. maritimus* on yield and its components. The treatments were weed-free and weedy plots at 1, 2, 3, 4, and 5 WT with weed-free and weedy control plots.

Heavy *S. maritimus* infestation resulted in no yield from the unweeded plots and from those kept weed free for only 1 wk from transplanting (Fig. 8). Plots weeded for 1 or 2 wk had heavy weed regrowth later in the season. For optimum grain yield, the crop needed to be free of *S. maritimus* for at least 4 WT or weeded after 3 wk.



8. *Scirpus maritimus* density at 8 WT and yield of TPR IR36 as influenced by time of weeding. IRRI, 1983 WS.

Panicle weight showed the same response as yield to duration of *S. maritimus* competition with the crop (Table 27). Panicle number and length of plants kept weed free for 3 wk did not differ significantly from those of plants kept completely weed free. Sensitivity of IR36 yield components to longer duration of *S. maritimus* competition was panicle > panicle number > panicle length.

Control of *Scirpus maritimus* with herbicides. Experiments during the 1983 DS compared the effects of single and combined herbicide treatments on *S. maritimus* control and yield of lowland IR36.

Transplanted rice. All herbicides except propanil significantly reduced *S. maritimus* stand, but some treatments did not differ in yield from the untreated check because weed population was low (Table 28).

Direct-seeded rice. Most of the herbicide treatments did not significantly reduce *S. maritimus* stand (Table 29). However, all herbicides except propanil applied alone (poorest weed control)

yielded significantly more than the untreated check.

Results suggest that herbicide combinations are not necessary to control single weed vegetation for optimum yields.

Table 27. Effect of time of weeding *Scirpus maritimus* on yield components of TPR IR36.[a] IRRI, 1983 WS.

Treatment	Panicles (no./m²)	Panicle wt (g)	Panicle length (cm)
Weed free for 1 wk	0 d	0 e	0 c
Weed free for 2 wk	288 c	1.3 cd	17 b
Weed free for 3 wk	383 ab	1.4 bcd	19 ab
Weed free for 4 wk	421 a	1.5 abc	20 a
Weed free for 5 wk	432 a	1.5 abc	20 a
Completely weed free	439 a	1.7 a	20 a
Weedy for 1 wk	433 a	1.6 ab	20 a
Weedy for 2 wk	400 ab	1.5 abc	20 a
Weedy for 3 wk	421 a	1.6 ab	20 a
Weedy for 4 wk	405 ab	1.3 cd	19 ab
Weedy for 5 wk	317 bc	1.2 d	18 ab
No weeding	0 d	0 e	0 c

[a]Av of 4 replications.

Table 28. Effect of herbicides applied 26 DT on control of *Scirpus maritimus* and yield of TPR IR36.[a] IRRI, 1983 DS.

Treatment[b]	Rate (kg ai/ha)	Weed wt (g/m²)	Yield (t/ha)
Bentazon + propanil	0.8 + 1.7	10 ab	6.0 a
Bentazon + 2,4-D	0.5 + 0.5	4 a	5.6 a
Bentazon + propanil	0.5 + 1.5	6 ab	5.6 a
Bentazon + 2,4-D	0.5 + 0.25	10 ab	5.6 a
Bentazon – dicamba	0.48 - 0.5	16 ab	5.6 a
HW check	–	26 bc	5.6 a
Bentazon	1.0	25 ab	5.5 ab
2,4-D	0.75	12 ab	5.5 ab
Bentazon – MCPA	0.6 - 0.9	10 ab	5.4 ab
Propanil + 2,4-D	1.0 + 0.5	6 ab	5.4 ab
Propanil	2.0	20 bc	5.3 ab
Untreated check	–	65 c	4.7 b

[a]Av of 4 replications. [b]A plus (+) means the 2 herbicides were applied tank-mixed. A spaced dash (–) means the 2 herbicides were applied as a proprietary mixture. The HW check was weeded 15 DT.

Tillage for control of wild rice in deepwater rice. In deepwater rice areas of Thailand, fields are dry plowed and then broadcast seeded before or soon after the first rains. This practice has resulted in increased infestation of wild rice *Oryza rufipogon*.

The effect of timing and number of plowings was examined at Pitsanulok. Early plowing and early broadcasting resulted in dense populations of wild rice and low yields of deepwater rice LMN III (Table 30). Delaying the second plowing until after initial wild rice germination reduced its population and increased deepwater yields. Increasing the seed rate slightly decreased wild rice in treatment 2 compared with treatment 1. Three plowings were

Table 29. Effect of herbicides applied 25 DAS on control of *Scirpus maritimus* and yield of direct-seeded flooded IR36.[a] IRRI, 1983 DS.

Treatment[b]	Rate (kg ai/ha)	Weed wt (g/m²)	Yield (t/ha)
Bentazon + 2,4-D	0.5 + 0.5	30 a	4.1 a
Bentazon – MCPA	0.6 – 0.9	46 a	3.6 ab
Propanil + 2,4-D	1.5 + 0.5	69 abc	3.5 ab
Bentazon	1.0	81 abc	3.3 ab
Bentazon + propanil	0.8 + 1.7	45 ab	3.2 ab
2,4-D	0.75	118 bc	3.1 ab
Bentazon + 2,4-D	0.5 + 0.25	91 bc	3.0 bc
Bentazon + propanil	0.5 + 1.5	62 abc	2.9 bc
Bentazon – dicamba	0.48 – 0.5	89 bc	2.8 bc
Propanil + 2,4-D	1.0 + 0.5	109 bc	2.8 bc
Propanil	2.0	132 bc	2.1 cd
Untreated check	–	188 c	1.8 d

[a]Av of 4 replications. [b]A plus (+) means the 2 herbicides were applied tank-mixed. A spaced dash (–) means the 2 herbicides were applied as a proprietary mixture.

Table 30. Effects of time of tillage on wild rice populations and yield of a deepwater rice. Pitsanulok, Thailand, 1983.

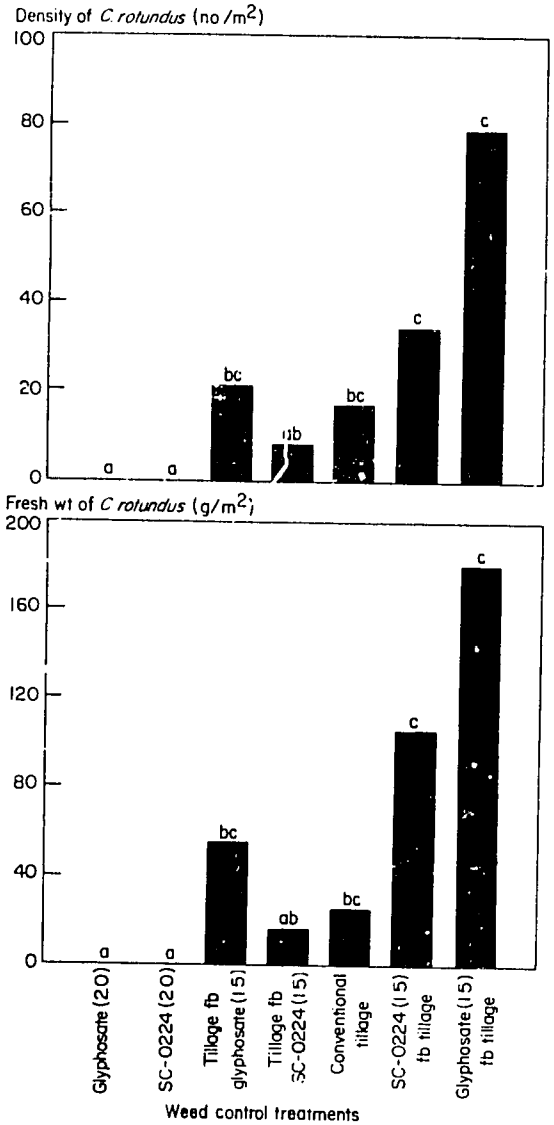
Treatment	Plowing date	Wild rice (plants/m²)	Grain yield (t/ha)
1	8 Apr, 18 May	277 c	0.13 b
2[a]	8 Apr, 18 May	202 b	0.08 c
3	8 Apr, 9 Jun	135 ab	0.79 a
4[b]	8 Apr, 9 Jun	91 a	0.72 a
5	8 Apr, 18 May, 9 Jun	100 a	0.73 a
6	8 Apr, 24 Jun	141 ab	0.85 a
7[b]	8 Apr, 24 Jun	134 ab	1.03 a

[a]Seed rate increased from 20 to 30 kg/ha. For all plots the seed was broadcast immediately after final plowing. [b]Plots sprayed with paraquat 1 d before final plowing.

Table 31. Effect of different weed control methods on the density of *Cyperus rotundus* and yield of upland IR36. IRRI, 1983 WS.

Preplant treatment[a]	Density of *C. rotundus*[b] (no./m²)					Grain yield (t/ha)
	Bentazon (1.5)	2,4-D (1.0)	Hand-weeded check	Untreated check	Means	
Glyphosate (2.0)	1 a	0 a	6 a	17 a	6	1.0
SC-0224 (2.0)	0 a	0 a	23 ab	12 a	9	0.7
Rototillage fb SC-0224 (1.5)	14 a	8 ab	15 ab	13 a	12	0.7
Rototillage fb glyphosate (1.5)	1 a	21 bc	8 a	19 a	12	0.8
Conventional tillage	12 a	17 bc	43 ab	35 a	27	1.3
SC-0224 (1.5) fb rototillage	11 a	34 c	28 ab	72 a	36	1.1
Glyphosate (1.5) fb rototillage	7 a	79 c	65 b	13 a	41	1.1
Means	7	23	27	26	21	ns

[a]Conventional tillage = 1 plowing + 3 rototillings. Herbicide rate in kg ai/ha are in the parentheses. [b]*C. rotundus* was sampled at 30 DE.



9. Density and fresh weight of *Cyperus rotundus* in 2,4-D-treated plots as affected by preplant weed control treatments. IRRI, 1983.

no better than two. Soil conditions at time of tillage limited effectiveness of the treatments.

Control of *Cyperus rotundus*. An IRRI experiment during 1983 WS evaluated the performance of preplant herbicides glyphosate and SC-0224, applied alone and followed or preceded by 1 rototilling to control *C. rotundus*. The herbicides were compared with the conventional method of 1 plowing and 3 rototillings. Postemergence weed control treatments included bentazon, 2,4-D, two HWs, and an untreated check.

At 30 DE, *C. rotundus* density in the bentazon-treated plots was unaffected by the different preplant treatments (Table 31). Apparently, bentazon controlled the weed so well that it masked the effect of the preplant treatments. There were also no significant differences in weed control among the preplant treatments in the HW and untreated plots.

However, glyphosate or SC-0224 (2.0) fb 2,4-D excellently controlled the weed as did SC-0224 (1.5) preceded by 1 rototilling (Fig. 9). Glyphosate did not control *C. rotundus* effectively when applied either before or after rototilling, but SC-0224 performed better when applied after tillage.

Yields were obtained from the HW plots only, because of heavy grass infestation, particularly with *R. exaltata*, toward the reproductive stage of rice. Yields did not vary significantly among the preplant treatments.

Irrigation water management

Irrigation Water Management Department

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Irrigation research in the Philippines is in collaboration with the National Irrigation Administration (NIA).

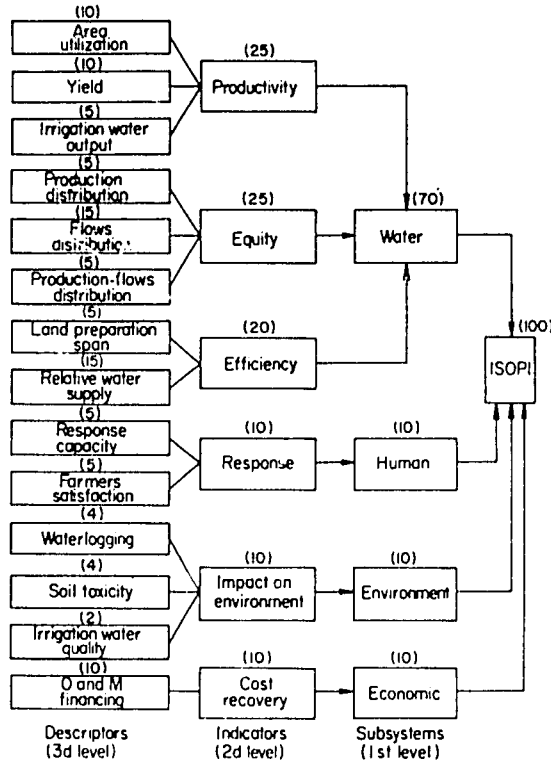
METHODOLOGY TO EVALUATE IRRIGATION SYSTEM PERFORMANCE

There is no present sound, practical method to evaluate the operating performance of irrigation systems in physical, economic, and social terms. Neither criteria to assess performance nor procedures to measure and integrate them have been established. In 1981-82, a cooperative research project with Cornell University developed a methodology for evaluating the performance of Philippine rice irrigation systems that is also adaptable for use abroad.

The resulting model can estimate the irrigation system overall performance index (ISOPI) for a crop season. The index is a 3-tier structure: the highest level is the subsystem; the intermediate level, the indicators; and the lowest level, the descriptors (Fig. 1). Four subsystems cover the most common irrigation systems concerns. Evaluation moves from the lower to higher levels so that final subsystem evaluation can take place only after the descriptors and indicators have been evaluated.

Each of the subsystems, indicators, and descriptors were weighted (Fig. 1) to establish scores for quantitative estimation. The total scores result in the ISOPI estimate for a season. By using an interactive computer program in the BASIC language, sensitivity analyses can determine what will happen if the weights change and also can estimate the ISOPI value for each season. The program also allows the user of the model to shift it from the most rigorous *research level* analysis (as in Fig. 1) using all the cells of the model, to a less intensive *agency level* analysis which uses only data usually collected by the irrigation agency. The extreme is the quick *consultant level* analysis which depends on data easily collected from irrigation system studies in a short time.

The model increases understanding of factors affecting the system's performance and analyzes its strong and weak points. The methodology was used to evaluate data from one irrigation system at the research level, six irrigation systems at the agency level, and four systems at the consultant level. All were operated by the NIA on Luzon. For the agency level analysis, weights were redistributed



1. Irrigation systems overall performance index (ISOPI) model. IRRI, 1983. The value of each item is in parentheses.

because only 10 of the 14 descriptors were used. For the consultant level analysis, eight descriptors were used.

Analysis of results for each level (Table 1) allows the following inferences.

1. The methodology can evaluate irrigation systems in the Philippines and is adaptable for various types of irrigation systems with diverse service area backgrounds.
2. The systems studied are in transition from a stage where land is the most scarce production factor to the stage where water is relatively scarce and management skills are needed. These systems are typified by a high percentage of irrigable area actually irrigated and relatively low water supply.
3. ISOPI values were 55-84% (av 74%) for DS and 67% for WS. Subsystems scores suggest that human resource and economic subsystems need improvement to prevent irrigation systems' continued dependence on government subsidies to sustain their operation and management.

Table 1. Estimation of irrigation system overall performance index (ISOPI)[a] for selected Central Luzon, Philippines, systems.

System	Potential service area (ha)	Season	Subsystem score				ISOPI (100)
			Water (70)	Human (10)	Environment (10)	Economic (10)	
Libmanan-Cabusao Pump Irrigation System	3916	1981 WS	50.7	1.8	6.0	0.4	58.9
		1982 DS	58.4	6.0	6.0	4.2	74.6
		1982 WS	53.5	4.9	8.0	0.6	67.0
San Fabian River Irrigation System	3500	1981 WS	34.8	3.4	9.7	7.2	55.1
Lower Talavera River Irrigation System	2580	1981 WS	42.7	7.9	10.0	9.3	69.9
		1982 DS	52.2	7.9	10.0	8.1	78.2
Caulaman River Irrigation System	2000	1982 DS	55.9	4.2	2.5	1.6	64.2
Mayor River Irrigation System	400	1982 DS	58.6	2.9	5.0	8.5	75.0
Malaunod River Irrigation System	230	1982 DS	61.0	5.1	10.0	2.2	78.3

[a]The agency level model with 10 descriptors (Fig. 1) was used. The numbers in parentheses indicate the total weight given to the subsystems.

4. The Lower Talavera River Irrigation System had more equitable water distribution than the others.
5. For the systems evaluated, yields of irrigated fields ranged from 1.6 to 2.9 times higher than those of nearby rainfed areas.

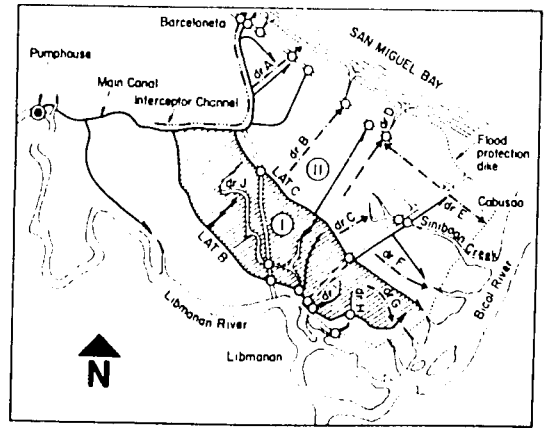
The model's flexibility and simplicity make it a useful tool for evaluating and comparing the performance of irrigation systems. The irrigation agency can decide on the most suitable analysis level based on its resources and needs, and thus standardize field data collection.

DRAINAGE PROBLEMS ANALYSIS FOR THE LIBMANAN-CABUSAO PUMP IRRIGATION SYSTEM

Little research has attempted to analyze the drainage problems that abound in rice irrigation systems. A major IRRI-NIA research program aims to improve water management and use in the 3,916-ha service area of the Libmanan-Cabusao Pump Irrigation System (LCPIS) in the flood-prone Bicol region (Annual report for 1982). A study during 1982-83 analyzed the causes and effects of flooding and waterlogging.

The LCPIS internal drainage system was designed to have a discharge capacity of 11.4 litres/s per ha, which would remove the excess water in about 3 d from a 1-d rainfall of 291 mm expected to occur once every 5 yr. But during 1981-83, 2 to 3 typhoons occurred yearly, bringing 1-d rainfalls of 140 mm or more and inundating 80 to 100% of the service area. After each major typhoon, about 800-900 ha were waterlogged for 1 wk or more and about 250 ha for 2-5 wk. This affected the standing crop as well as cropping intensity. The present drainage system's capacity to dispose of excess water is much less than what was originally planned.

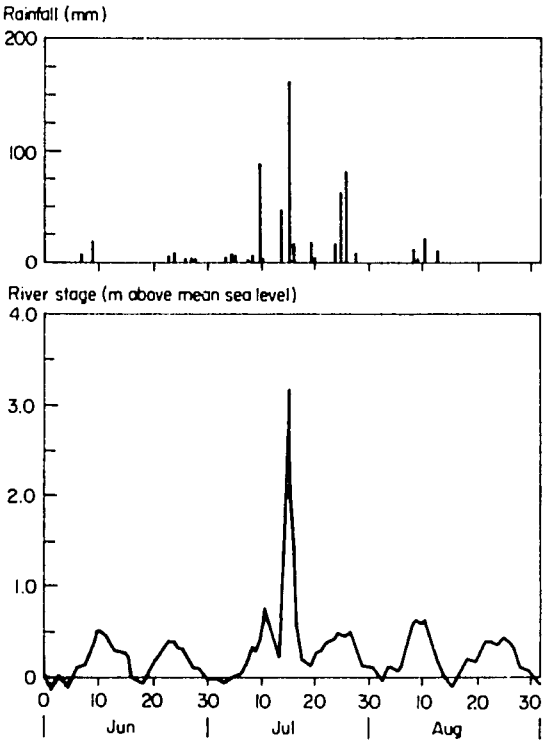
Flooding and waterlogging characteristics. Lateral C divides the service area into two hydrologically different sections. Area I to the southwest



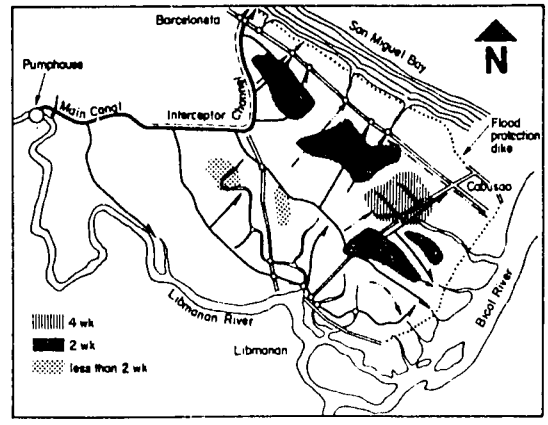
2. LCPIS service area, Camarines Sur, Philippines, 1983.

constitutes about 40% of the service area and drains to the Libmanan and Bicol Rivers. Area II to the northeast drains to the San Miguel Bay (Fig. 2). Area I is hydrologically connected with the Libmanan River through ungated natural drain J, and drains H and I which have flap gates that farmers keep open to remove excess water. When a typhoon occurs, the river stage rises and flashfloods area I, but goes back to normal in about 2-3 d (Fig. 3). The floodwater recedes in 2-5 d, except in small isolated low spots where it may remain for 10-12 d (Fig. 4). Area I has reasonably good drainage capacity.

Area II has a ground surface elevation less than 2 m above mean sea level. About 750 ha are at 1-m elevation or lower. In addition to rainfall during typhoons, area II receives runoff from higher areas through the irrigation canals where the control gates are kept open to prevent canal embankments from washing out. The drains, provided with flap gates to protect the area from seawater intrusion, are inadequate to get rid of excess water. The situation is aggravated by low available head between floodwater and seawater at the mouth of



3. Graph of daily rainfall at LCPIS and river stage at the Libmanan River, Camarines Sur, Philippines, 1983.



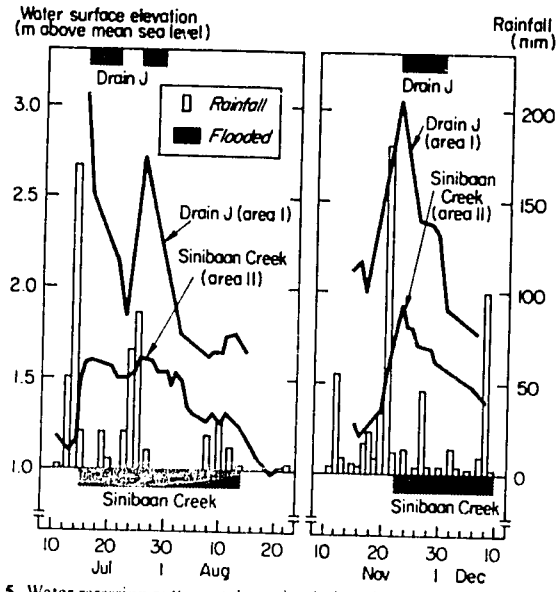
4. Duration of severe flooding in LCPIS during a typhoon 14-15 Jul 1983, Camarines Sur, Philippines.

the drains. Poor drainage canal maintenance causes prolific vegetation growth and consequent reduction in the canal's flow capacity. The rate of floodwater recession in area II is therefore much slower than in area I. Water surface elevations for major drains of each area (drain J of area I and the Sinibaan Creek of area II) after two major typhoons in July and November of 1983 (Fig. 5) show different rates of floodwater recession.

Drainage capability. Roads, protection dikes, irrigation canals, and flap gates slow the removal of excess water since they obstruct natural flow from high to low levels. The situation is worse if the critical crossing structures are poorly designed. Culverts with inadequate flow capacities and inverted siphons of drains, though needed to cross a road or a canal, also impede quick disposal of excess water. Such inadequate flow capacity was noted in lateral drain B in area II at the inverted siphon crossing of Cabusao-Barceloneta road and lateral drain A at the road crossing. In 1983, both were provided with an additional 1-m-diameter culvert at the crossing to facilitate quick drainage.

LCPIS has about 44 km of main, lateral, and sublateral irrigation canals which have 36 km of all-weather service road. But the 50 km of natural and excavated major drains have no service roads. Since access to the drains is very difficult, siltation, erosion, and vegetation growth are major problems. They also have reduced flow capacity which prolonged floodwater stagnation.

During a typhoon on 14-15 July 1983, the interceptor channel, which was blocked by ac-



5. Water recession pattern at the major drains of area I and area II, and flooding duration near the drains after a typhoon in July 1983 and another in November 1983, LCPIS, Philippines.

cumulated water hyacinth and debris, failed to carry the runoff to the sea from the system's high fringe area. The sudden rush of floodwater washed out the main canal embankment near lateral D and caused prolonged waterlogging for about 200 ha that were to be drained by lateral drain A. This breakdown of the embankment affected drainage capacity in the delicately balanced irrigation system.

Effects of flooding and waterlogging on crop production. Flooding and waterlogging at LCPIS influence farmers' chemical input, rice yield, and cropping intensity. Farmers in the flood-prone sites harvested less than in the flood-free sites. Fewer farmers in the flood-prone area applied fertilizers and those who did used less (Table 2). There was no substantial difference in their use of insecticides and herbicides.

During WS, all farmers tend to transplant early to avoid risk of flooding, especially during typhoon-prone October and November. But since farmers in the flood-prone areas have standing water in their fields, they have to delay land preparation and transplanting (Fig. 6). The effect of this delay is carried into the succeeding DS (Fig. 7). Some farmers have to forgo a WS crop because of the prolonged waterlogging problem. In 1982 WS, of the farmers who still could not transplant in the flood-prone area by third week of September (Fig. 6), only about 10% succeeded in planting later.

WATER USE AND PRODUCTIVITY IMPROVEMENT IN NORTH BANGLADESH TUBEWELL IRRIGATION SYSTEM

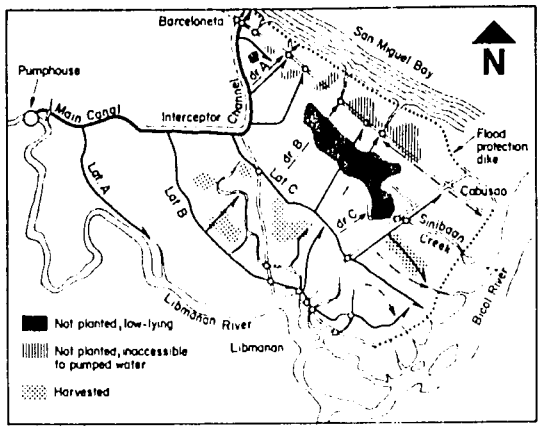
Collaborative studies in Bangladesh are with the Bangladesh Rice Research Institute and the Bangladesh Water Development Board. The aim of the applied research project is to identify irrigation and crop production problems and develop and test practical ways to lessen them. In 1982 DS, tubewell water availability and technical delivery problems as well as farmers' production constraints and socioeconomic background were analyzed. Field research in 12 pilot tubewell areas concentrated on

- improving reliability and predictability of the water delivery system,
- using better extension activities to introduce and facilitate farmer adoption of MVs,
- testing and recommending rice-based cropping

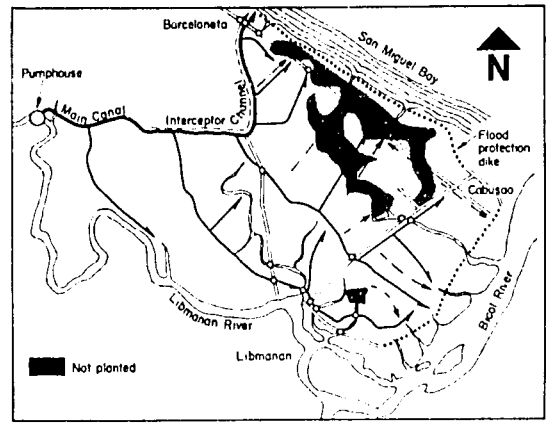
Table 2. Grain yield and input use[a] of sample farmers in the flood-prone and flood-free areas of LCPIS, 1981-83.

	WS 1981		DS 1982		WS 1982		DS 1983	
	Flood-prone	Flood-free	Flood-prone	Flood-free	Flood-prone	Flood-free	Flood-prone	Flood-free
Number of samples	4	49	17	75	16	88	17	86
Mean yield (t/ha)	2.1	3.3	2.2	3.4	2.3	2.7	2.3	2.8
Inputs (kg/ha)								
N	0	16.7 (50)	7.0 (29)	27.4 (72)	33.1 (62)	48.8 (78)	30.1 (77)	41.1 (81)
P	0	5.3 (31)	2.0 (18)	6.7 (41)	15.0 (31)	17.8 (50)	15.3 (29)	18.3 (42)
K	0	3.6 (25)	0.5 (6)	2.8 (26)	6.5 (12)	16.2 (36.4)	5.3 (6)	12.8 (29)
Insecticide (₱/ha)	50.50 (100)	93.60 (98)	76.80 (100)	83.70 (99)	110.57 (100)	101.68 (100)	108.46 (100)	85.63 (100)
Herbicide (₱/ha)	33.50 (100)	33.10 (86)	37.60 (94)	48.90 (92)	59.97 (100)	62.01 (85)	58.39 (88)	54.43 (91)

[a]Figures in parentheses are the percentages of sample farmers who applied the corresponding input.



6. Status of farming activities at LCPIS, 17-23 Sep (week 38), 1982 WS.



7. Status of planting activity at LCPIS, 26 Feb-4 Mar (week 9), 1983 DS.

patterns to increase both production and farm income, and

- developing and promoting water users' organizations which will enable farmers to benefit from the other efforts.

Irrigation conveyance loss and remedy. Water conveyance loss caused by seepage and percolation from lined main canals was very high (Annual report for 1982). In 1983, after repairing the lining in 8 tubewell systems using improved methods, conveyance loss rate was reduced by 69-89% (av 78%) (Table 3). Reducing loss improved the tubewell system capacity to deliver water in a timely and economical way. It also eliminated excessive water supply through seepage and percolation to areas that did not need water.

Increase in irrigation water use. Since 1982, efforts have been made to use tubewells to their capacity by improving pump delivery measurements, supervising pump operation and water allocation, organizing farmers for systematic use of water and proper maintenance of field channels. These efforts increased the 12 pilot tubewell service area by 150% in the 1982 aman (Jul-Oct) compared to the 1981 aman. In 1983 rabi (Nov-Mar), the service area increased 101% compared to the 1982 season (Table 4).

Crop production factors for wheat in rabi. *Crop production.* For each of the 12 pilot tubewell systems, production records were collected from 50 sample farmers during each season. In 1983 rabi, all but three of the farmers who produced crops grew wheat after aman rice. Sonalika was the most popular wheat variety, grown on 97% of 230 plots monitored in the 12 systems. The others grew Inia or Pavon. The wheat yields, obtained from crop-cuts, ranged from 1.0 to 3.7 t/ha, with an average 2.36 t/ha.

Wheat varietal choice. Sonalika and Balaka wheat varieties were grown with recommended fertilizer applications and yields were compared to farm production in tubewell area no. 126 where cropping pattern tests are conducted. Although 80-26-33 kg NPK/ha was recommended, average farmer usage was 52-28-36.5 kg NPK/ha. Balaka outyielded Sonalika under both management levels. The average (n = 7) yield of Sonalika was 1.57 t/ha with higher fertilizer application and 1.47 t/ha at the farmer's level. Balaka's average (n = 2) yield was 2.25 t/ha with higher fertilizer use and 2.20 t/ha in farmers' plots.

Table 3. Conveyance loss rate of pumped water measured by ponding method in the lined main canal and its reduction from improved lining repair. North Bangladesh Tubewell Irrigation System, 1982-83 rabi.

Tubewell no.	Conveyance loss rate (litres/s per m² of wetted area)		Reduction in conveyance loss rate (%)
	1982 rabi (benchmark)	1983 rabi (after repair)	
63	113	22	80
77	94	10	89
89	52	7	87
93	85	24	72
117	138	43	69
118	90	20	78
119	177	35	80
120	70	15	79
Average	102	22	78

Table 4. Increases in irrigated area in the 12 pilot tubewell systems during 1982 aman and 1983 rabi seasons compared with previous seasons. North Bangladesh Tubewell Irrigation System, Bangladesh.

Tubewell no.	Irrigated area					
	Aman			Rabi		
	1981 benchmark (ha)	1982 (ha)	% increase	1982 benchmark (ha)	1983 (ha)	% increase
63	14.1	31.8	126	8.1	16.1	100
77	20.2	30.6	72	1.2	18.1	1408
89	6.0	32.7	440	8.1	24.6	204
93	28.2	34.3	21	22.6	26.6	18
117	2.8	28.6	914	6.0	13.7	128
118	15.3	38.7	153	8.5	14.1	9
119	7.7	26.2	242	8.1	11.7	44
120	0	36.3	–	12.9	12.5	-3
125	23.4	50.4	116	2.4	22.2	825
126	16.5	41.4	149	6.0	10.9	82
138	23.4	48.4	107	6.4	10.1	58
148	16.9	35.9	112	4.4	9.3	111
All tubewells	174.6	435.1	149	94.7	190.0	101

Earlier research shows that wheat grown after 15 Nov averages loss of about 8 kg/ha for each day of delay. To test whether the popular Sonalika variety was superior to others when sown late in the season, four varieties were sown on 30 Dec 1983 in two tubewell areas. At 80-26-33 kg NPK/ha, Balaka and BAW28 produced about 0.4 t/ha (Table 5) more than the other varieties and Sonalika yielded lowest. For many farmers whose aman rice harvest is delayed and who are forced into sowing a late wheat crop, Sonalika is not a productive choice.

Water productivity for wheat. Water productivity, the amount of grain produced per unit area per unit of water supplied, was estimated for the 1983 rabi wheat crop in tubewell area no. 126, where crop production experiments were conducted. Water productivity in the tail research block was much higher than that in the head and middle blocks (Table 6) because of the combined effect of higher yield and less irrigation water supplied. The middle block's yield was much lower than that of the two others because of excessive seepage from other farmers' adjacent rice plots.

GROUNDWATER AND IRRIGATION DEVELOPMENT IN BANGLADESH

Trend in groundwater use. Groundwater has become more and more important in the agricultural development strategy of Bangladesh. The government plans to use groundwater to increase the irrigated area from 11.5% of the total in the late 1970s to 50% by the middle of the 1980s, when the total irrigated area will have increased to 2.9 million ha. The future expansion is planned with installation of deep tubewells (DTs), shallow tubewells (STs) and handpump tubewells (HTs). The number of STs increased by over 460% between mid-1978 and the end of 1982 when 78,400 units were operating (Fig. 8) and that number of units is expected to double by 1984-85. The HTs have increased 550% from about 30,000 in 1975, to 165,000 in 1982. By 1984-85, 25,000 DTs are to be operating, and 500,000 more HTs are to be installed.

Potential and actual use of tubewell capacity. The full capacity of tubewells has not been used. More research has been done on increasing use of

Table 5. Performance of 4 late-sown wheat varieties during 1983 rabi. North Bangladesh Tubewell Irrigation System, Bangladesh.

Variety	Av yield (t/ha)		Mean yield (t/ha)
	Tubewell no. 118 (n=3)	Tubewell no. 125 (n=3)	
Sonalika	1.54	1.64	1.59
Balaka	1.91	2.14	2.03
BAW18	1.66	1.81	1.73
BAW28	2.16	1.91	2.04

Table 6. Water productivity of wheat grown in the head, middle and tail blocks of tubewell no. 126, North Bangladesh Tubewell Irrigation System, 1983 rabi.

Location	Irrigation water supplied (mm)	Rainfall (mm)	Total water supplied (mm)	Yield[a] (t/ha)	Water productivity (kg/ha per mm water)
Head	262	84	346	1.97	5.7
Middle	226	84	310	0.87	2.8
Tail	187	84	271	2.33	8.6

[a]Av of 3 replications.

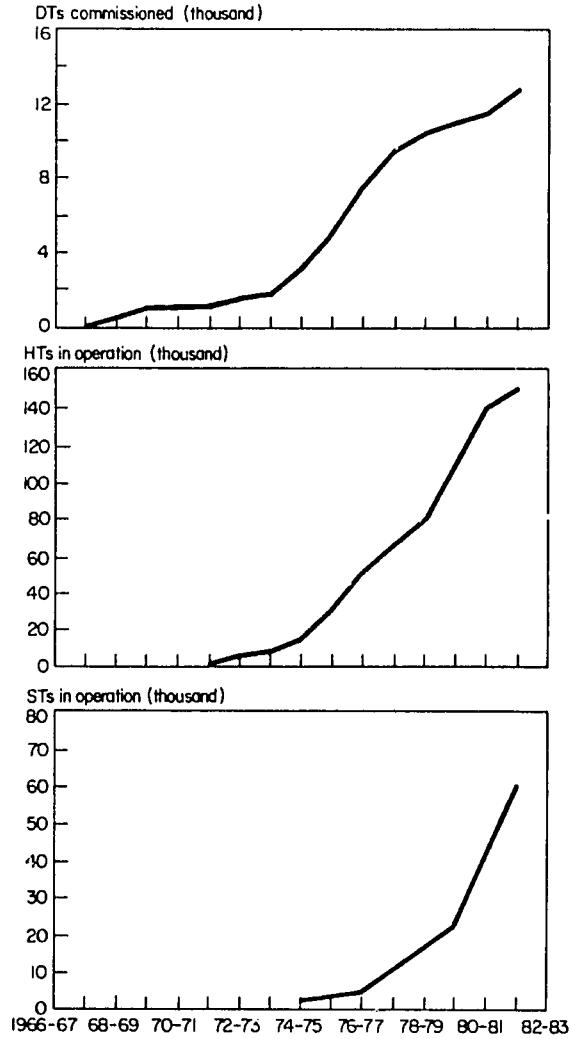
DTs than of the smaller types, because the DTs are expensive and 90-95% of the cost has been paid by the government.

DT capacity and actual use differ because some wells are not working, and others can handle a larger service area than what they have. Data from the Bangladesh Agricultural Development Corporation (BADC), responsible for most DT installation and monitoring, show significant improvement since 1977-78 in the number of operating wells and area irrigated by each tubewell designed to discharge 57 litres/s (Table 7). The wide gap is caused by poor well sites, inadequate maintenance and repair of equipment, defective water conveyance and distribution systems, and organization and management problems of the user association. These groups have many members with small fragmented landholdings and others who are powerful in the rural community and interfere with and exploit the system. Recent field research indicates that improved system management and better farmer organization can increase DT capacity utilization substantially.

BADC data indicate that ST capacity use is even worse than DT: the average area irrigated during 1979-82 was only 4.8 ha/ST. At an average discharge capacity of 14 litres/s, this area is equivalent to about 19.5 ha/DT at discharge capacity of 57 litres/s. The possibility to improve capacity utilization is greater with STs which have the advantage of fewer farmers sharing the water source.

Choice of scale. What type of tubewell is most appropriate for Bangladesh? All three major options — DTs, STs, and HTs — are useful but none alone can technically or economically fill the need. They should be mixed according to the hydrogeologic status of the area. In areas where there are no shallow aquifers, DTs are the only alternative. With available shallow groundwater, STs and HTs are the most economically attractive.

There is an urgent need to describe areas suitable for each tubewell type to prevent installation of the wrong kind or mix. If an ST is located within the hydrologic zone of influence of a DT, and if both are operated simultaneously and draw water from the same aquifer or interconnected aquifers, the ST cannot pump its designed discharge. Similar problems can occur when DT and HT or ST and HT are incorrectly mixed. These problems have already occurred in the field. Government action is necessary because several agencies are promoting tubewell sales without coordinating their programs.



8. Increase of number of deep tubewells (DTs), shallow tubewells (STs), and hand pump tubewells (HTs) in Bangladesh, 1966-67 to 1981-82.

Table 7. Development and use of DTs in Bangladesh.[a]

Year	DTs commissioned (no., cumulative)	DTs operated[b] (no., cumulative)	Av area irrigated per DT (ha)
1967-68	105	109 (97)	16.1
1968-69	397	390 (98)	16.9
1969-70	1,034	980 (95)	12.1
1970-71	1,069	796 (74)	16.1
1971-72	1,090	906 (83)	12.9
1972-73	1,424	1,237 (87)	12.5
1973-74	1,822	1,343 (74)	17.3
1974-75	3,324	2,540 (76)	18.5
1975-76	5,001	3,826 (76)	16.5
1976-77	7,393	4,471 (60)	15.3
1977-78	9,484	7,463 (79)	18.9
1978-79	10,552	9,329 (88)	21.8
1979-80	10,844	9,795 (90)	26.2
1980-81	11,532	10,131 (88)	25.4
1981-82	12,822	11,491 (90)	27.8

[a]Source of data is BADC. [b]Figures in parentheses indicate the percentage of commissioned tubewell in operation.

There is a need to standardize all tubewell equipment as well as installation methods to prevent development of substandard equipment, parts, and techniques.

The government's program of *privatization* of groundwater development would reduce national financial burden caused by DT subsidies. The recent emphasis on shallower wells should help small farmers, but without improvement of capacity utilization of STs, their benefits will remain low.

Table 8. Area irrigated by DTs in Bangladesh during the 3 growing seasons of 1978-80 to 1981-82.[a]

Year	Area irrigated (ha)					
	Aman rice	Rabi			Aus rice	Total
		Boro rice	Wheat	Other crops		
1979-80	24,288 (8.3)	177,937 (69.2)	47,278 (18.4)	n.a.	10,616[b] (4.1)	257,283
1980-81	14,316 (5.5)	187,603 (72.2)	44,836 (17.3)	n.a.	12,890 (5.0)	259,648
1981-82	18,723 (5.8)	277,555 (85.6)	8,987 (3.0)	4,178 (1.3)	13,822 (4.3)	323,265

[a]Source: BADC. Values in parentheses are percentages of the total. n.a. = not available. [b]Includes other crops.

Seasonal use of tubewells. Groundwater use in DS for boro rice and wheat accounted for more than 85% of the total irrigated area during 1979-80 to 1981-82 (Table 8). Although tubewells are presently not heavily used for rice during the aus and aman seasons, it would be more economical to do so. Supplemental irrigation could establish an early aus season rice crop if the premonsoon rain is delayed. It could also help the aman crop avoid yield-decreasing water stress when the monsoon rain recedes too early, especially when the crop is in critical reproductive or grain-filling stages. With use of supplemental irrigation, a farmer could grow MVs during both aus and aman seasons.

Soil and crop management

Soil characterization

Soil Chemistry/ Physics Department

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POTENTIAL OF COASTAL SALINE SOILS

Physiographic features and soil and water properties of idle coastal saline sites were studied in Pangasinan, Philippines. The areas are flat and nearby creeks serve as drainage channels for flushing the surface soil of excess salts.

Although the topsoil is coarse to medium-textured, subsoils are fine-textured and it is impossible to leach excess salts. It is possible to pond rainwater, and sufficient salt could be removed during WS by repeated puddling and surface flushing to nearby creeks.

Aside from high salinity ranging from 13 to 39 dS/m, the soils are mostly neutral to alkaline, have high CEC, and are well supplied with bases. N and some P fertilization may be essential. Since excess salts could be removed in WS, these areas could be planted with salinity-tolerant rice. Submergence-tolerant varieties would be essential in some areas.

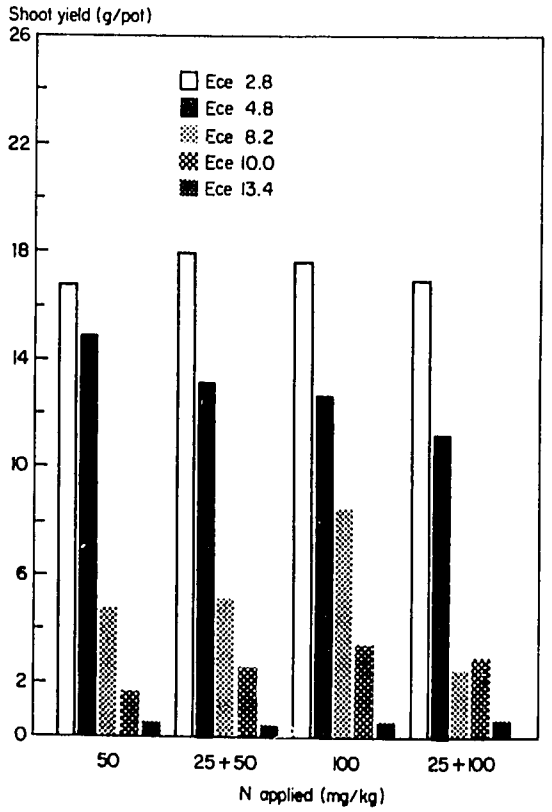
YIELD RESPONSE TO NITROGEN APPLICATION ON SALINE SOILS

To determine whether N fertilizer increases rice yields on saline soils, a greenhouse study used different N rates and application methods at varying EC_e levels.

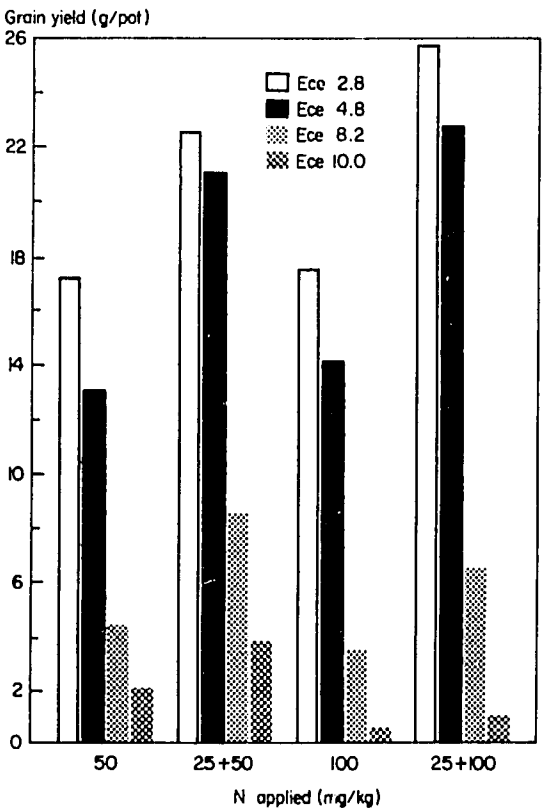
A sandy clay loam of the San Manuel series of Pangasinan (pH 7.4, OM 1.1%, total N 0.04%) was amended to EC_e levels of 2.8, 4.8, 8.2, 10.0, and 13.4 dS/m. Using IR56, basal application of 50 and 100 mg N/kg soil was compared with 2 split application treatments: basal 25 mg N/kg soil + 50 mg N/kg soil at PI and basal 25 mg N/kg soil + 100 mg N/kg soil at PI.

Increasing salinity markedly reduced shoot and grain yield with no grain harvested at an EC_e level of 13.4 dS/m (Fig. 1, 2).

Seedlings showed no visible response to increasing N application and shoot weights were the same.



1. Average shoot yield of IR56 as affected by salinity and N. IRRI greenhouse, 1983



2. Average grain yield of IR56 as affected by salinity and N. IRRI greenhouse, 1983.

No significant difference was observed between basal applications of 25, 50, and 100 mg N/kg soil.

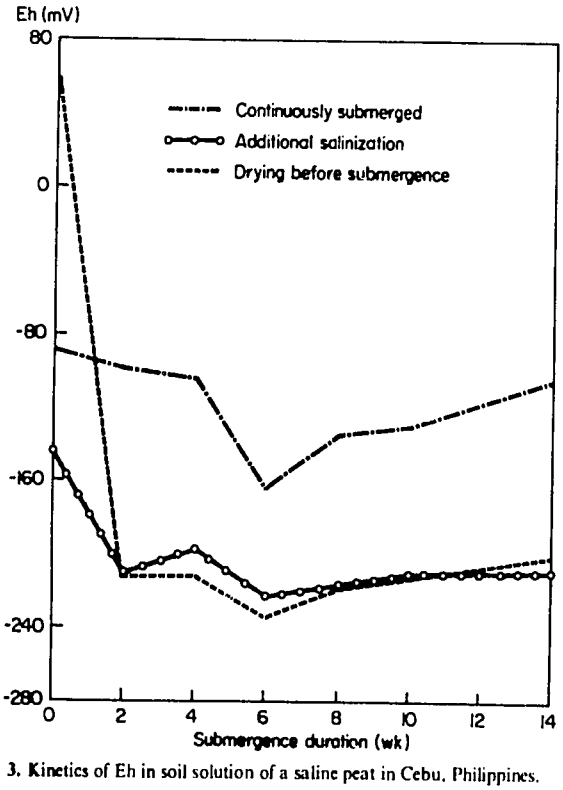
Topdressing at PI resulted in significant yield increases up to an EC_e level of 8.2 dS/m. Topdressing of 100 mg N/kg soil was superior to 50 mg N/kg soil only up to an EC_e level of 4.8.

EFFECT OF FREQUENT SEAWATER INUNDATION AND DRYING ON CHEMICAL PROPERTIES OF COASTAL PEAT SOILS AND RICE GROWTH

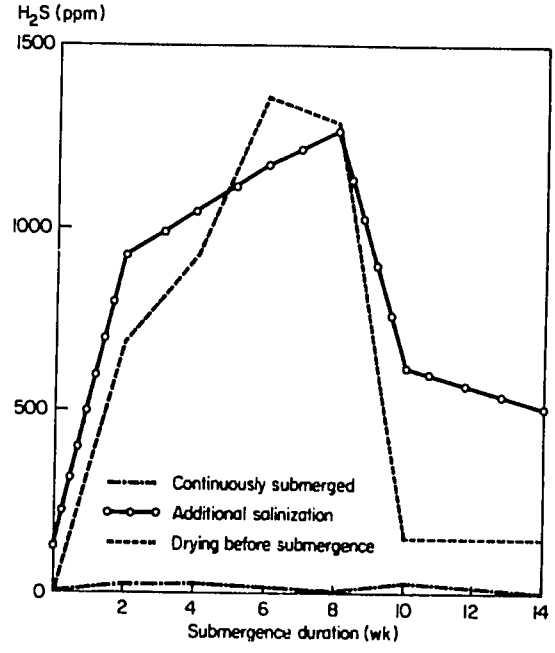
In a greenhouse study of a coastal peat from Cebu, Philippines, treatments were

- continuously submerged without additional salinization (2.0 dS/m) and with salinization (8.0 dS/m), and
- air-dried followed by continuous submergence with and without salinization.

The test varieties were IR42, tolerant of peat and saline soils; and IR26, moderately susceptible to peat and saline soils. They were fertilized with 50-10-50 mg NPK/kg soil and 25 mg N/kg soil was topdressed 7 WAS. Salinization as well as dry



3. Kinetics of Eh in soil solution of a saline peat in Cebu, Philippines.



4. Kinetics of H_2S in soil solution of a saline peat soil in Cebu, Philippines.

fallowing increased NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, and Na^+ concentrations in the soil solution.

Submergence resulted in higher pH values and salinization delayed the pH increase.

Redox potentials in the dry fallow as well as salinized treatments decreased to levels below -200 mV (Fig. 3). Because of low Fe and Mn contents, large amounts of highly toxic hydrogen sulfide were formed (Fig. 4). Rice plants did not survive in the salinized dry fallow treatment. Highest yield was obtained in the continuously submerged treatment without additional salinization, but plant growth was poor and the yield was very low. Zn deficiency might have been an additional problem since IR26 yielded lower than IR42.

To bring coastal peat soils under productive rice cultivation, the soil has to be protected from drying and frequent flooding by saline seawater.

AMELIORATION OF BORON TOXICITY

B toxicity was identified as a cause of yield decline at IRRI. It is especially a problem during DS when surface water becomes limited and geothermal water is used for irrigation.

Table 1. Differences in root length of efficient and inefficient P users at 4 WAS. IRRI, 1982 WS.

Designation	Score[a]	Root length (cm) 0.5 mg P/kg	Root length (cm) 10 mg P/kg
IR9209-181-3-5	1	27	18
IR54	3	37	34
IR42	3	27	27
IR52	3	28	28
IR50	3	18	20
IR9729-67-3	5	18	26
IR5440-1-1-3	7	18	30

[a]Based on relative tiller number.

Neither sulfur nor gypsum affected the B content of the soil.

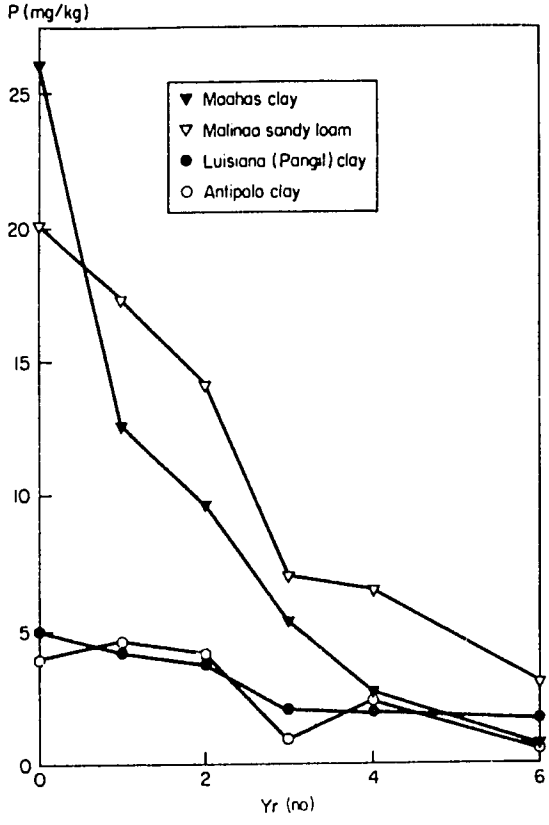
The amount of B extracted from Maahas clay is highly correlated ($r^2 = 0.999$) with water temperature. B is partially precipitated if geothermal water with a high B content is cooled in reservoirs before running into the field.

Field experiments show that with high soil temperature (up to 30° C) low-B soil water easily leaches excess soil B to below toxic levels of 5 ppm.

PHOSPHORUS-DEFICIENT SOILS

In culture solution tests, rices tolerant to P deficiency developed longer roots when P is deficient (Table 1). Longer roots may allow more efficient uptake of P as well as N, K, and Zn.

Continuous cropping over 6 yr of P-efficient IR26 on 4 P-deficient soils in the Philippines resulted in a gradual decrease of total P and a dramatic depletion of available P (Fig. 5). Though no yield decline was observed, P fertilization may become necessary in the future.



5. Changes in soil-available P of 4 P-deficient soils after continuous cropping for 6 yr with a P-efficient rice. IRRI, 1983.

Table 2. Effect of water saturation versus submergence on nutrient content of shoot and roots of IR42 8 WAS. IRRI, 1983.[a]

	pH		Zn R	Zn S	Cu R	Cu S	Mg R	Mg S	K R	K S	P R	P S	Si R	Si S	Na R	Na S	Fe R	Fe S
Luisiana clay	3.9	Sub	–	–	–	–	–	–	–	–	=	+	+	–	+	+	–	–
		WS	+	+	+	+	+	+	+	+	=	–	–	+	–	–	+	+
Calauan peat	5.0	Sub	–	–	–	=	–	–	–	–	+	+	+	=	+	+	+	–
		WS	+	+	+	=	+	+	+	+	–	–	–	=	–	–	–	+
Bakud Bayan	5.2	Sub	–	–	–	=	–	–	–	=	+	+	+	+	=	+	+	+
sandy loam		WS	+	+	+	=	+	+	+	=	–	–	–	–	=	–	–	–
Maahas clay	7.0	Sub	–	=	–	=	–	–	–	+	+	=	+	–	+	+	+	–
		WS	+	=	+	=	+	+	+	–	–	=	–	+	–	–	–	+
Pao calcareous	7.4	Sub	–	=	–	=	–	–	–	–	+	+	+	–	+	+	+	–
clay loam		WS	+	=	+	=	+	+	+	+	–	–	–	+	–	–	–	+
Saline soil	7.5	Sub	=	–	–	–	–	+	+	=	+	+	+	+	+	+	+	–
		WS	=	+	+	+	+	–	–	=	–	–	–	–	–	–	–	+
Sodic soil	8.7	Sub	–	–	–	–	–	–	=	+	+	+	+	=	+	–	=	+
		WS	+	+	+	+	+	+	=	–	–	–	–	=	–	+	=	–

[a]Sub = submergence, WS = water saturation, R = root, S = shoot.

CHEMICAL KINETICS OF SUBMERGED VERSUS WATER-SATURATED SOILS AND RICE GROWTH

Since water resources are limited, irrigation water use has to become more efficient so that less water can produce equal or greater crop yields. Water saturation and submergence were tested for their effect on chemical kinetics and rice growth on seven soils, ranging from peat to acid and sodic soils.

Fertilizers were added at the rate of 100 ppm N as ammonium sulfate, 50 ppm P as triple superphosphate and 100 ppm K as muriate of potash. Five-d-old germinated IR42 seeds were dibbled in the soils. Plants were pulled for root and shoot analysis at 8 WAS and DM weight at 13 WAS and at maturity.

Submergence resulted in lower redox potentials in all soils, except sodic and, hence, in higher availability of nutrients except Cu, Zn, and Mg. Because of greater nutrient uptake, shoot and root growth were better in submerged treatments.

In peat and sandy loam, growth improved little with submergence because of Zn deficiency.

Although submergence increased nutrient uptake, it produced lower root nutrient content of Zn, Cu, Mg, and K and higher P, Fe, Si, Ca, and Na (Table 2). At least 3-5 cm standing water seems to be essential for optimum rice growth.

Soil and crop management

Management of soil and fertilizer nitrogen

Agronomy, Agricultural Engineering, Soil Microbiology, and Soil Chemistry/Physics Departments; IRRI-International Fertilizer Development Center (IFDC) Cooperative Project; and IRRI-Justus Liebig University, West Germany, Cooperative Project

VARIETAL DIFFERENCES IN ABILITY TO EXPLOIT SOIL NITROGEN **244**
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VARIETAL DIFFERENCES IN ABILITY TO EXPLOIT SOIL NITROGEN

Agronomy Department

Cooperative studies with the University of California, Davis, showed that successful exploitation of differences in the ability of varieties to use soil N is important since soil is the major N source for lowland rice.

In 1981-82 DS and WS experiments where labeled fertilizer (^{15}N depleted AS) was applied, total N and atom % ^{15}N were determined on leaf and culm samples collected at 10 DT, 30 DT, and PI.

Grain yield and total N uptake were related to rice duration group (Table 1). In 1981 DS, long-duration varieties or lines absorbed most total N but least fertilizer N. In 1981 WS, however, total N uptake was highest in the medium-duration group. In 1982 DS, short-duration varieties or lines absorbed less N than the two other groups, which did not differ from each other. In general, short-duration varieties or lines used the most fertilizer N.

Mean values for % N derived from fertilizer (Ndff) for the different duration groups are shown in Table 2. Some samples at 10 DT show trends contrary to those established later, but the small seedling size suggests that these differences are of little significance. As expected, % Ndff decreased during the growing season and reached a minimum at harvest. It tended to be inversely related to duration period.

Table 1. Grain yield, total N and fertilizer N uptake by rice duration group. IRRI, 1981-82.

Duration group (d)	Grain yield (t/ha)	Total N uptake (kg/ha)	Fertilizer N uptake (kg/ha)
		1981 DS	
100	4.63	77.6	16.6
110	4.49	87.3	15.2
≥120	4.77	97.0	10.7
		1981 WS	
100	3.63	107	9.06
110	3.99	121	7.06
≥120	3.72	105	5.73
		1982 DS	
100	5.56	74.0	4.15
105-115	5.48	89.7	2.90
120-135	5.50	91.0	4.07

Table 2. Mean values for % N derived from fertilizer (Ndff) by duration group. IRRI, 1981-82.

Duration group (d)	Mean values for % Ndff			
	10 DT	30 DT	PI	Harvest
		1981 DS		
100	50.6	42.7	31.3	21.5
110	53.7	44.2	32.2	17.0
≥120	55.6	43.2	26.6	11.3
		1981 WS		
100	18.4	14.9	10.2	8.5
110	19.6	13.9	9.49	5.9
≥120	19.0	14.8	9.25	5.5
		1982 DS		
100	27.4	24.9	16.3	5.6
105-115	28.3	14.8	12.0	3.0
120-135	31.8	17.2	10.2	4.5

Duration groups overlapped in % Ndff (Table 3). The ranges become more narrow with increasing maturity, and long-duration varieties exhibit the narrowest range at harvest. Growth duration alone, however, cannot be used as a criterion of N utilization efficiency since there is much variability within a group. Other plant characteristics such as tillering patterns may influence exploitation of soil N.

Up to 30 DT, medium-duration IR42 uses soil N more efficiently than the very early IR9729-67-3 (Fig. 1). After 30 DT, IR42 also uses fertilizer N better than IR9729-67-3.

Preliminary results suggest that short-season varieties are more dependent on fertilizer N than are long-duration rices.

EFFECT OF TIME, METHOD, AND RATE OF NITROGEN APPLICATION ON YIELD OF RICE WITH DIFFERENT SOIL NITROGEN LEVELS

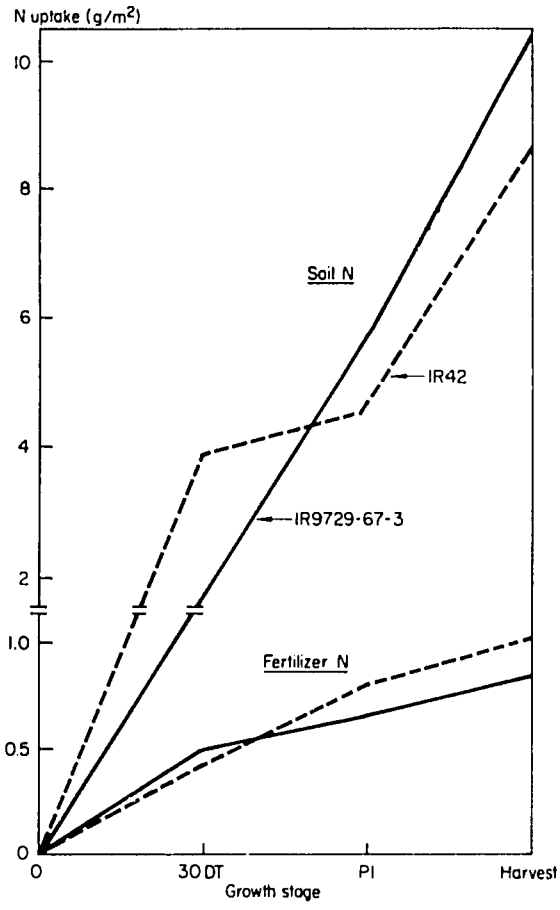
Agronomy Department, IRRI-International Fertilizer Development Center (IFDC) Cooperative Project

Experiments were conducted during DS at five sites with varying N content. Two plots were at IRRI and three at the Maligaya Rice Research and Training Center (MRRTC), Nueva Ecija, Philippines. During WS, only 2 trials were repeated: one at IRRI with 0.18% soil N and another at MRRTC with 0.06%.

Soil samples from the sites were submerged and

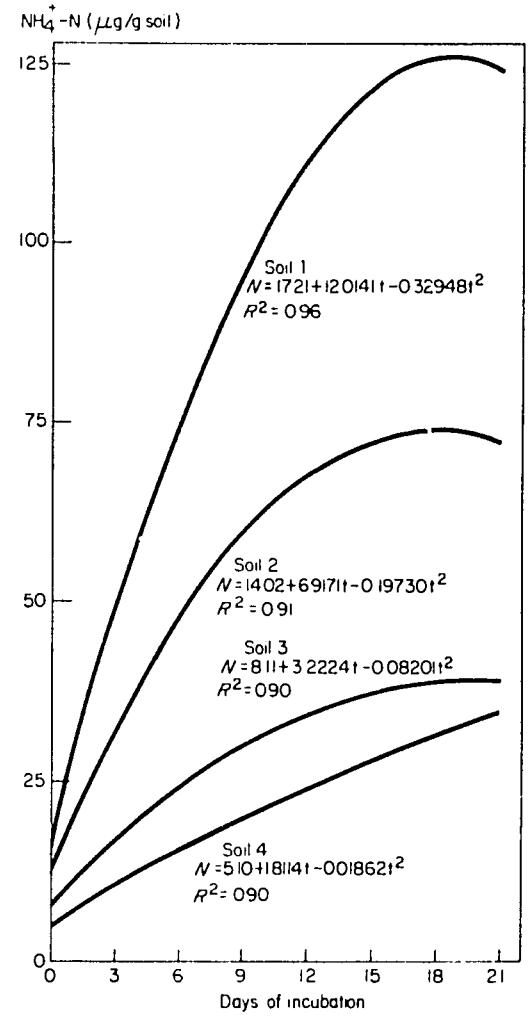
Table 3. Ranges of % N derived from fertilizer (Ndff) by duration group. IRRI, 1981-82.

Duration group (d)	Ranges of % Ndff			
	10 DT	30 DT	PI	Harvest
		1981 DS		
100	41.7 -68.0	34.4 -48.4	24.4 -38.5	11.5 -37.8
110	36.1 -67.0	33.4 -52.3	22.2 -40.4	9.58-29.9
≥120	48.9 -62.9	36.6 -49.8	17.6 -38.2	6.32-17.9
		1981 WS		
100	11.3 -29.9	10.8 -20.2	16.44-13.1	27.90-12.9
110	8.57-28.9	10.5 -19.6	5.65-12.2	3.63-9.10
≥120	10.7 -24.9	6.44-19.9	6.23-11.6	2.93-8.61
		1982 DS		
100	19.4 -35.1	18.2 -34.8	13.6 -20.7	3.48-7.94
105-115	22.8 -36.8	10.3 -16.8	8.86-15.4	0.43-7.79
120-135	24.6 -45.7	13.3 -21.0	8.60-13.2	2.68-6.18



1. Uptake of soil and fertilizer N (^{15}N-depleted) by medium-duration IR42 and early-maturing IR9729-67-3. IRRI, 1982 WS.

incubated to determine NH_4^+-N production. Estimated concentrations in the soils are shown in Figure 2.



2. Estimated NH_4^+-N production in 0-20 cm layer of 4 soils (submerged at sampling and during incubation). IRRI and MRRTC, 1983 DS.

Table 4. Effect of time, method, and rate of urea-N application on grain yield of IR36 and IR42 at 2 sites with different total soil N content. IRRI farm, 1983 DS.

Source	Method of application[a]	N rate (kg/ha)	Yield[b] (t/ha)							
			Site 1 (Ns = 0.18%)				Site 2 (Ns = 0.15%)			
			Basal	5 DBPI	Mean	Difference	Basal	5 DBPI	Mean	Difference
						IR36				
		0	3.1	3.1	0.0	0.0	4.1	3.5	3.8	0.6
PU	Broadcast	29	3.6 c	3.3 c	3.5	0.3	4.5 d	4.5 c	4.5	0.0
PU	Broadcast	58	4.8 cd	4.7 ab	4.8	0.1	5.1 bcd	5.2 abc	5.2	−0.1
PU	Broadcast	87	5.2 bc	4.8 ab	5.0	0.4	6.0 bc	5.7 ab	5.9	0.3
PU	Broadcast	145	6.3 a	5.2 a	5.8	1.1	6.2 b	6.2 a	6.2	0.0
USG	Deep-point placement	29	4.0 de	3.9 bc	4.0	0.1	4.8 cd	4.6 bc	4.7	0.2
USG	Deep-point placement	58	4.1 de	4.8 ab	4.5	−0.7	5.4 bcd	5.7 ab	5.6	−0.3
USG	Deep-point placement	87	5.8 abc	5.3 a	5.6	0.5	5.8 bc	5.9 a	5.9	−0.1
USG	Deep-point placement	145	6.0 ab	5.7 a	5.9	0.3	7.3 a	6.3 a	6.8	1.0
						IR42				
		0	3.8	4.2	4.0	−0.4	3.8	4.3	4.1	−0.5
PU	Broadcast	29	5.0 b	4.9 d	5.0	0.1	5.5 b	5.1 c	5.3	0.4
PU	Broadcast	58	5.3 b	5.5 abcd	5.4	−0.2	5.7 b	5.0 c	5.4	0.7
PU	Broadcast	87	6.0 b	6.3 ab	6.2	−0.3	6.5 ab	6.8 a	6.7	−0.3
PU	Broadcast	145	7.1 a	6.1 abc	6.6	1.0	7.3 a	6.8 a	7.1	0.5
USG	Deep-point placement	29	5.6 b	5.4 bcd	5.5	0.2	5.6 b	5.4 b	5.5	0.2
USG	Deep-point placement	58	6.0 b	5.2	5.6	0.8	6.6 ab	5.8 abc	6.2	0.8
USG	Deep-point placement	87	7.1 a	6.5 a	6.8	0.6	6.9 a	6.3 ab	6.6	0.6
USG	Deep-point placement	145	7.7 a	6.5 a	7.1	1.2	7.1 a	6.7 a	6.9	0.4

[a]Broadcast basal was incorporated; broadcast 5 DBPI was not incorporated. Deep-point placement was done by inserting USG at 10-12 cm soil depth between alternate 4 hills 1 DT. [b]Ns is mean soil total N at 0-20 cm.

Table 5. Effect of time, method, and rate of urea-N application on grain yield of IR36 and IR42 at 2 sites with different total soil N content. MRRTC, Nueva Ecija, 1983 DS.

Source	Method of application[a]	N rate (kg/ha)	Yield[b] (t/ha)							
			Site 3 (Ns = 0.09%)				Site 4 (Ns = 0.06%)			
			Basal	5 DBPI	Mean	Difference	Basal	5 DBPI	Mean	Difference
						IR36				
		0	2.9	3.0	3.0	−0.1	2.3	2.3	2.3	0.0
PU	Broadcast	29	4.1 c	3.7 c	3.9	0.4^{ns}	3.1 c	3.4 cd	3.3	−0.3^{ns}
PU	Broadcast	58	5.0 c	3.9 c	4.5	1.1*	3.8 c	2.9 d	3.4	0.9^{ns}
PU	Broadcast	116	6.3 b	4.9 b	5.6	1.4**	5.0 b	4.2 bc	4.6	0.8^{ns}
PU	Broadcast	174	7.7 a	5.1 ab	6.4	2.6**	6.5 a	5.1 ab	5.8	1.4**
USG	Deep-point placement	29	4.8 c	4.4 bc	4.6	0.4^{ns}	2.9 c	3.1 d	3.0	0.2^{ns}
USG	Deep-point placement	58	5.9 b	5.1 ab	5.5	0.8^{ns}	4.7 b	4.2 bc	4.5	0.5^{ns}
USG	Deep-point placement	116	7.2 a	5.0 b	6.1	2.2**	5.9 a	4.9 ab	5.4	1.0*
USG	Deep-point placement	174	7.5 a	6.0 a	6.8	1.5**	6.3 a	5.3 a	5.8	1.0*
						IR42				
		0	3.5	3.6	3.6	−0.1	2.5	1.9	2.2	0.6
PU	Broadcast	29	3.7 f	4.0 c	3.9	−0.3^{ns}	3.1 d	2.6 c	2.9	0.5^{ns}
PU	Broadcast	58	5.3 de	4.6 bc	5.0	0.7^{ns}	3.6 cd	3.2 bc	3.4	0.4^{ns}
PU	Broadcast	116	6.4 bc	5.5 ab	6.0	0.9*	5.0 b	4.4 a	4.7	0.6^{ns}
PU	Broadcast	174	7.9 a	5.4 ab	6.7	2.5**	6.7 a	4.6 a	5.7	2.1**
USG	Deep-point placement	29	4.7 e	4.4 c	4.6	0.3^{ns}	3.5 cd	3.5 b	3.5	0.0^{ns}
USG	Deep-point placement	58	6.0 cd	5.6 a	5.8	0.4^{ns}	4.1 c.	3.7 ab	3.9	0.4^{ns}
USG	Deep-point placement	116	7.1 ab	6.1 a	6.6	1.0*	6.1 a	3.8 ab	5.0	2.3**
USG	Deep-point placement	174	7.6 a	5.8 a	6.7	1.8**	6.9 a	4.6 a	5.8	2.3**

[a]Broadcast basal was incorporated; broadcast 5 DBPI was not incorporated. Deep-point placement was done by inserting USG at 10-12 cm soil depth between alternate 4 hills 1 DT. [b]Ns is mean soil total N at 0-20 cm.

Table 6. IR36 and IR42 grain yield response to rate, method, and time of urea-N application (site 5, mean soil total N = 0.08%). MRRTC, Nueva Ecija, 1983 DS.

Source	Method of application[a]	N rate (kg/ha)	Yield (t/ha)			Yield difference		
			Basal (A)	5 DBPI (B)	Split (C)	A-B	A-C	B-C
					IR36			
–	–	0	4.1	3.1	2.9	1.0	1.2	0.2
PU	Broadcast	29	5.1 cd	4.0 b	4.7 cd	1.1^{ns}	0.4^{ns}	−0.7^{ns}
PU	Broadcast	58	5.0 cd	5.2 ab	5.3 cd	−0.2^{ns}	−0.3^{ns}	−0.1^{ns}
PU	Broadcast	116	6.1 abc	5.9 a	6.7 ab	0.2^{ns}	−0.6^{ns}	−0.8^{ns}
PU	Broadcast	174	7.0 a	5.7 a	7.2 a	1.3*	−0.2^{ns}	−1.5*
USG	Deep-point placement	29	4.7 d	4.0 b	4.2 d	0.7^{ns}	0.5^{ns}	−0.2^{ns}
USG	Deep-point placement	58	5.5 bcd	4.8 ab	5.8 bc	0.7^{ns}	−0.3^{ns}	−1.0^{ns}
USG	Deep-point placement	116	6.6 ab	5.7 a	6.6 ab	0.9^{ns}	0.0^{ns}	−0.9^{ns}
USG	Deep-point placement	174	7.0 a	6.1 a	7.6 a	0.9^{ns}	−0.6^{ns}	−1.5*
					IR42			
–	–	0	3.1	2.9	3.1	0.2	0.0	−0.2
PU	Broadcast	29	4.1 d	4.3 b	3.8 e	−0.2^{ns}	0.3^{ns}	0.5^{ns}
PU	Broadcast	58	4.4 cd	4.6 b	4.6 e	−0.2^{ns}	−0.2^{ns}	0.0^{ns}
PU	Broadcast	116	5.8 b	5.1 ab	6.1 bc	0.7^{ns}	−0.3^{ns}	−1.0^{ns}
PU	Broadcast	174	7.6 a	5.6 a	7.2 ab	2.0*	0.4^{ns}	−1.6*
USG	Deep-point placement	29	4.2 d	4.4 b	4.8 de	−0.2^{ns}	−0.6^{ns}	−0.4^{ns}
USG	Deep-point placement	58	5.5 bc	5.1 ab	5.9 cd	0.4^{ns}	−0.4^{ns}	−0.8^{ns}
USG	Deep-point placement	116	7.0 a	6.0 a	6.8 abc	1.0^{ns}	0.2^{ns}	−0.8^{ns}
USG	Deep-point placement	174	7.5 a	6.3 a	7.6 a	1.2^{ns}	0.1^{ns}	−1.3^{ns}

[a]Broadcast basal was incorporated; broadcast 5 DBPI was not incorporated. Deep-point placement was done by inserting USG at 10-12 cm soil depth between alternate 4 hills 1 DT.

Table 7. Mean yield by location, variety, method, timing, and rate of urea-N application. IRRI farm and MRRTC, Nueva Ecija, 1983 DS.[a]

	Mean yield (t/ha)					
	Site 1 (NS = 0.18%)	Site 2 (Ns = 0.15%)	Site 3 (Ns = 0.09%)	Site 4 (Ns = 0.06%)	Site 5 (Ns = 0.08%)	Mean
Variety						
IR36	4.6	5.4	5.1	4.2	5.4	4.9
IR42	5.8	6.0	5.4	4.1	5.3	5.3
Time						
Basal	5.6	6.0	6.1	4.8	5.8	5.7
5 DBPI	5.2	5.8	5.0	4.0	5.2	5.0
Basal + 5 DBPI	–	–	–	–	5.9	–
Method						
Broadcast (B)	5.3	5.8	5.2	4.2	5.5	5.2
Deep point-placed (DPP)	5.6	6.0	5.8	4.6	5.8	5.7
Time/method						
Basal – B&I	5.4	5.8	5.8	4.6	5.6	5.4
Basal – DPP	5.8	6.2	6.4	5.0	6.0	5.9
5 DBPI – B	5.1	5.7	4.6	3.8	5.0	4.8
5 DBPI – DPP	5.4	5.8	5.3	4.1	5.3	5.2
Basal + 5 DBPI – B	–	–	–	–	5.7	–
Basal + 5 DBPI – DPP	–	–	–	–	6.2	–
N rate (kg/ha)						
0	3.6	3.9	3.2	2.2	3.2	3.2
29	4.5	5.0	4.2	3.2	4.4	4.3
58	5.0	5.6	5.2	3.8	5.1	4.9
87	5.9	6.2	–	–	–	
116	–	–	6.1	4.9	6.2	
145	6.3	6.7	–	–	–	
174	–	–	6.6	5.8	6.9	

[a]Ns = mean soil total N (0-20 cm).

Regardless of soil N, variety, time, and method of application, grain yield increased with increasing rate of applied N (Tables 4-6). In high N soil (0.18% and 0.15%), IR36 and IR42 yields were higher when all N was applied basally rather than 5 DBPI. Although differences were nonsignificant at all N levels, basal application was significantly better at higher N rates than 5 DBPI when soil N was low (Table 5).

In MRRTC with 3 N applications, there was no significant yield difference between basal full dose and 2 equal split doses at planting and 5 DBPI. Both timings were significantly better at the highest N rate than when all N was applied 5 DBPI (Table 6).

Table 7 shows the grain yield trend in soils of varying N content.

During WS at IRRI, IR42 was damaged by

Table 8. Effect of time, method, and rate of urea-N application on yield responses of IR36, (mean soil total N = 0.18%). IRRI farm, 1983 WS.

Source	Method of application	N rate (kg/ha)	Yield (t/ha)			
			Basal	5 DBPI	Mean	Difference
		0	2.9	2.9	2.9	0.0
PU	Broadcast[a]	29	3.0 a	3.1 a	3.0	-0.1
		58	2.7 a	1.7 bc	2.2	1.0
		87	2.7 a	2.1 abc	2.4	-0.4
		116	2.0 a	1.0 c	1.5	1.0
USG	Deep-point placement[b]	29	3.1 a	2.5 ab	2.8	0.6
		58	2.8 a	2.5 ab	2.6	0.3
		87	2.6 a	2.5 ab	2.6	0.1
		116	1.1 b	2.4 ab	1.9	-1.3

[a]Broadcast basal fertilizer was incorporated; that which was broadcast 5 DBPI was not incorporated. [b]Done by inserting USG at 10- to 12-cm soil depth between alternate 4 hills 1 DT.

Table 9. Effect of time, method, and rate of urea-N application on yield responses of IR36 and IR42 (mean soil total N = 0.06%). MRRTC, Nueva Ecija, 1983 WS.

Source	Method of application[a]	N rate (kg/ha)	Yield (t/ha)			
			Basal	5 DBPI	Mean	Difference
				IR36		
–	–	0	1.9	2.1	2.0	0.2
PU	Broadcast	29	2.9 c	2.8 c	2.8	0.1^{ns}
PU	Broadcast	58	3.6 abc	3.5 bc	3.6	0.1^{ns}
PU	Broadcast	87	4.0 a	3.6 ab	3.8	0.4^{ns}
PU	Broadcast	145	4.4 a	4.3 a	4.4	0.1^{ns}
USG	Deep-point placement	29	3.2 bc	2.7 c	3.0	0.5^{ns}
USG	Deep-point placement	58	3.7 ab	3.1 bc	3.4	0.6^{ns}
USG	Deep-point placement	87	4.3 a	3.0 bc	3.6	1.3**
USG	Deep-point placement	145	4.3 a	3.3 bc	3.8	1.0**
				IR42		
–	–	0	2.1	2.3	2.2	-0.2
PU	Broadcast	29	3.1 bcd	2.2 a	2.6	0.9*
PU	Broadcast	58	3.5 ab	1.9 a	2.7	1.6**
PU	Broadcast	87	3.8 ab	1.9 a	2.8	1.9**
PU	Broadcast	145	4.0 a	1.9 a	3.0	2.1**
USG	Deep-point placement	29	2.4 d	2.5 a	2.4	-0.1^{ns}
USG	Deep-point placement	58	2.7 cd	2.6 a	2.6	0.1^{ns}
USG	Deep-point placement	87	3.2 bc	2.0 a	2.6	1.2**
USG	Deep-point placement	145	2.6 cd	2.3 a	2.4	0.3^{ns}

[a]Broadcast basal was incorporated; broadcast 5 DBPI was not incorporated. Deep-point placement was done by inserting USG at 10-12 cm soil depth between alternate 4 hills 1 DT.

Table 10. Effect of source and method of applying 90 kg N/ha on grain yield of broadcast-seeded flooded IR36 rice. IRRI, 1983 DS.

Nitrogen source[a]	Application time and method	Grain yield (t/ha)
No fertilizer N	–	3.4 e
Super 60/urea	Basal, B&I	5.5 bcd
Super 60/urea	2/3 B&I + 1/3 5-7 DBPI	5.5 bcd
PU	Basal, B&I	5.9 abc
PU	2/3 B&I + 1/3 5-7 DBPI	5.9 abc
PU	1/2 20 DAS + 1/2 10 DAPI	5.0 d
PU + 10% DCD	Basal, B&I	5.3 cd
PU + 10% DCD	2/3 B&I + 1/3 5-7 DBPI	5.8 abc
AS	Basal, B&I	6.1 ab
AS	2/3 B&I + 1/3 5-7 DBPI	6.0 abc
AS + 10% DCD	Basal, B&I	5.6 bcd
AS + 10% DCD	2/3 B&I + 1/3 5-7 DBPI	5.7 abcd
Forestry grade SCU	Basal, B&I	6.4 a

[a]DCD = dicyandiamide.

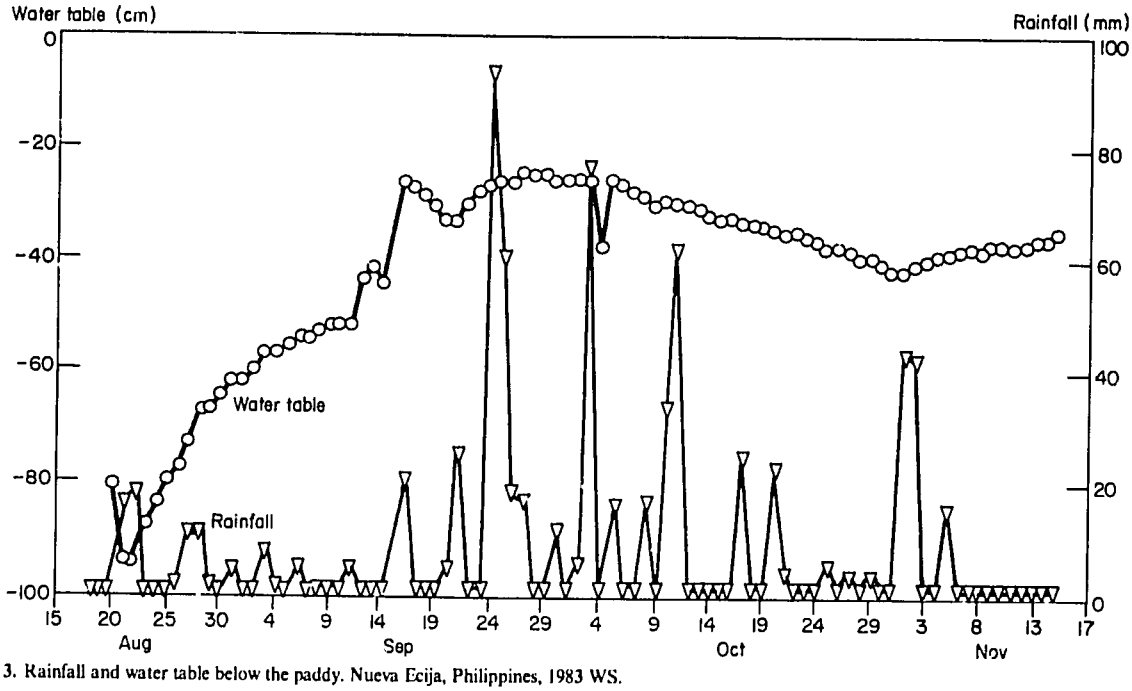
RTV, so only IR36 grain yields were analyzed. N application did not increase yield significantly (Table 8). During WS, added N may not be needed in high N soils.

At MRRTC, yields for both IR36 and IR42 increased with increasing rates of N either as basal full dose or at 5 DBPI. Time of application produced a significant yield difference at higher N rates only when urea N was deep point-placed for IR36 (Table 9). With IR42, topdressing N at 5 DBPI reduced yield. During drought, deep-point placement is still more advantageous than surface broadcast without incorporation.

EFFICIENCY OF NITROGEN SOURCES AND APPLICATION METHODS

Agronomy Department

Broadcast-seeded flooded rice. An experiment with broadcast-seeded flooded IR36 during DS



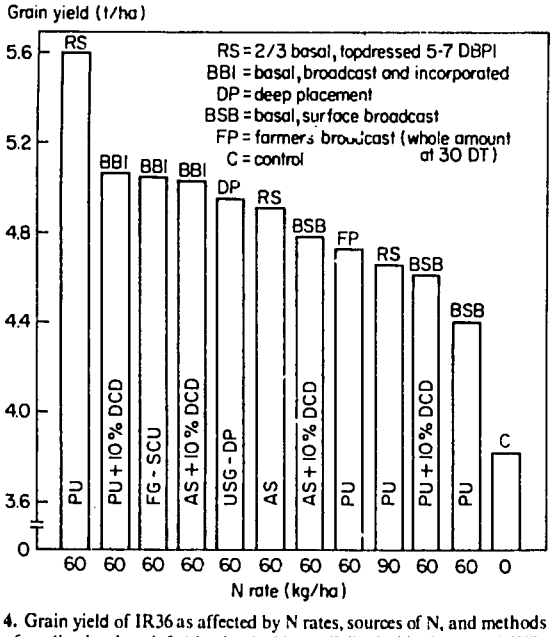
3. Rainfall and water table below the paddy. Nueva Ecija, Philippines, 1983 WS.

evaluated the effectiveness of N sources and their application methods.

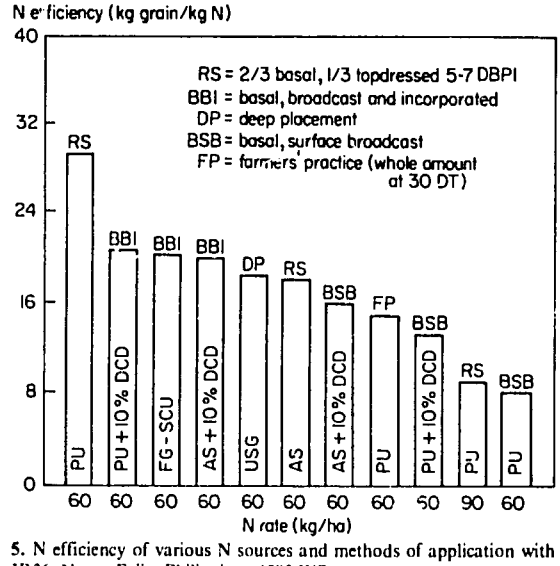
With the same N source, a single basal incorporation produced yields comparable to split application as two-thirds basal B&I plus one-third topdressed at PI (Table 10). PU applied in equal doses at 20 DAS and at 10 DAPI was inferior to slow-release SCU. It was also inferior to other application methods and timing using either PU or AS with and without dicyandiamide (DCD), a nitrification inhibitor. With the same method and timing, PU or AS with and without DCD gave comparable yields.

Rainfed lowland rice. In 1983 WS, N source efficiency and application methods in rainfed lowlands were evaluated in Central Luzon and Santa Rosa, Laguna. Treatments using IR36 had four replications. Rainfall was evenly distributed during the growing season; it contributed to the shallow water table and prevented water stress (Fig. 3). Grain yield with split application of PU (2/3 basal incorporated, 1/3 topdressed 5 DBPI) was comparable to that with the experimental fertilizer N sources: forestry grade SCU, USG, or DCD added to either PU or AS (Fig. 4). Low yields resulted when PU or AS, even with DCD, was not soil incorporated before transplanting. Figure 5 shows fertilizer efficiency (kg grain/kg N) of the N sources. PU, basal incorporated and topdressed 5 DBPI, was more efficient than basal broadcast of either PU or AS. The farmers' practice of applying the whole amount at 30 DT produced unsatisfactory grain yield and fertilizer efficiency.

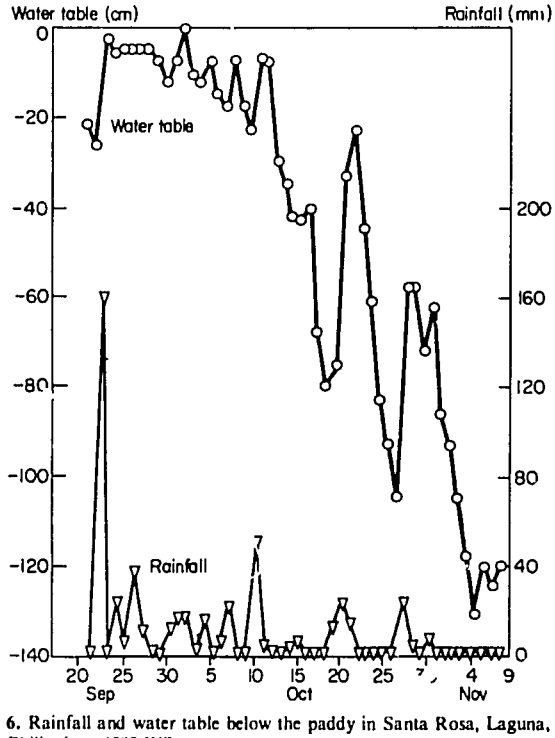
Rice in Santa Rosa, Laguna, received low, erratic rainfall (Fig. 6) and consequently produced



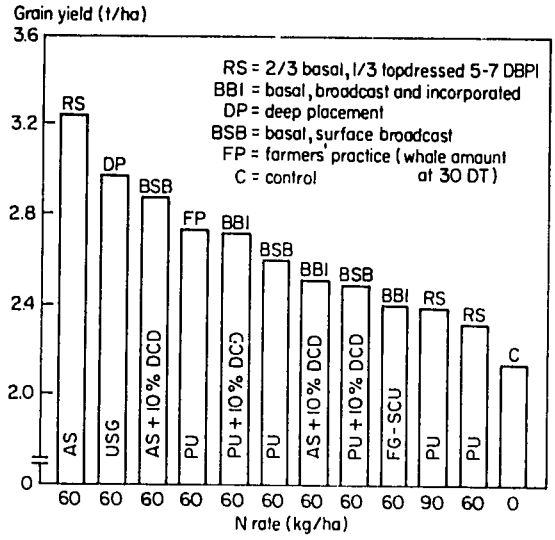
4. Grain yield of IR36 as affected by N rates, sources of N, and methods of application in rainfed lowlands. Nueva Ecija, Philippines, 1983 WS.



5. N efficiency of various N sources and methods of application with IR36. Nueva Ecija, Philippines, 1983 WS.



6. Rainfall and water table below the paddy in Santa Rosa, Laguna, Philippines, 1983 WS.



7. Grain yield of IR36 as affected by N rates, sources of N, and methods of application in rainfed lowlands. Santa Rosa, Laguna, Philippines, 1983 WS.

low yields with all N treatments because of water stress during the reproductive phase (Fig. 7). Results with the farmers' practice of a single fertilizer application at 30 DT were comparable with those from modified N sources and other application methods.

EVALUATION OF PLACEMENT MACHINES TO INCREASE NITROGEN EFFICIENCY IN TRANSPLANTED RICE

Agronomy and Agricultural Engineering Departments

Different IRRI-designed placement machines were tested in conjunction with either the farmers' practice of urea application or the researchers' improved method and timing.

In 1983 DS tests at IRRI, neither hand point-placed USG nor deep machine placement increased yields over the researchers' method and timing of applying urea in split doses (Table 11). Hand point-placed USG produced the lowest floodwater N, while topdressing urea at 5 DBPI produced the highest.

The three most promising placement machines were tested at IRRI and at MRRTC during the 1983 DS. At IRRI, machine fertilizer delivery varied widely (-8.6% to +15.5%) from the intended rate of 58 kg N/ha (Table 12). Variation from the intended rate at Nueva Ecija was lower (-6.9% to -12.1%) than at IRRI. In both sites, yields from researchers' timing were comparable to those from machine- or hand-placed N. But yields from farmers' practice were lower than with the improved timing by 0.4 t/ha at IRRI and 1.0 t/ha less at Maligaya.

Band placement of PU with the spring auger required the least labor.

WS results at IRRI showed that band placement of PU either by oscillating plunger or spring auger machine produced the highest yield (Table 13). When researchers broadcast urea and incorporated it in 5 cm water during the first application, grain yield was similar to that from farmers' practice but was 0.6 t/ha lower than when urea was incorporated without water.

The farmers' practice of broadcasting urea into the floodwater 10 DT resulted in the highest floodwater N, suggesting high potential N loss

Table 11. Effect of fertilizer application techniques on grain yield of IR36, fertilizer efficiency, and total floodwater N. IRRI, 1983 DS.

Urea source	Application method	Machine	Actual N rate (kg N/ha)	Grain yield (t/ha)	Fertilizer efficiency (kg rough rice/kg N)	Total floodwater[a] (kg N/ha)
No fertilizer N	–	–	0	3.8 b	–	0.[illegible]
Prilled	Researchers' split	–	87	5.6 a	21	1.3 (12.1)
Supergranule	Point placement	Hand	87	5.9 a	24	0.1
Prilled	Band placement	Spring auger (push type)	78	5.9 a	28	2.6
Forestry-grade	Band placement	Rolling press wheel	84	6.0 a	26	1.0
Prilled	Point placement	Transplanter with liquid injector	83	5.9 a	[illegible].6	0.9
Prilled	Point placement	Transplanter with spring auger	82	5.6 a	23	2.2
Supergranule	Point placement	Deep plunger	84	5.5 a	21	3.6

[a]Urea-N plus NH_4^+-N 1 d after basal fertilizer application. Value in parentheses is total floodwater N 1 d after the second fertilizer dose (topdressing) was applied.

Table 12. Effect of hand and machine fertilizer application techniques on applied N, labor during application, and yield of IR36. IRRI and MRRTC, Nueva Ecija, 1983 DS.

Urea source	Application method	Nitrogen applied (kg N/ha)		Application time[a] (h/ha)	Grain yield (t/ha)	
		Maahas clay	Maligaya silty clay		Maahas clay	Maligaya silty clay
No fertilizer N	–	0	0	–	4.6 b	3.5 d
Prilled	Point placement by transplanter with liquid injector	64	54	20	5.7 a	5.1 c
Prilled	Band placement by spring auger	67	58	14	6.0 a	5.6 abc
Supergranule	Point placement by deep plunger	53	51	38	6.0 a	5.5 abc
Supergranule	Point placement by hand	58	58	50	5.9 a	5.9 ab
Prilled	Researchers' split[b]	58	58	8	5.8 a	6.2 a
Prilled	Farmers' split[c]	58	58	9	5.4 a	5.2 bc

[a]Av of 2 sites (IRRI and Maligaya) and 3 replications. [b]Two-thirds basal B&I and one-third topdressed at 5-7 DBPI. [c]Equal-split doses at 10 DT and 10 DAPI.

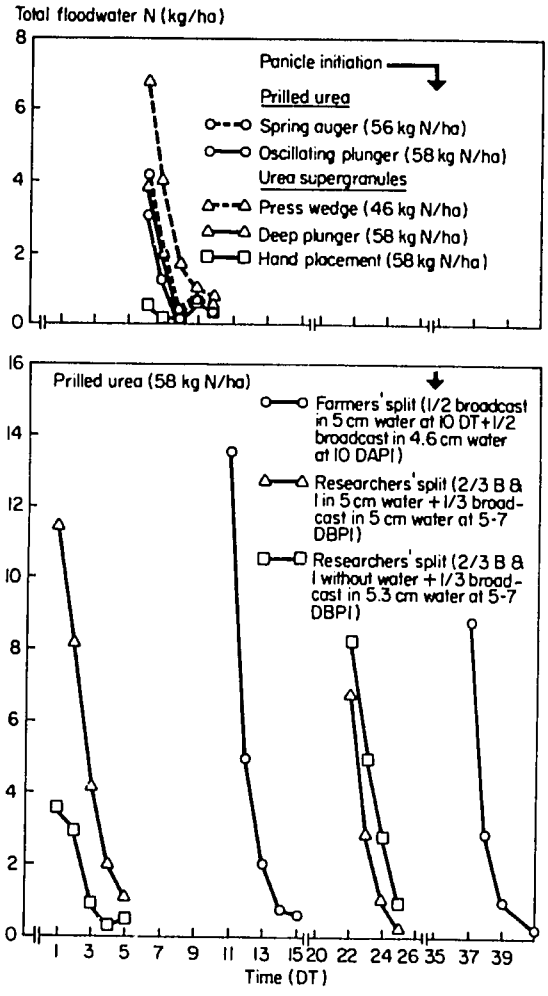
(Fig. 8). B&I of the first PU dose, into 5 cm of water, tripled the amount of N in floodwater. Deep placement produced low floodwater N but hand point-placed USG produced least.

In WS at Maligaya, the delivery of intended N rate with press wheel and press wedge applicators was more satisfactory than with the oscillating plunger. Yields with the four placement machines were comparable with those from the improved method and timing of urea application (Table 14).

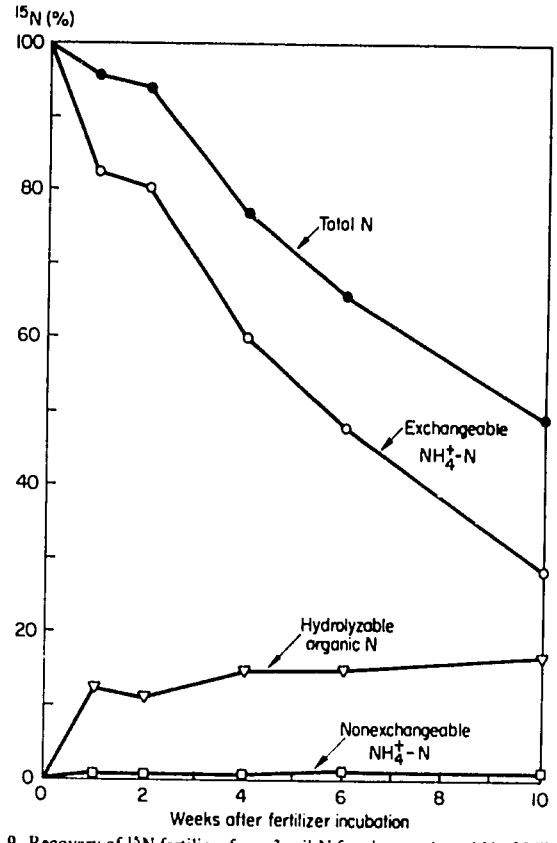
Table 13. Effect of hand or machine fertilizer application techniques on the actual amount of N applied and yield of IR58 at IRRI. 1983 WS.

Urea source	Application method	Nitrogen applied (kg N/ha)	Water depth (cm) during basal fertilizer application	Grain yield (t/ha)
No fertilizer N	–	0	–	2.9 c
Prilled	Point placement by transplanter with spring auger	58	1.3	4.4 ab
Prilled	Band placement by spring auger	56	4.6	4.7 ab
Prilled	Band placement by oscillating plunger	58	4.8	5.1 a
Supergranule	Point placement by deep plunger	58	4.9	4.4 ab
Supergranule	Point placement by press wedge	46	5.1	4.3 b
Supergranule	Point placement by press wheel	65	4.7	4.4 ab
Supergranule	Point placement by hand	58	5.3	4.6 ab
Prilled	Researchers' split[a]	58	5.0	4.2 b
Prilled	Researchers' split[a]	58	0	4.8 ab
Prilled	Farmers' split[b]	58	5.0	4.3 b
Prilled	Researchers' split[a]	87	0	4.8 ab

[a]Two-thirds basal B&I and one-third topdressed 5-7 DBPI. [b]Equal-split doses at 10 DT and 10 DAPI.



8. Total floodwater N (urea-N + NH_4^+-N) at 1300-1400 h as affected by fertilizer application techniques using hand and machine. IRRI, 1983 WS.



9. Recovery of ^{15}N fertilizer from 3 soil N fractions and total N of Pili loam at various sampling times. IRRI, 1983.

AMMONIUM DYNAMICS IN FLOODED RICE SOILS

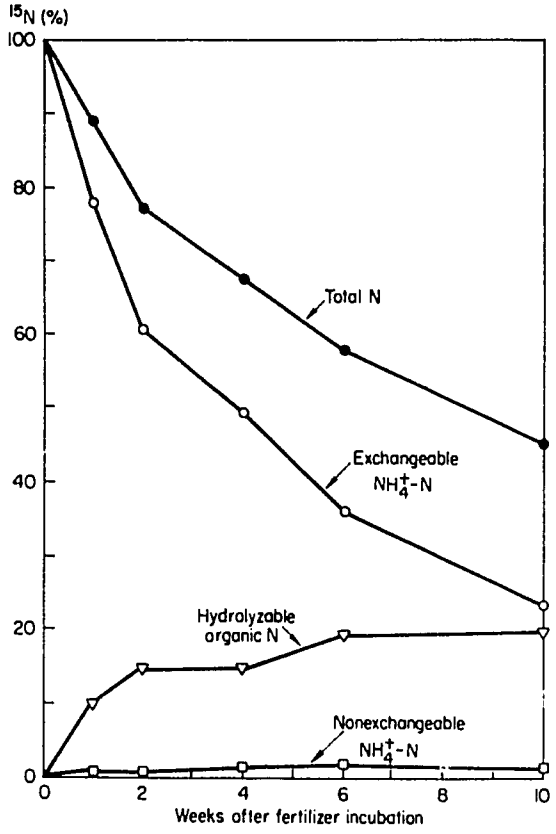
Agronomy Department and IRRI-Justus Liebig University West Germany Cooperative Project

N dynamics in different cultivation systems and

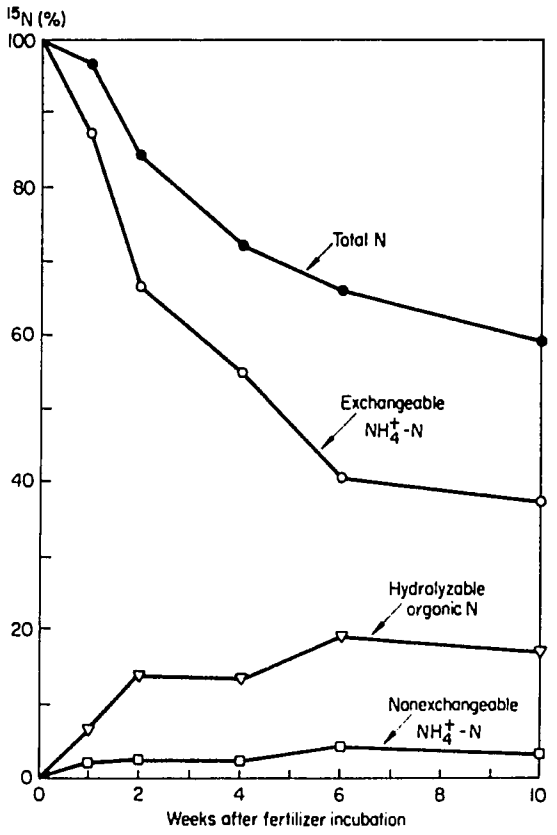
Table 14. Yield of IR42 and actual amount of N applied as affected by method of N application by hand and with machines. MRRTC, Nueva Ecija, 1983 WS.

Method of application	Machine	N source	Actual N rate (kg/ha)	Grain yield (t/ha)
Control	–	–	–	4.8 a
Band placement	Spring auger	PU	29	5.0 a
Band placement	Oscillating plunger	PU	17	5.5 a
Point placement	Press wedge	USG	30	5.0 a
Point placement	Press wheel	USG	28	5.4 a
Point placement	Hand	USG	29	5.0 a
Researchers' split[a]	–	PU	29	5.1 a
Band placement	Spring auger	PU	65	4.8 a
Band placement	Oscillating plunger	PU	63	5.3 a
Point placement	Press wedge	USG	55	5.2 a
Point placement	Press wheel	USG	56	5.3 a
Point placement	Hand	USG	58	5.4 a
Researchers' split[a]	–	PU	58	5.3 a
Researchers' split[a]	–	PU	87	5.4 a

[a]2/3 basal B&I and 1/3 topdressed 5-7 DBPI.



10. Recovery of ^{15}N fertilizer from 3 soil N fractions and total N of Guadalupe clay at various sampling times. IRRI, 1983.



11. Recovery of ^{15}N fertilizer from 3 soil N fractions and total N of Santa Rita clay at various sampling times. IRRI, 1983.

soil fractions, i.e. exchangeable NH_4^+, nonexchangeable (clay-fixed) NH_4^+, and organic N have been studied at IRRI.

Laboratory experiments. Fresh soil samples were collected from Bicol, Cabuyao, Iloilo, Maligaya, and IRRI. N was added as ^{15}N-labeled AS at 100 ppm. The pots were flooded with 3 cm of water and incubated at 30° C (± 1° C).

After 10 wk, ^{15}N fertilizer was recovered from each soil. Pili loam yielded 49.4% (Fig. 9); Guadalupe clay, 45.2% (Fig. 10); Sta. Rita clay, 59.2% (Fig. 11); Maahas clay, 38.5% (Fig. 12); and Maligaya silty clay loam, 60.3% (Fig. 13).

In Maligaya silty clay loam, N fixed by the nonexchangeable (clay-fixed) fraction exceeded that of the organic-N fraction because the vermiculite in the soil fixes considerable NH_4^+ ions in wet conditions (Fig. 13). Other wet soils, containing montmorillonite, fix less NH_4^+-N.

Greenhouse experiments. Air-dried soils in the greenhouse were flooded for weeks before N fertilizer as ^{15}N-labeled AS was added to each soil at 100 ppm.

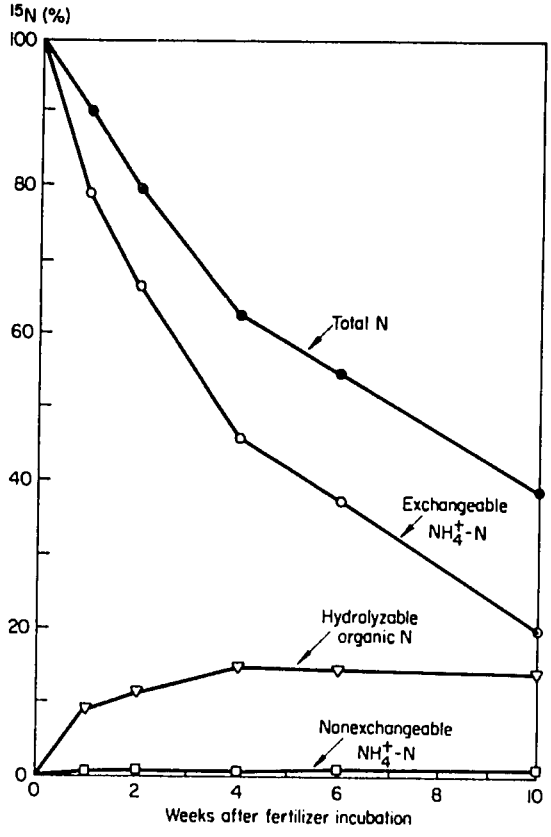
In Maligaya silty clay loam, 15% of ^{15}N was fixed as nonexchangeable N but was released between 20 DT and maturity. In all other soils, the nonexchangeable fraction played a minor role in fixing ^{15}N (Fig. 14, 15, 16) as did incorporation of ^{15}N into the nonhydrolyzable fraction.

Plant and soil recovery of fertilizer N was high in greenhouse studies compared to those in the field. Maligaya silty clay loam showed almost ideal behavior as it stored NH_4^+-N in the nonexchangeable fraction and provided N for later crop growth.

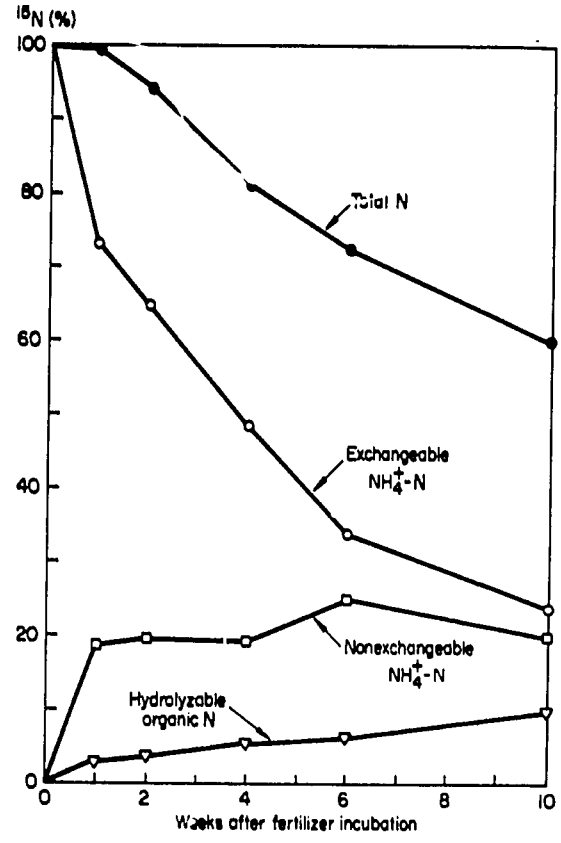
DYNAMICS OF MICROBIOMASS N IN FLOODED SOIL

Soil Microbiology Department

Biomass N is the source of available N to plant.



12. Recovery of ^{15}N fertilizer from 3 soil N fractions and total N of Maahas clay at various sampling times. IRRI, 1983.



13. Recovery of ^{15}N fertilizer from 3 soil N fractions and total N of Maligaya silty clay loam at various sampling times. IRRI, 1983.

Microbiomass N accumulates at the soil surface during flooding for the first and second crops. In the laboratory, black cloth covering the pots stopped accumulation of microbiomass N at the surface, indicating that the accumulated microorganisms are photodependent. Rice plants absorbed ammonium N applied as basal fertilizer until 40 DT. Thereafter, N absorbed by the plant came from soil N. Until 40 DT, the amount of ^{15}N atom % excess absorbed by the rice plant was similar to that in NH_4^+-N in soil. Plant ^{15}N content absorbed from 40 DT to harvest was similar to that in the microbiomass fraction in soil, but much higher than that in NH_4^+-N. This means that microbiomass N is a major N source for the plant in later growth stages. Although total amount of microbiomass N was slightly lower in planted plots than in fallow plots, the difference was much smaller than N absorbed by the plant in later growth stage. The data suggest that the plant can partly replenish available soil N (Fig. 17).

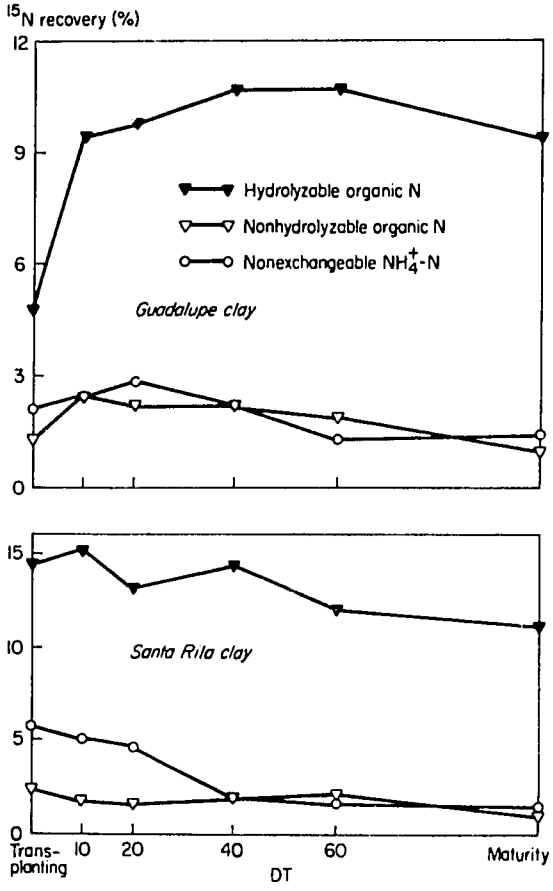
AMMONIA VOLATILIZATION

Soil Chemistry/Physics, Agronomy, and Soil Microbiology Departments, and IRRI-IFDC Cooperative Project

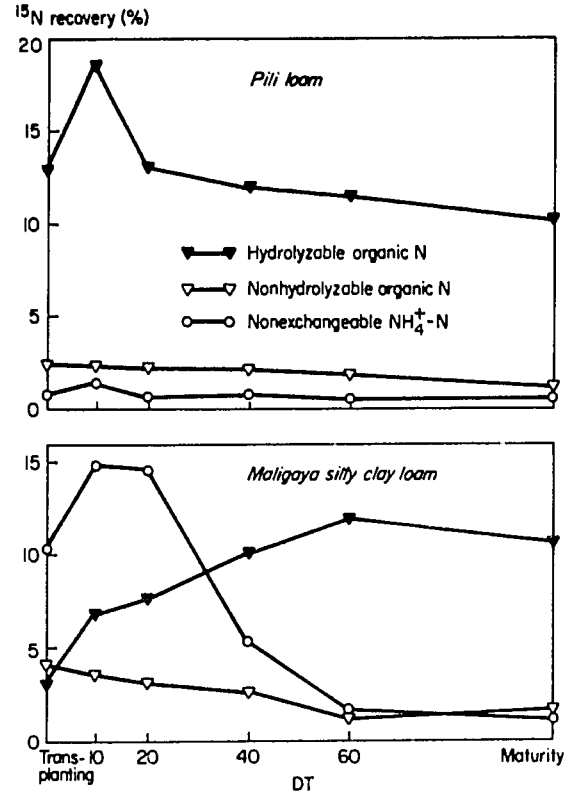
The effect of N form, urea or AS, on the rate of NH_3 volatilization was evaluated in the field using micrometeorological techniques. Experiments were conducted to determine NH_3 loss from AS and to confirm the importance of NH_3 volatilization when using urea. Ammonia flux from urea and AS was measured concurrently.

Substantial fluxes of NH_3 were measured when AS was applied to the floodwater 18 DT with the maximum flux (0.74 kg N/ha per h) obtained immediately after application (Fig. 18). The total measured NH_3 loss was 37% of applied N.

In contrast, NH_3 fluxes from urea-amended



14. Recovery of ^{15}N fertilizer from 3 soil N fractions at various growth stages of IR36 rice in Guadalupe clay and Santa Rita clay. IRRI, Oct 1982-Jan 1983.

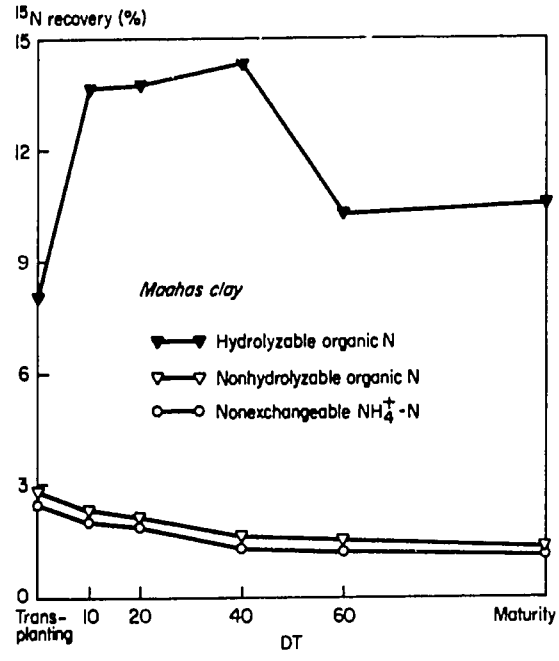


15. Recovery of ^{15}N fertilizer from 3 soil N fractions at various growth stages of IR36 rice in Pili loam and Maligaya silty clay loam. IRRI, Oct 1982-Jan 1983.

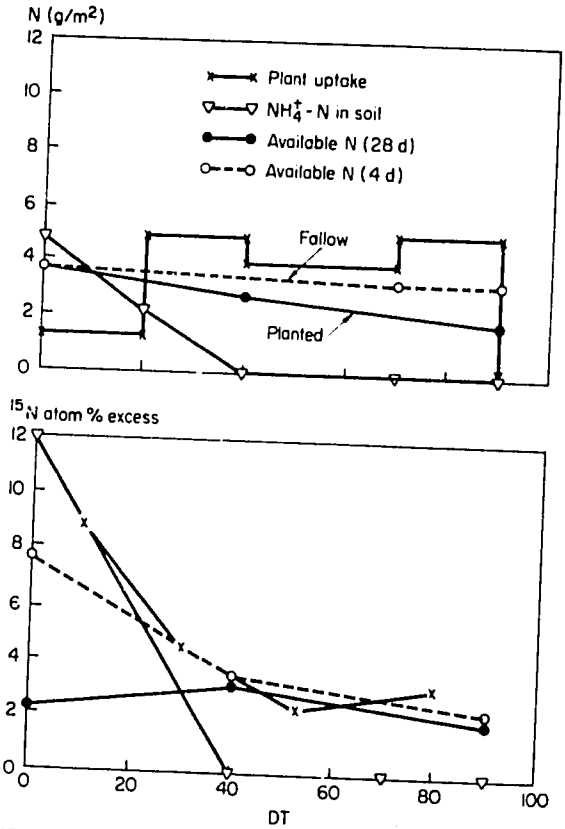
floodwater were maximum on the third day after urea application. The total measured NH_3 loss was 36% of the N applied. Volatilization in both sources was similar under identical atmospheric conditions on the same soil.

Factors affecting NH_3 loss. Some pattern differences in NH_3 loss are closely related to the ammoniacal N concentrations and partial pressures of NH_3 in the floodwater after the addition of urea and AS. Floodwater ammoniacal N was at maximum concentration (~ 50 μg N/litre) soon after AS application and then declined sharply (Fig. 19). In the urea-amended field, ammoniacal N reached highest concentrations of only ~12 μg N/litre 3 to 5 d after urea application coinciding with maximum NH_3 fluxes.

Maximum partial pressures of NH_3 (pNH_3) in the floodwater were comparable in both treatments although floodwater ammoniacal N concentrations



16. Recovery of ^{15}N fertilizer from 3 soil N fractions at various growth stages of IR36 rice in Maahas clay. IRRI, Oct 1982-Jan 1983.

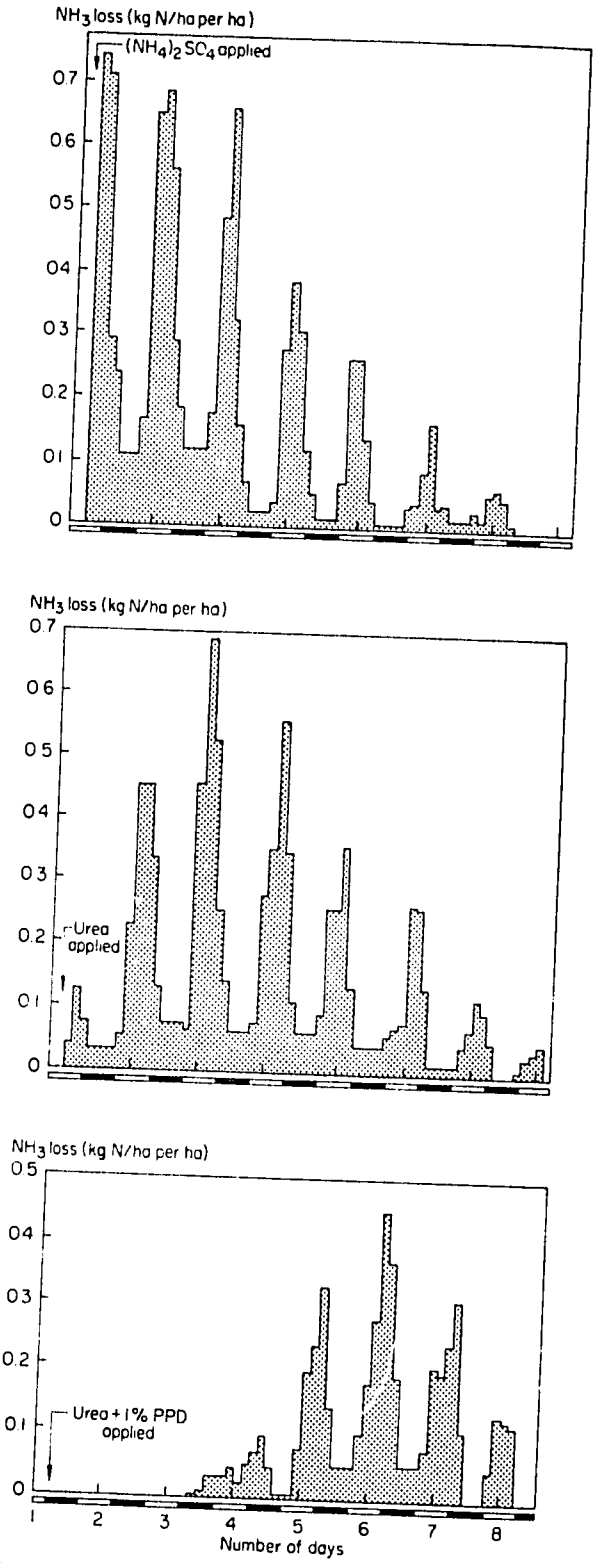


17. N uptake by rice and ^{15}N contents in available and ammonium N in Maligaya soil. IRRI, 1983.

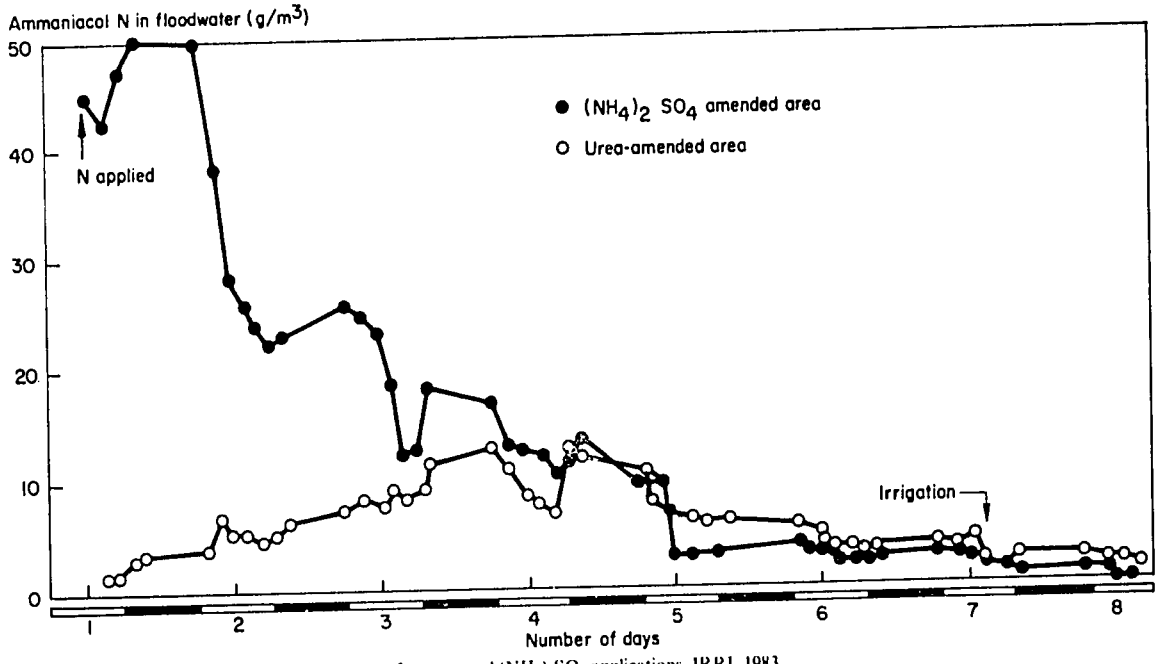
were higher with AS (Fig. 20). Its lower floodwater pH also reduced pNH_3 possibly because NH_4HCO_3 formed and buffered the pH to 8.0 during the first and second days of the study (Fig. 21).

Total titratable alkalinity in the floodwater initially ranged between 3 and 4 meq/litre in all fields. Irrigation water contained ~1.6 meq/litre. Diurnal changes in floodwater alkalinity suggest that biological processes may contribute alkalinity. Moderate floodwater alkalinity in fields irrigated with low alkaline water explains high loss of NH_3 from AS and urea.

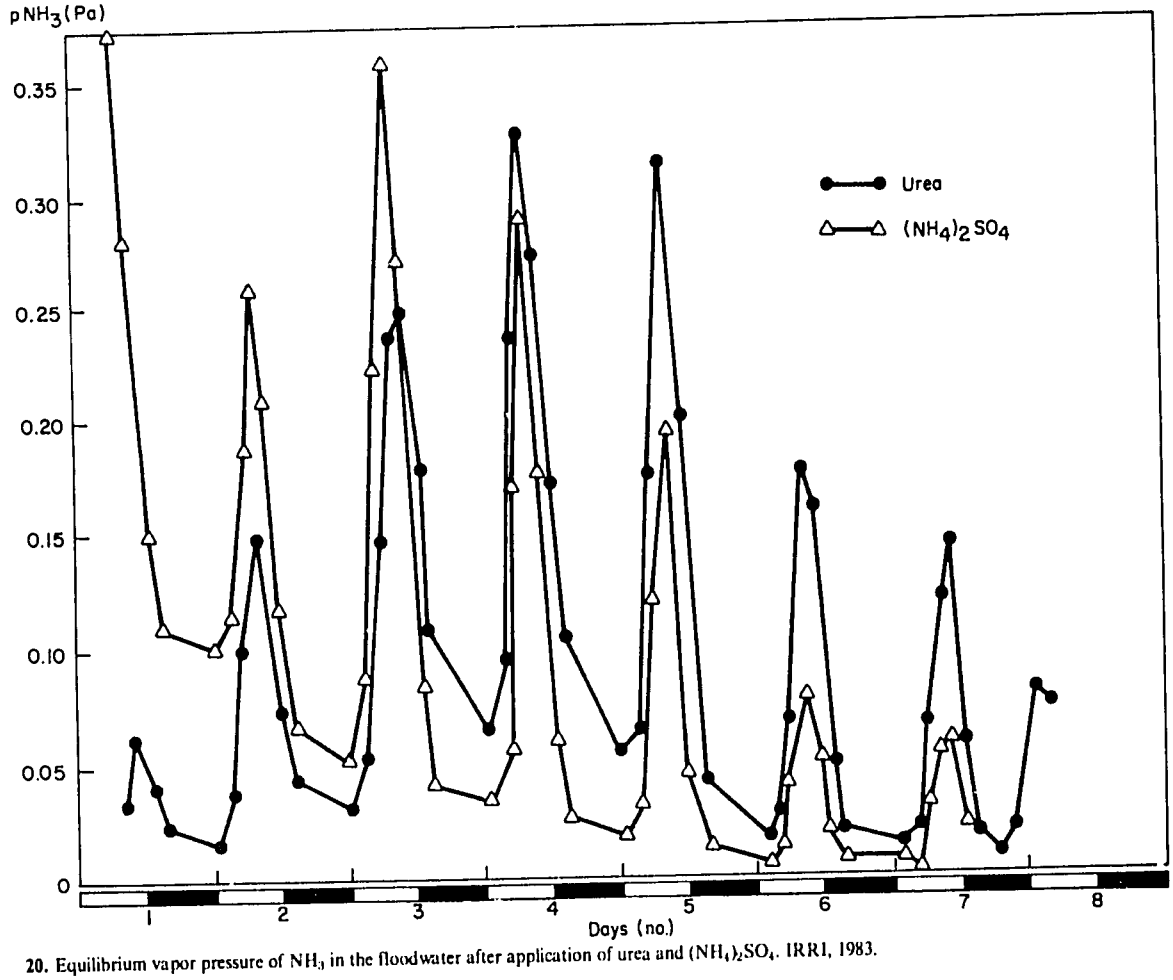
Submerged photosynthetic biomass. Pronounced diurnal fluctuations in floodwater pH in the urea study (Fig. 22) and after 3 d in AS-amended floodwater highlight the role of the submerged photosynthetic biomass. The number of N_2-fixing and total algal flora on the soil surface are shown in Table 15. Non-N_2-fixing blue-green algae dominated total algal flora before N application. Few unicellular green algae were observed



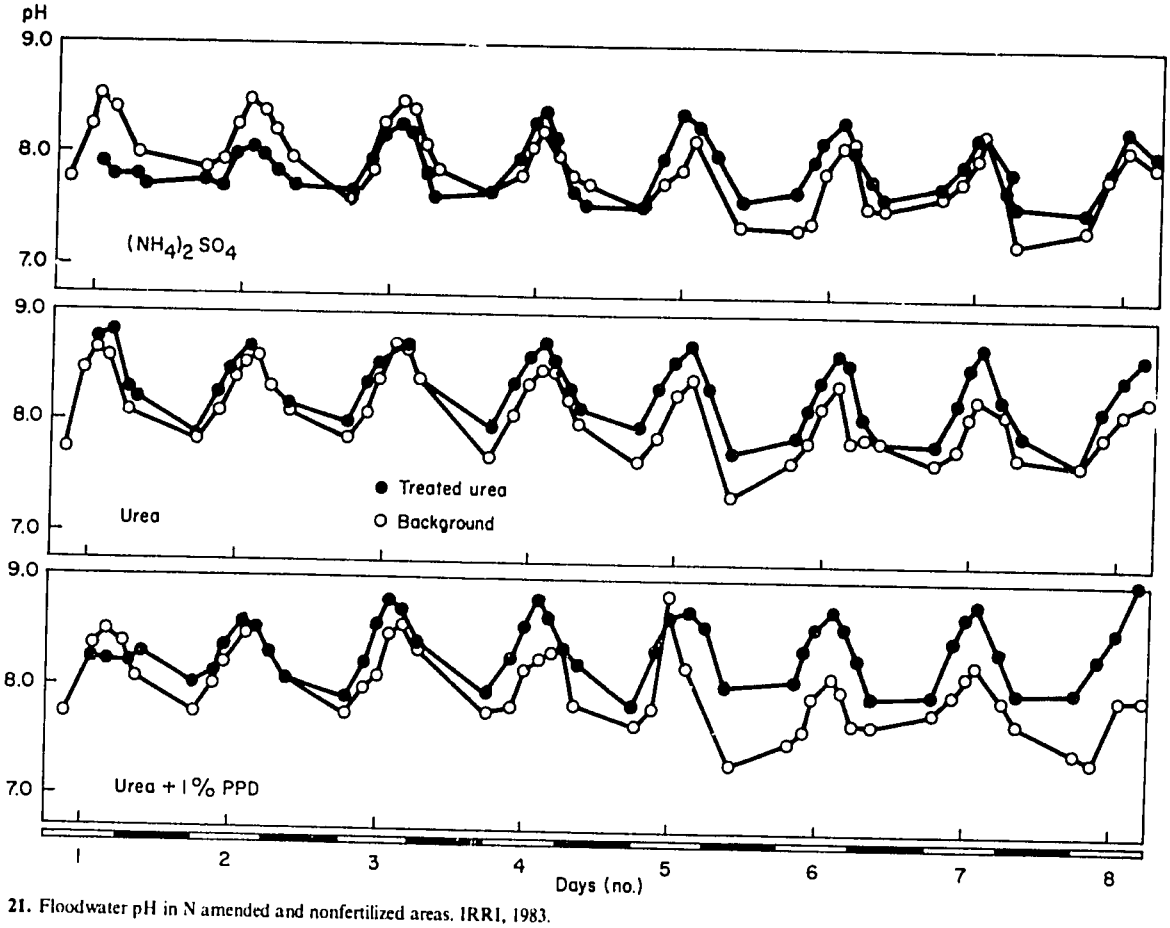
18. Ammonia fluxes following application of $(NH_4)_2SO_4$, urea, and urea amended with PPD. N applied at 58 kg/ha. MRRTC, 1983. PPD = phenylphosphorodiamidate.



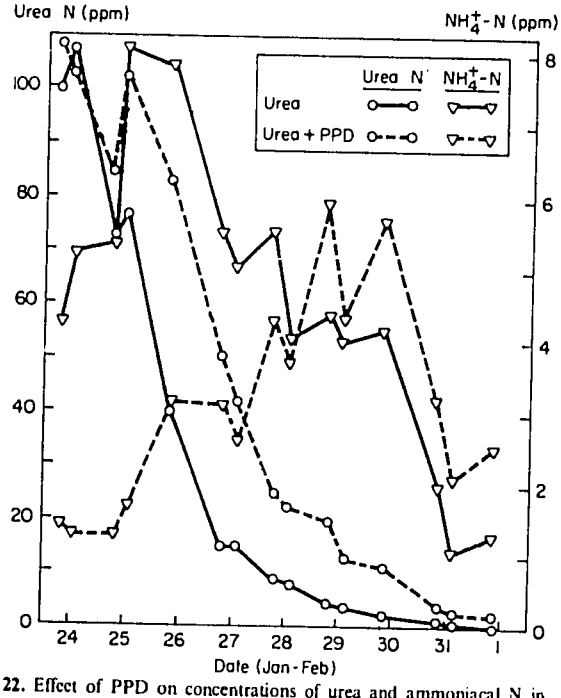
19. Ammoniacal N concentration in floodwater after urea and $(NH_4)_2SO_4$ applications. IRRI, 1983.



20. Equilibrium vapor pressure of NH_3 in the floodwater after application of urea and $(NH_4)_2SO_4$. IRRI, 1983.



21. Floodwater pH in N amended and nonfertilized areas. IRRI, 1983.



22. Effect of PPD on concentrations of urea and ammoniacal N in floodwater. MRRTC, 1983 DS.

and diatoms comprised only about 25% of the colony-forming units (CFU) per m^2. N application to the floodwater increased the total CFU. In contrast, N_2-fixing flora was substantially reduced 7 d after N application compared to the control. Only a few hundred kg fresh weight of algae/ha were obtained for the AS-treated area 7 DAT with N.

It appears that large algal populations are not required to raise floodwater pH to levels which support rapid NH_3 loss.

FATE AND EFFICIENCY OF FERTILIZER N (^{15}N-LABELED) IN LOWLAND RICE

Agronomy and Soil Chemistry/Physics Departments, and IRRI-IFDC Cooperative Project

Early IRRI research showed that slow-release urea and deep N placement effectively decrease N losses and increase N fertilizer efficiency in lowland rice.

N distribution, after various methods of fertilizer

Table 15. Algae counts and relative abundance[a] of the dominant components of the algal flora on a medium for N_2-fixing blue-green algae (CO) and a medium for total algal flora (GN). IRRI, 1983.

Treatment	11 Dec, control	8 Jan, at trans-planting, control	Control	21 Jan, 13 DT AS	Urea	Control	27 Jan, 1 d after N application AS	Urea	Control	3 Feb, 7 d after N application AS	Urea
GO medium											
Unicellular fixing			–	–	–	3	7	13	1	4	–
Anabaena	5	38	65	72	63	67	55	61	60	41	21
Nodularia	–	–	3	–	–	2	–	–	–	2	–
Nostoc	73	61	11	7	14	17	32	11	16	35	34
Scytonema	4	–	–	7	–	4	–	–	–	5	2
Calothrix	16	1	6	14	23	7	3	15	23	13	43
Fischerella	2	–	15	–	–	–	3	–	–	–	–
Total GO[b]	(4.1)[8]	(2.9)[8]	(4.0)[8]	(5 1)[8]	(2.7)[8]	(6.1)[8]	(4.3)[8]	(5.0)[8]	(2.4)[9]	(1.4)[8]	(4.9)[8]
GN medium	nd	nd									
Unicellular BGA			6	2	37	nd	nd	nd	–	1	2
Pseudanabaena			4	18	4	nd	nd	nd	5	4	3
L.P.P.O.			62	52	48	nd	nd	nd	68	81	71
N_2-fixing			3	6	–	nd	nd	nd	7	–	–
Unicellular green			–	–	–	nd	nd	nd	–	–	–
Diatoms			25	22	11	nd	nd	nd	20	14	24
Total GN[b]			(1.4)[10]	(1.4)[10]	(1.1)[10]	(2.0)[10]	(1.6)[10]	(1.8)[10]	(2.4)[10]	(4.0)[10]	(3.8)[10]

[a]Relative abundance as % of total colony-forming units. nd = no data. [b]Number of colony forming units per m^2 of rice field.

application, was studied using ^{15}N-labeled urea during the 1983 DS and WS. Point placement at 10 cm deep and band placement were compared with researchers' split (2/3 basal + 1/3 5-7 DBPI), farmers' split (2/3 at 15 DT + 1/3 at booting), and control. The experiment was conducted in Maligaya soil (pH 5.7) and San Manuel clay loam (pH 7.2), which is calcareous and has a CEC of 39 meq/100 g and 30 meq of exchangeable Ca/100 g soil (Table 16). IR58, a short-duration variety, was the test variety.

Table 16. Soil characteristics of farmers' fields used for fate and efficiency of ^{15}N-labeled fertilizer N in lowland rice. IRRI, 1983.

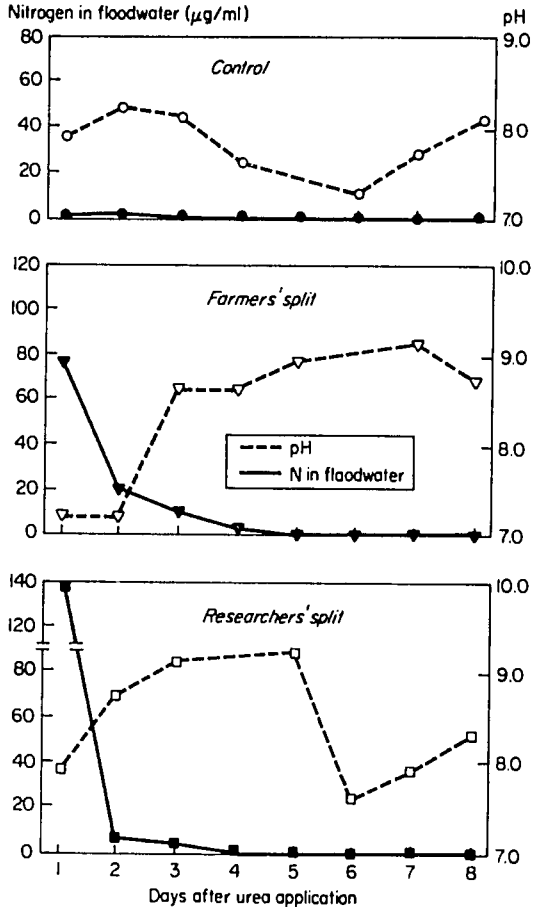
Characteristic	Maligaya Muñoz, Nueva Ecija	Kaaringayan, Laoac, Pangasinan
pH[a]	5.7	7.2
Total N (%)	0.10	0.15
Organic matter[b] (%)	1.90	2.41
Exchangeable Na[c] (meq/100 g soil)	0.52	0.87
Exchangeable K[c] (meq/100 g soil)	0.34	0.22
Exchangeable Mg[c] (meq/100 g soil)	9.23	5.37
Exchangeable Ca[c] (meq/100 g soil)	10.5	30.0
CEC[c] (meq/100 g soil)	27	39
Olsen available P (ppm)	3	8
Available Zn[d] (ppm)	1.09	Nil
Soil texture[e]	Clay	Clay loam
Soil series	Maligaya	San Manuel

[a]Beckman pH meter in (1:1) (soil:water) ratio. [b]Walkley-Black method. [c]1N NH_4 OAc pH 7 as extractant. [d]0.05 N HCl extractant. [e]Bouyoucous hydrometer method.

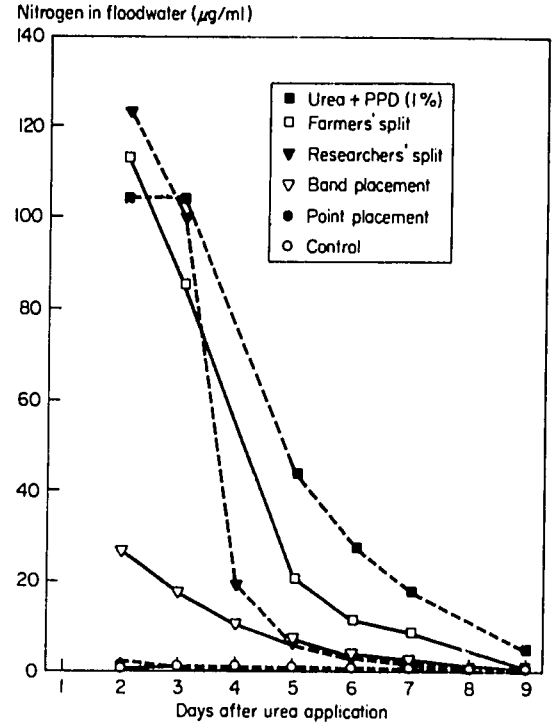
Additional treatments included farmers' split of urea with 1% PPD applied at 15 DT in Maligaya clay and researchers' split of AS in San Manuel clay loam.

Floodwater chemistry. Potential N loss through ammonia volatilization was monitored by the presence of urea-N and NH_4^+-N concentration in the floodwater after fertilizer application. NH_4^+-N + urea N concentrations and pH of the floodwater were measured at 1200-1400 h after the fertilizer application up to 8 d.

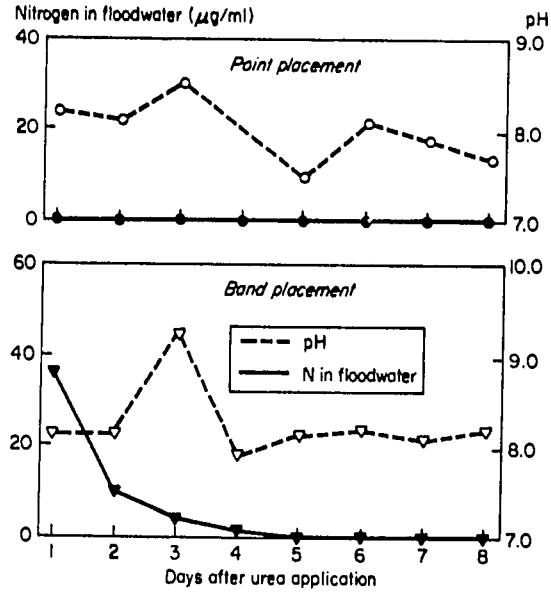
In DS, urea was applied as farmers' split (2/3 15 DT + 1/3 at booting) and researchers' split (2/3 basal + 1/3 5-7 DAPI). On the first day, potential N losses through volatilization were indicated by the presence of 75 μg N/ml from the farmers' split and 138 μg N/ml from the researchers' split in the floodwater in San Manuel clay loam (Fig. 23). Potential volatilization losses in Maligaya soil (Fig.



23. Changes in pH and total N concentration of floodwater of San Manuel clay loam as affected by fertilizer application methods. Pangasinan, Philippines, 1983 DS.



24. Changes in total N concentration of floodwater of Maligaya clay as affected by fertilizer application methods. MRRTC, 1983 DS.



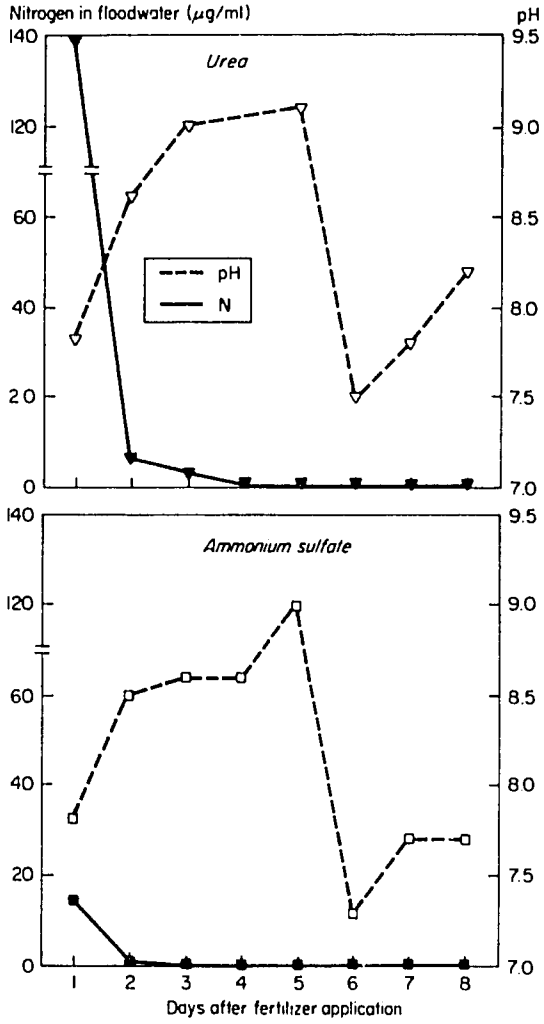
25. Changes in pH and total N concentration of floodwater of San Manuel clay loam as affected by fertilizer placement methods, 1983 DS.

24) were 113 μg N/ml with the farmers' split and 122 μg N/ml in the researchers' split. N concentrations dropped to 0 after 5-6 d. Floodwater pH in San Manuel clay loam receiving the researchers' split and in the unfertilized control initially were similar, but showed varied patterns on succeeding days. The rise in pH with farmers' split was slower than with researchers' split.

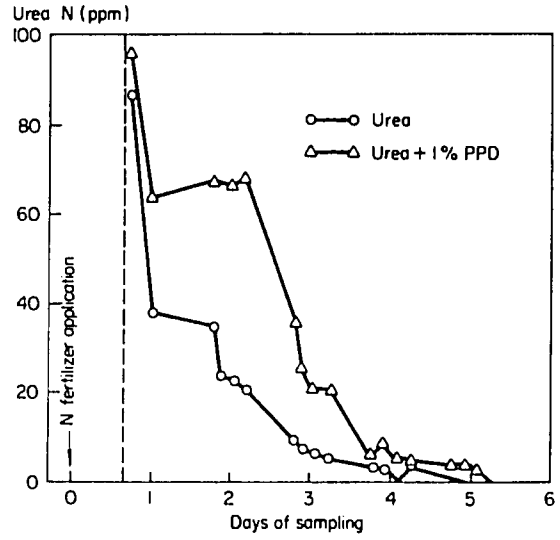
Band placement at 8.5 cm soil depth produced 36 μg N/ml concentrations in San Manuel soil (Fig. 25) and 26 μg N/ml in Maligaya soil (Fig. 24). Point placement at 10 cm produced negligible concentrations in floodwater in both locations.

In San Manuel clay loam, total N concentration in the floodwater was 138 μg N/ml with urea and 14 μg N/ml with AS (Fig. 26). Although the rise in floodwater pH with AS was initially slower than with urea, the peak pH of 9.0 occurred on the 5th day for both sources.

Grain yield. Yield response of IR58 to N



26. Changes in pH and total N concentration of floodwater of San Manuel clay loam as affected by sources of N fertilizer, 1983 DS.



27. Effect of the urease inhibitor phenylphosphorodiamidate (PPD) on floodwater urea concentration. IRRI, 1983 DS. Urea was applied to floodwater 26 DT.

fertilizer was more than 3 t/ha in DS and 1 t/ha in WS (Table 17).

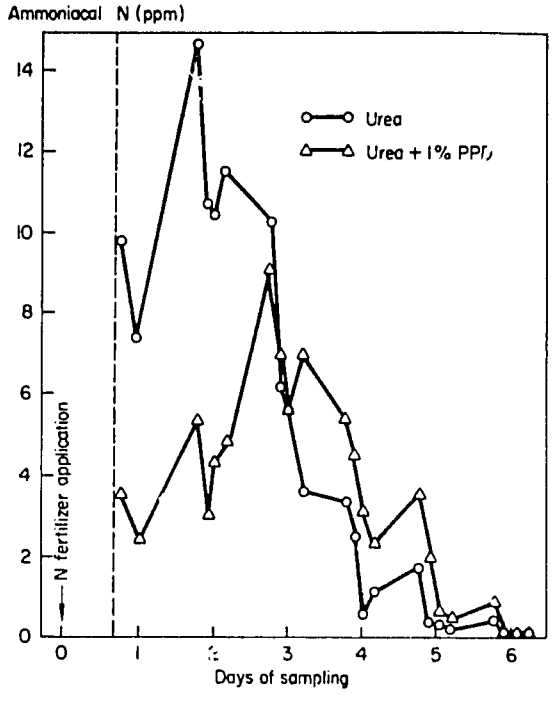
In DS, point placement at 10-cm soil depth gave the highest yield: 7.2 t/ha in Maligaya clay and 7.1 t/ha in San Manuel clay loam. In Maligaya clay, band placement and researchers' split of urea had similar yields and did not differ from point placement of urea.

In San Manuel clay loam, IR58 yielded significantly higher with urea point placement than with other treatments. The farmers' fertilizer split yielded lowest. PPD addition did not increase yield

Table 17. Grain yield of IR58 as affected by fertilizer N application methods on two soils in the Philippines. 1983 DS and WS.[a]

Application method	Yield (t/ha)			
	DS		WS	
	Maligaya clay, Nueva Ecija	San Manuel clay loam, Pangasinan	Maligaya clay, Nueva Ecija	San Manuel clay loam, Pangasinan
Unfertilized control	3.5 c	3.2 d	3.9 c	3.5 c
Point placement	7.2 a	7.1 a	5.3 a	5.5 a
Band placement	6.9 a	6.4 b	4.8 b	5.4 a
Researchers' split[b]	6.9 a	6.4 b	5.2 ab	5.2 ab
Farmers' split[c]	6.0 b	5.2 c	4.7 b	4.7 b
Farmers' split[c] with 1% PPD[d]	6.0 b	–	–	–
Researchers' split of ammonium sulfate[b]	–	6.6 b	5.2 ab	5.2 ab

[a]Nitrogen levels were 87 kg/ha in DS and 58 kg/ha WS. [b]2/3 basal plus 1/3 5-7 DBPI. [c]2/3 15 DT plus 1/3 booting stage. [d]A urease inhibitor.



28. Effect of the urease inhibitor phenylphosphorodiamidate (PPD) on floodwater ammoniacal N concentration. IRRI, 1983 DS. Urea was applied to floodwater 26 DT.

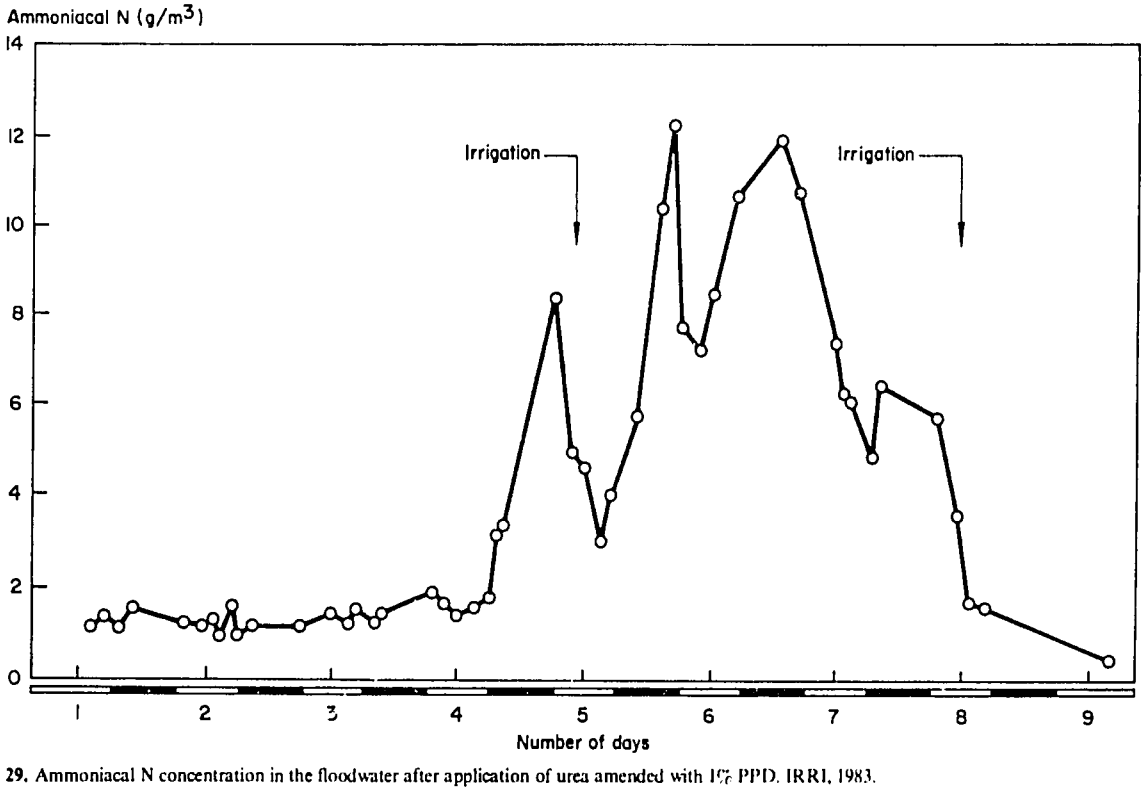
over the farmers' split. Yields with researchers' split of urea and of AS were similar. N sources performed equally well in the calcareous soil.

WS yields were lower than those in DS, but the trend of yield response to application methods was similar.

Effect of phenyl phosphorodiamidate on N recovery and grain yield. The effect of PPD on the rate of urea hydrolysis, plant uptake of N, ^{15}N recovery, and NH_3 volatilization was evaluated at MRRTC and IRRI.

PPD delayed hydrolysis of urea and retarded the buildup of ammoniacal N in all studies (Fig. 27, 28, 29). However, there was no effect on floodwater pH and its diurnal pattern. PPD with urea significantly increased N uptake and grain yield (Table 18) in an IRRI experiment where urea or urea + 1% PPD were topdressed 26 DT. PPD did not increase yields in a comparable experiment at MRRTC where urea or urea + 1% PPD were applied 17 DT (Table 19).

MRRTC and IRRI studied ^{15}N balance to evaluate the effect of PPD on N loss from topdressed urea. PPD (1% wt/wt) with urea



29. Ammoniacal N concentration in the floodwater after application of urea amended with 1% PPD. IRRI, 1983.

Table 18. Effect of urea source and application method on IR36 grain yield. IRRI, 1983 DS.

Treatment	Grain yield (t/ha)
Farmers' split with PPD amended urea (2/3 with PPD 26 DT + 1/3 at booting)	5.24 a
Farmers' split with urea (2/3 26 DT + 1/3 at booting)	4.70 cd
Researchers' split with urea (2/3 basal B&I + 1/3 5-7 DBPI	4.88 bc
Deep-point placement with USG	5.16 ab
Osmocote basal B&I	4.56 d
Control	3.01 e

Table 19. Effect of sources and application method of urea on grain yield of IR58 rice in ^{15}N balance experiment. MRRTC, 1983 DS.

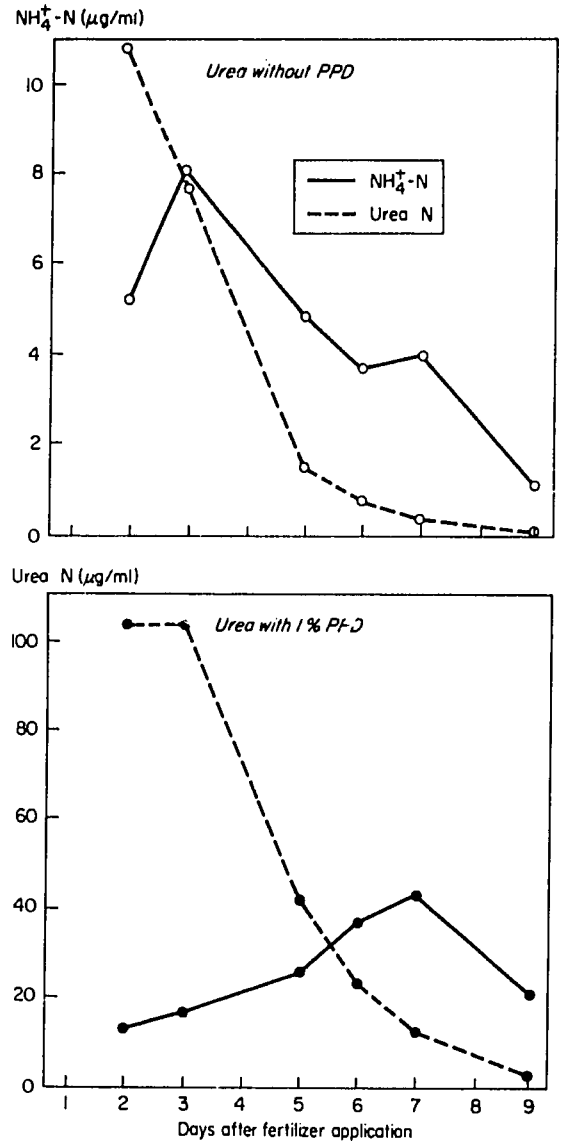
Treatment	Grain yield (t/ha)
No fertilizer N	3.5 c
Point placement of USG at 10 cm	7.2 a
Band placement of PU	6.9 a
Researchers' split with PU (2/3 B&I + 1/3 5-7 DBPI)	6.8 a
Farmers' split with PU (2/3 17 DT + 1/3 at booting)	6.0 b
Farmers' split with PU (2/3 with 1% PPD 15 DT + 1/3 at booting)	6.0 b

Table 20. Recovery of ^{15}N-labeled urea and urea + 1% PPD at 30 DT (MRRTC) or 40 DT (IRRI), 1983.

Location	Distribution	% ^{15}N applied	
		Urea	Urea + 1% PPD
MRRTC, Muñoz[a]	Exchangeable NH_4^+	9.8	23.9
	Nonexchangeable NH_4^+	26.4	29.8
	Straw	34.5	28.8
	Roots	3.2	3.1
	Total	73.9	85.5
IRRI, Los Baños[b]	Exchangeable NH_4^+	1.1	1.1
	Nonexchangeable NH_4^+	25.7	29.4
	Straw	26.5	35.9
	Roots	6.8	8.1
	Total	60.1	74.5

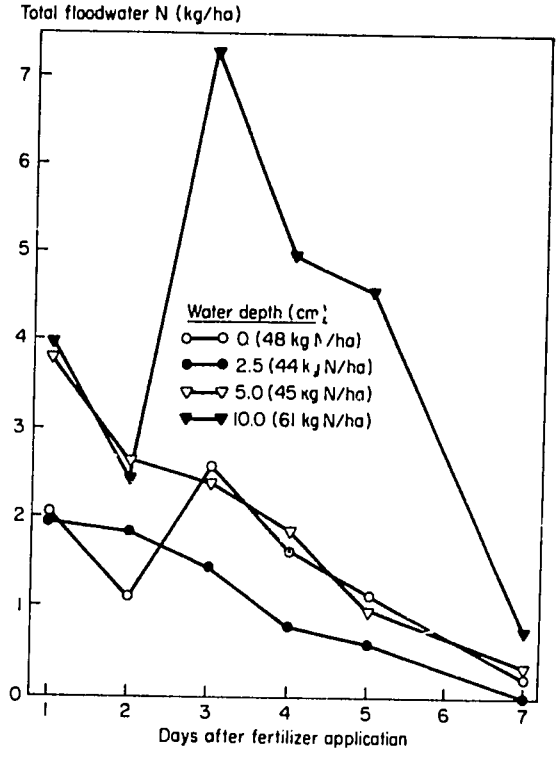
[a]Urea and urea + 1% PPD topdressed 18 DT. [b]Urea and urea + 1% PPD topdressed 26 DT.

increased ^{15}N recovery by 14% of the applied N at IRRI and 12% at MRRTC (Table 20). Increased ^{15}N recovery at IRRI was mostly from the plant pool, while the exchangeable NH_4^+ fraction at MRRTC contained higher quantities of ^{15}N where PPD was applied with urea.

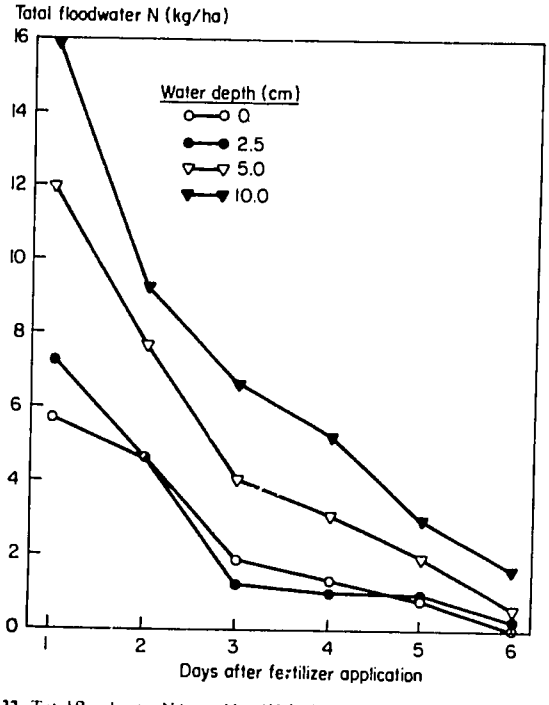


30. Effect of 1% PPD on the concentration of urea and ammonium in floodwater in Maligaya clay, 1983 DS.

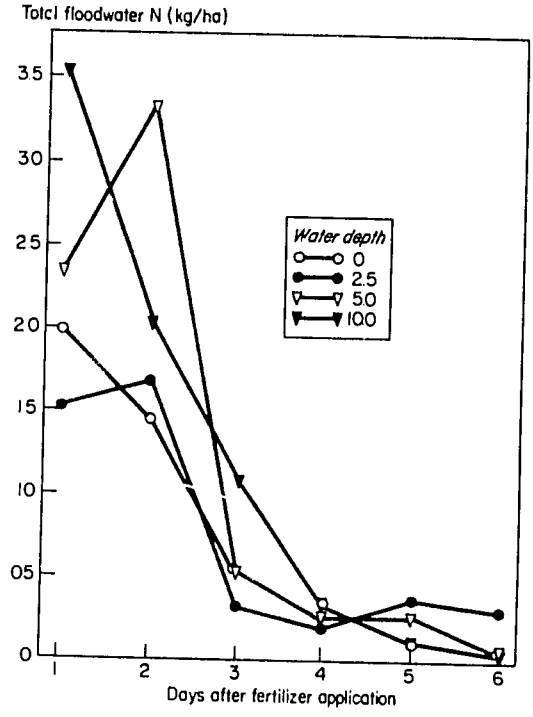
In a micrometeorological study, PPD (1% wt/wt) with urea reduced NH_3 loss from 22 to 12 kg N/ha when 58 kg urea/ha was applied to floodwater 18 DT. Floodwater ammoniacal N remained at low concentrations for 3 d after application of urea + 1% PPD; however, substantial concentrations were detected on day 4 and maximum concentration (12 µg N/ml) was obtained on day 6 (Fig. 30).



31. Total floodwater N (urea-N + NH_4^+-N) after band placement of PU by oscillating plunger machine. IRRI, 1983 WS.



32. Total floodwater N (urea-N + NH_4^+-N) after point placement of 58 kg N/ha as USG by deep-plunger machine. IRRI, 1983 WS.



33. Total floodwater N (urea-N + NH_4^+-N) after deep point placement by hand of 58 kg N/ha as USG. IRRI, 1983 WS.

WATER DEPTH EFFECTS ON NITROGEN LOSSES IN FLOODED RICE

Agronomy Department

A field experiment in 1983 WS evaluated the effect of water depth during fertilizer application by hand or machine on reducing N losses with transplanted IR58 rice. Floodwater depths during urea application were 0, 2.5, 5, and 10 cm. For 0 cm treatment, water depth was increased to 5 cm after application. For the other treatments, existing water depth was maintained up to the 6th day after application.

Floodwater samples and water depths were measured from 1 to 6 d after fertilizer application to determine the amount of urea and NH_4^+-N.

Analysis showed high total (urea + NH_4^+) N levels with hand- and machine-placed fertilizers when water was 10 cm deep during fertilizer application (Fig. 31, 32, 33). However, total floodwater N (kg/ha) was lower with the 0 cm (saturation) and 2.5 cm water depth.

Total floodwater N was appreciably lower with hand point-placed USG. With a deep plunger machine, point-placed USG increased floodwater N four times more than with hand point placement.

PU band-placed with the oscillating plunger resulted in twice as much floodwater N as with hand point-placed USG. Increased floodwater N indicates higher potential N losses. Deeper standing water during N application results in a greater amount of N in the floodwater. Fertilizer N should be applied onto mud and incorporated before transplanting.

Soil and crop management

Nitrogen fixation for wetland rice

Soil Microbiology Department

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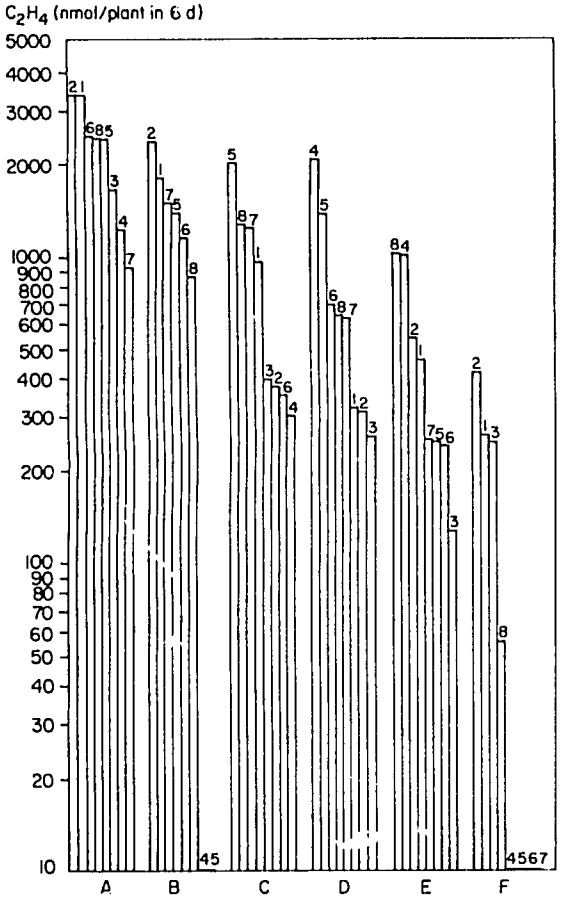
ASSOCIATIVE NITROGEN FIXATION

Varietal differences in stimulating N_2 fixation (spermosphere model). Sterile rice seeds were germinated on semisolid agar, inoculated with N_2-fixing bacteria, and grown in the dark. Acetylene reduction activity (ARA) was measured from 4 to 10 d after germination. Because previous results showed more activity with larger seeds, rice varieties with large and small seeds were used. They were inoculated with three strains of *Azospirillum lipoferum*, two strains of *Pseudomonas* sp., and one unidentified strain (Fig. 1). Increase in seed size did not correlate with increase in N_2-fixing activity. Therefore, the quality as well as the quantity of organic substances from the seedling determine



1. Acetylene reduction in spermosphere system of varieties in association with bacteria. IRRI, 1983. Rice varieties with seed wt (mg) in parentheses follow: 1 = TD 52 (41), 2 = Kap Nhay (41), 3 = KU 79-1 (31), 4 = IRAT 115 (22), 5 = Tulakhi (11), 6 = Giza (15), 7 = Motta (8), 8 = Kalajira (9). Bacterial strains are A = 34H *A. lipoferum*, B = SGBP4 unidentified, C = FS *A. lipoferum*, D = H8 *Pseudomonas*, E = KLH76 *Pseudomonas*, F = RO7 *A. lipoferum*.

Table 1. Effect of H_2 on acetylene reduction[a] in an intact plant of irrigated rice. IRRI, 1983.

	Ethylene (nmol) formed in 24 h/g dry weight plant		
	Trial 1 heading IR42	Trial 2 heading IR42	Trial 3 heading IR52
With H_2 (10%)	810	880	1590
Without H_2	580	320	960

[a] All differences were significant at 5% level.

N_2-fixing activity. No rice variety produced uniformly high activity with all bacterial strains, showing that the relationship between rice varieties and bacterial strains is quite specific. *A. lipoferum* 34H showed the highest average activities, and *A. brasilense* R07 showed the greatest variation depending upon variety. This suggests that some bacteria have a higher affinity for rice seedlings. The spermosphere model is more suitable for detecting active N_2-fixing bacteria than varietal differences.

Effect of hydrogen gas on nitrogen fixation. Some aerobic N_2-fixing bacteria can grow and fix N by using H_2 and CO_2 (chemolithotrophy). More H_2-utilizing N_2-fixing bacteria were associated with irrigated rice.

H_2 (10%) stimulated N_2 fixation in dominant rice rhizospheric N_2-fixing bacteria, *Pseudomonas* sp. and *Azospirillum* sp. H_2 also stimulated the N_2-fixing activity of these bacteria when inoculated on rice seedlings.

H_2 stimulated acetylene reduction of the rice plant (Table 1) and the excised root (Table 2) grown in a flooded field. The rice root could oxidize H_2. To confirm data based on acetylene reduction, the excised rice plant grown in the field was covered with a cylinder and supplied with a $^{15}N_2$ gas mixture for 60 h. H_2 stimulated $^{15}N_2$ incorporation by the excised rice. Because H_2 evolves in irrigated soils, N_2 fixation associated with rice roots and basal stems may be stimulated by H_2.

Bacteria identification. Acid- and gas-producing N_2-fixing enterobacteria isolated from rice roots and leaf sheaths were characterized biochemically and serologically. Using selected cultural and biochemical tests, all isolates from rice were iden-

Table 2. Effect of H_2 on dinitrogen reduction in an excised plant of irrigated rice. IRRI, 1983.

	Root		Submerged shoot		Aerial shoot		Total	
	With H_2	Without H_2	With H_2	Without H_2	With H_2	Without H_2	With H_2	Without H_2
Atom % excess	0.179	0.119	0.173	0.145	0.096	0.069		
N from fixation μg N	74.0	45.2	66.8	58.0	71.0	57.2	212	160
t (df = 8)	2.41						2.31	

tified as *Enterobacter cloacae* except two isolates, later identified as *Klebsiella planticola*. Fluorescent antibodies from two species showed separate serogroups.

Enzyme-linked immunosorbent assay (ELISA) for rapid identification and enumeration. The fluorescent antibody technique is sensitive and highly specific, but is time-consuming and cannot identify a large number of bacterial isolates. The indirect enzyme-linked immunosorbent assay was standardized and employed to identify N_2-fixing *Pseudomonas* H8 isolated from rice plants grown in different soils. The ELISA cross reactions of *Pseudomonas* H8 were checked against several reference bacteria and those isolated from rice. Of 50 unrelated bacteria, only 8 showed a slight cross reaction with H8 antibody, but their ELISA values were significantly different from that of H8. ELISA confirmed that some *Pseudomonas* strains found by fluorescent antibody reaction were closely related to H8. A few other strains were not. The failure of KLH 76 to cross-react against the H8 antibody supports the earlier view that it belongs to another serotype. Table 3 shows the results of ELISA survey of *Pseudomonas* from rice roots in different soils. Almost all irrigated rice-growing sites yielded isolates serologically similar to H8. Soils high in soluble Fe (Labo, Luisiana) seem to have a lower percentage of H8-type bacteria.

Preliminary results with ELISA suggest that it can distinguish closely related strains from intermediate or distantly related strains. The test is highly sensitive and can be used in the rapid and large-scale detection and identification of N_2-fixing bacteria.

Rice varietal differences in N_2 fixation. Field experiments were conducted at IRRI (Maahas soil) and at the Maligaya Rice Research Station in

Table 3. Survey by ELISA of *Pseudomonas* sp. H8 from rice roots in different soils. IRRI, 1983.

Source of isolates[a]		Isolates tested[b] (no.) (C)	Isolates (no.) that showed cross reaction[c]: Significant over control (no antigen) (A)	Isolates (no.) that showed cross reaction[c]: Not significant over strain H8[d] (B)	Relative value[e] of similarity with H8 (%)
Maligaya	– IR36 (UF)	67	11	7	18.6
Maligaya	– IR36 (F)	66	11	4	14.4
Labo	– IR8 (UF)	50	6	1	8.0
Pili	– IR8 (UF)	36	17	9	48.6
Pili	– IR36 (UF)	90	13	3	10.6
Luisiana	– IR36 (UF)	18	3	0	8.3
Luisiana	– IR42 (UF)	55	15	1	15.45
Maahas	– IR42 (UF)	93	26	8	22.5
Maahas	– *Oryza glaberrima* 109 (F, dryland)	34	0	0	0.0

[a]UF = unfertilized, F = fertilized with N. [b]Include N_2-fixing and non-N_2-fixing. [c]Based on *t*-values (1 and 5% points). [d]All isolates in this column were N_2-fixing. [e] $\frac{(A) + 2 \times (B)}{2 \times (C)} \times 100.$

1983 WS. Six rice varieties (Table 4) were grown in flooded soils and the following parameters studied at different growth stages:

- acetylene-reducing activity of the whole plant in water culture technique and of the excised plant-soil system,
- the count of heterotrophic N_2-fixing and non-N_2-fixing bacteria in rhizosphere soil, root, and submerged portion of the plant, and
- rice yield.

Table 4 shows ARA at three growth stages of six rice varieties grown in Maahas soil. The acetylene reduction assay of the excised plant-soil system was better.

Initial results showed significant varietal differences in N_2-fixing activity in at least one of three growth stages in two soils. A great variation in ARA among the replications seems to be caused by variation in plant growth.

There were no significant differences in the number of non-N_2-fixing heterotrophs and N_2-fixing heterotrophs because of varieties and growth stages. The rhizosphere soil (RS) consistently showed less bacteria than the root (R) and stem leaf sheath (SL). Regardless of growth stage and variety, colony-forming units (CFU) per g dry weight of total heterotrophs was about 10^8 for RS and 10^8-10^9 for R and SL; those of N_2-fixing bacteria were 10^6-10^7 for RS and 10^8-10^9 for R and SL.

Table 4. Acetylene-reducing activity (excised plant-soil assay) of 6 rice varieties grown in a flooded IRRI field during 1983 WS.

Variety	Ethylene[a] (nmol)/6 h per plant		
	21 DT	42 DT	Heading[b]
IR58	515 ± 166	3022 ± 841 ab	1893 ± 71 b (82)
IR26	347 ± 36	2713 ± 633 bc	5282 ± 446 a (92)
IR42	523 ± 222	4690 ± 740 a	5031 ± 959 a (68)
Hua-chou-chi-mo-mor	180 ± 4	1919 ± 410 bc	3319 ± 454 b (82)
BPI-76	500 ± 232	2677 ± 423 bc	5203 ± 755 a (75)
OS4	215 ± 24	914 ± 204 c	2599 ± 690 b
F value	1.21^{ns}	5.23*	7.27*
CV (%)	91.3	50.5	32.9

[a]Values are averages of 3 replications ± standard error of the mean. [b]Values in parentheses are heading time in days.

AUTOTROPHIC NITROGEN FIXATION

Standardization of the method for estimating BGA abundance in the soils. A standardized plating method has been developed to count algae in submerged and dry soils.

The effect of preparing dry samples on counts was tested. Six soil-based inocula were ground and sieved at 2.0, 1.0, 0.4, or 0.25 mm and then stirred for 15, 30, or 60 min when preparing the 10^{-1} dilution. Particle and time of stirring had no effect on total BGA counts. But in one multistrain sample ground at 2 mm, counts of one of the strains (*Nostoc* sp.) significantly increased with time of stirring.

Competition between petri dish colonies was studied by comparing triplicate counts at 2 consecutive dilutions from 133 soil samples. When there are more than 40 colonies on a dish at the lower dilution, the ratio between counts at 2 consecutive dilutions (theoretically equal to 10) is lower than 10 and is negatively correlated with the number of colonies. When a dish has more than 40 colonies, there will probably be an underestimation because of colony competition.

The reproducibility of the method was tested by plating 30 composite samples collected from a 16-m^2 plot and counting total and N_2-fixing BGA flora. Distribution was about normal and standard errors were 32 and 26% of the mean. The accuracy of a single count is about ± 60% and two results of a count are not significantly different if the ratio between the higher and the lower is less than 4.

The interplot variability of the counts was studied from 28 groups in 4 replicated 16-m^2 plots. Coefficients of variation ($c\bar{v}$) ranged from a few percent to about 100%. $c\bar{v}$ were higher with growing populations of BGA and lower with dry soils or where the contribution of spores in the soil was high. Spores in soil are more evenly distributed after plowing than populations whose pattern approximates a log-normal distribution.

The number of replications needed for a given accuracy was calculated, assuming a log-normal distribution. From the average of standard errors, 3 replications are needed to obtain significant differences between 2 means whose ratio is 10 and 6 replications for a ratio of 2. Taking the upper limit

of standard error below which 97% of cases fall, 4 replications are needed for a ratio of 10 and 16 for a ratio of 2.

Long-term inoculation experiment. A 2-yr DS field experiment highlighted problems encountered when trying to increase populations of N_2-fixing BGA in an irrigated rice field by inoculation and controlling grazing by aquatic invertebrates. Inoculation of nonindigenous strains, with either dried or fresh viable inocula at high levels of application, was unsuccessful. Grazing had an obvious limiting effect especially during the first crop. But it was not the only factor since inoculated strains still did not grow during the second crop even with strict grazing control.

During the second crop, grazing control permitted the establishment of an efficient N_2-fixing bloom of indigenous *Anabaena* sp. The bloom lasted for only a few days and was replaced by prolific mucilaginous strains which are resistant to grazing but much less efficient in N_2 fixation. Controlling grazing has a positive effect on N_2 fixation, but the increase was of little significance compared with the total N_2-fixing activity along the crop cycle. The extrapolation of acetylene reduction assay measurements of N_2-fixing activity (the value of which is debatable) showed that soil algae produced about 3 kg N/ha and floating algae, 10 kg N/ha during the first crop. During the second crop, soil algae produced about 3 kg N/ha in grazed plots and 6 kg N/ha in plots treated with neem and molluscide. The average contribution of floating algae, distributed equally in all plots, was about 20 kg N/ha.

There were no yield differences between treatments. Neither insecticide use to increase biological N_2 fixation nor algal inoculation techniques had any economic justification.

Growth-regulating effects of BGA. The effect of BGA cultures, culture filtrates, and BGA extracts on rice germination and seedling growth was tested on solutions using small floating screen trays. The method was unsatisfactory because most variations were caused by artifacts introduced by the experimental design, especially the BGA culture medium. BGA treatments had no significant effect on germination but increased seedling growth (Table 5).

Table 5. Effect of algal treatment on length of 14-d-old seedlings. IRRI, 1983.

Treatment	Mean length (cm) of seedling	
	GO medium	Water
BGA culture	8.32 a	7.90 a
BGA filtrate	8.07 ab	5.55 cd
BGA extract	6.99 bc	6.29 c
Control	6.30 c	5.31 d

Table 6. Effect of seedling pretreatment and algal inoculation on yield (pot experiment). IRRI, 1983.

Treatment	Dry wt of straw (g/pot)	Filled grains (%)	Grain yield (g/pot)
Without black cloth			
Control	46.83 ab	26.6 c	12.77 c
Inoculated (71 mg algal N)	31.96 c	46.0 abc	16.32 bc
Urea (71 mg N)	37.97 bc	55.7 ab	21.81 ab
With black cloth			
Inoculated (71 mg algal N)	49.48 a	50.0 ab	22.97 ab
Urea (71 mg N)	50.15 a	44.9 b	20.39 a
Algal extract	42.60 a	65.6 a	27.74 d

A pot experiment estimated the importance of BGA N and its "growth-promoting" effects in increasing rice yields. Results were strongly affected by

- great variability among replicated pots,
- abundant growth of indigenous BGA in uninoculated pots exposed to light, and
- higher temperature brought about by the black cloth covering half of the pots to prevent algal growth.

Yields increased when rice was germinated and grown in a BGA extract. The effects of rice germination and growth in a BGA culture and inoculation of BGA in the pots were less clear (Table 6). Yields in inoculated pots were not significantly different from those in pots receiving a urea N equivalent.

Production of BGA inoculum. Different methods for producing BGA inoculum have been tested in the greenhouse. Methods using artificial liquid media, either in open culture or in large plastic tubes, were expensive and unsatisfactory because tested strains were frequently damaged by phytooxidation of pigments (bleaching). Bleaching also occurred when Chinese-recommended mix-

Table 7. Characteristics of some dry soil[a] based algal flakes from monostrain inocula. IRRI, 1983.

	Anabaena variabilis	*Aulosira fertilissima*	*Nostoc* sp.	*Tolypothrix tenuis*
Dry wt harvested per m^2 (g of flakes)	313	470	377	356
N_2-fixing CFU (g dry wt algal flakes)	2.1×10^7	8.5×10^6	3.3×10^6	2.2×10^7
Non-N_2-fixing CFU (g dry wt algal flakes)	3.5×10^6	3.0×10^6	8.0×10^6	1.7×10^6
Ash (% dry wt)	78.5	79.0	79.3	79.8
Total N (% dry wt including NO_3^-)	0.509	0.545	0.566	0.514
P (ppm dry wt)	1828	1772	1897	1616
C (% dry wt)	3.78	3.92	4.25	3.92
Dry wt BGA (kg/ha)	158	250	226	203
BGA N (kg/ha)	13.3	11.5	18.9	15.9
% N in BGA, ash-free basis	7.2	7.6	7.0	6.5

[a]Soil used for multiplication had 84.4% ash, 0.150% N, 1.33% C, and 428 ppm P.

tures of water, superphosphate, and rice straw ash were used as culture media. Burmese and Indian methods which use soil and superphosphate were more successful. The Burmese method, which uses 5 kg dry soil, 10 g superphosphate, 2 ml perthane, 2 g NaCl/m^2, and 5 cm water proved to be most efficient during the Philippine DS. The large quantity of soil used may provide more nutrients and CO_2 to the algae, making them less sensitive to phytooxidation of pigments under high light intensities. The Burmese method was used to test the growth performance of 33 N_2-fixing strains in small trays. Material produced has CFU counts ranging from less than 10^3 to 10^7/g dry weight. The most efficient strains were tested in triplicate in 1-m^2 trays. Under favorable conditions, 3 successive crops of algae were harvested from 1 tray in about 1 mo. Algal flakes had CFU ranging from 10^5 to 10^7/g dry weight (Table 7), an average of 1000 times more than in the first cm of a dry rice soil rich in BGA. Algal flakes are characterized by high ash and P contents.

When produced in the greenhouse, without predators and with ample available P, BGA develop a dense bloom covering the floodwater surface in the tray. Analysis of such blooms can predict the maximum standing biomass expected in the field. Dry weights calculated on an ash-free basis ranged from 150 to 250 kg/ha, corresponding to 11 to 19 kg N/ha (Table 7).

Isozymes. Isozymes of 18 enzymes of 26 strains of N_2-fixing BGA were studied to evaluate the possibility of using zymograms to identify BGA strains. Four enzymes were selected which have high frequency (F) and a high number of zymograms (n.z.): phosphoglucose isomerase (F = 92%, n.z. = 6), 6-phosphogluconate dehydrogenase (F = 84%, n.z. = 5), glucokinase (F = 69%, n.z. = 5), and superoxide dismutase (F = 87%, n.z. = 5). They have been used to compare zymograms of 12 genera of BGA and 10 species of *Anabaena* at different ages and grown in different conditions. The extraction methods were tested, and they showed that cell breakage in small mortars was most convenient. The method is highly discriminating at genus and species levels and has a satisfactory repeatability useful for strain characterization. More data are needed before the tests are used for taxonomic purposes.

Effects of tubificids. Aquatic invertebrates, such as tubificid worms and other saprophytic Oligochaeta, are important in recycling mineral and organic matter between floodwater and soil. IRRI cooperated with Boyce Thompson Institute to study the role of tubificids in soil mineralization and recovery of algal N by irrigated rice.

^{15}N-labeled *Nostoc* sp. was either buried 10 cm deep or placed on the soil surface. In the tubificid treatment, *Tubifex tubifex* was added to give an initial density of 12,500/m^2, which is the normal range in Philippine rice soils. Five days after algal and tubificid treatments, rice seedlings were transplanted into the treated soil in 15-litre pots and placed in a temperature-controlled light-supplied

greenhouse. After the first rice harvest, soil was thoroughly mixed, and 2 wk later, a second crop was transplanted.

The results of ^{15}N recovery and plant N uptake are shown in Table 8. Tubificid activities reduced recovery of buried algal N by rice, increased plant uptake of soil N, and doubled losses of ^{15}N from the system. Soil N and algal N mineralization in flooded soil was doubled in 17 d by tubificid activities. ^{15}N-labeled algae and rice straw were placed on the soil surface with tubificids. In 70 d, tubificids helped move ^{15}N-labeled rice straw and algal material or their degradation products 12 cm down in the soil.

Lower recovery and higher losses of algal N by tubificid activity may be explained in the following ways. Tubificids change the redox potential of soil to favor nitrification. Diffusion of NH_4^+N from decomposing algae and tubificid excretion is enhanced by tubificid activities in the reduced layer. Some of this N is lost. At the same time, tubificids enhance mineralization which increases the plant's soil N uptake but competes with algal N uptake. Probably tubificid action in N transformation in flooded soil is more complex than it appears. Further studies are needed.

N BALANCE AND ^{15}N TECHNIQUES

Application of ^{15}N dilution technique in screening rice varieties that can stimulate biological N_2 fixation. N balance studies using Kjeldahl analysis showed great differences among rice varieties' ability to stimulate N gains in flooded soils. The N balance method is time-consuming and laborious. Simpler methods are needed to identify varieties that can efficiently stimulate N gains or depend on biological N_2 fixation. Since the ^{15}N dilution method is now widely used in selecting legumes higher in symbiotic N fixation, the same principle was applied to irrigated rice.

Pot experiment. IRRI field soil was put into pots (200 cm^2) with added ^{15}N (25.85 atom % excess)-labeled ammonium sulfate (74.3 mg/pot — 26 kg N/ha). IR26, Mahsuri, and OS4 were transplanted in flooded pots and IR26 was grown in upland conditions. Pot surfaces were covered with black cloth and 3 consecutive crops were grown with 3-wk intervals between. ^{15}N contents and total N balance were measured to find the whole-plant atom % excess in the first, second, and third crops (Table 9). Atom % excess of the plant decreased as growth duration increased, because the atom % excess in the available N pool diminished. Atom % excess in the first crop of upland IR26 was apparently lower than that of flooded IR26. Because growth duration differed greatly, the apparent difference in ^{15}N atom % excess could have been caused by the long growth period of upland IR26.

To eliminate the effect of growth duration, the regression equation between atom % excess and number of days from the beginning of the experiment to harvest was calculated. The positive difference between the observed and the expected atom % excess means higher atom % excess,

Table 8. Percentages of recovery of algal ^{15}N and total N uptake by rice. IRRI, 1983.

	Surface-applied alga		Buried alga	
	With tubificids	Without tubificids	With tubificids	Without tubificids
Recovery (%)				
First crop	23.7	24.6	29.5	43.9
Second crop	8.3	6.7	8.4	11.2
Total to two crops	32.00	33.3	37.9	55.1
Soil	50.7	58.0	51.8	40.4
Unaccounted for	17.3	8.7	10.3	4.5
N uptake by rice[a] (mg N/pot)				
First crop, from soil	63.4	51.5	59.2	45.6
from algae	3.80	3.95	4.73	7.04
Total	67.2	55.5	63.9	52.6
Second crop	34.2	40.4	42.7	43.8

[a]Only to grain and straw.

Table 9. ^{15}N content in 3 crops of rice grown in ^{15}N-labeled soil. IRRI, 1983.

	^{15}N atom % excess in whole plant (a)	Harvest date (d after transplanting of the first crop)	Estimated[a] ^{15}N atom % excess (b)	Difference (a – b)
		First crop		
OS4	3.56	112	3.43	0.12
Mahsuri	2.94	141	2.55	0.38
IR26 wetland	3.10	115	3.29	–0.09
IR26 dryland	2.75	151	2.13	0.61
		Second crop		
OS4	0.67	248	0.96	–0.29
Mahsuri	0.61	291	0.74	–0.13
IR26 wetland	0.63	253	0.93	–0.30
IR26 dryland	0.79	310	0.67	0.11
		Third crop		
OS4	0.47	404	0.43	0.03
Mahsuri	0.48	442	0.43	0.10
IR26 wetland	0.48	404	0.43	0.04

[a] Log (atom % excess) = 23.3 – 19.78 $(d)^{0.03}$

keeping growth duration equal. Upland IR26 depended more on ^{15}N-labeled available N than flooded IR26, which is consistent with lower N_2 fixation associated with upland rice. The lower value of atom % excess in Mahsuri was caused by its longer growth duration.

In applying the ^{15}N dilution technique, data for varieties with different growth durations should be treated carefully.

N gains for 3 crops were 146 ± 22 mg N/pot (means ± standard error) for IR26 (flooded) and 177 ± 75 for OS4. ^{15}N atom % excess was always highest in the grain and lowest in the root. Underwater culms always had lower ^{15}N content than those above water. In upland conditions, differences in ^{15}N contents among different parts of rice were small. This suggests that lower ^{15}N content in underwater roots and culms is caused by their N_2 fixation.

The difference in ^{15}N content among plant tissues needs further study.

Field experiments. In concrete plots with 4 kinds of soil, 2 rice crops were grown after applying ^{15}N ammonium. Five rice varieties (IR58, IR42, BPI76, Hua-chou-chi-mo-mor, and OS4) were used. ^{15}N atom % excess in the grain of IR58 was higher than that of Hua-chou-chi-mo-mor at 79 DT. Among IR42, BPI76, and OS4 with similar growth duration, OS4 had the highest ^{15}N atom % excess. In previous pot experiments, it also was lower in stimulating N gains. This preliminary trial showed a rough correlation between ^{15}N atom % excess and N gains.

Careful methodology (to prevent sampling errors and difference in ^{15}N content among different plant parts) is needed to apply ^{15}N dilution in the screening of varieties.

Soil and crop management

Management of organic manures

Soil Chemistry/ Physics, Agronomy, Entomology, and Soil Microbiology Departments

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SOIL AMENDMENT WITH STRAW

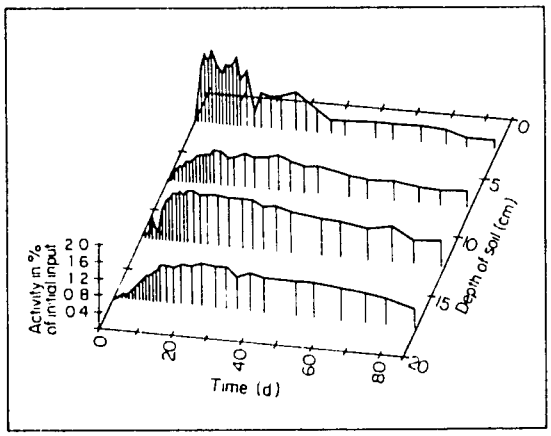
Soil Chemistry/ Physics Department

Decomposition of ^{14}C-labeled rice straw in submerged soils. ^{14}C-labeled rice straw was incorporated into soil layers of different depths in a permanently submerged Haplaquoll on the IRRI farm and the remaining ^{14}C was monitored over time.

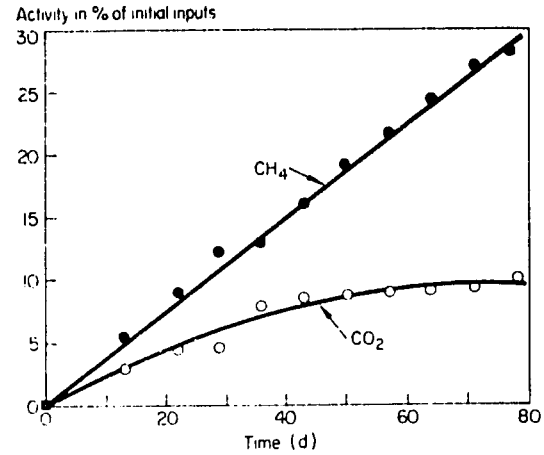
Shortly after incorporation, the soil was contaminated down to the dense layer with water-soluble C compounds (Fig. 1). The resulting CO_2 production leveled off after a few weeks, but methane formation was maintained. Nearly 30% of the incorporated C was transformed to methane in 80 d (Fig. 2). The decomposition pattern was similar to that in tropical uplands, having a half-life of 43 d (Fig. 3). As depth of incorporation increased rice straw decomposition slowed down, and water-soluble C compounds that were translocated upward were degraded faster (Table 1).

Long-term experiments on straw management. As in previous years, the straw equivalent to 5 t/ha in outdoor drums significantly increased straw and grain mean yields in 3 soils (1.3-2.0% C, pH 4.8-7.5). Straw-treated soils had higher C, N, and K content, resulting in significantly higher N, P, and K uptake by IR52.

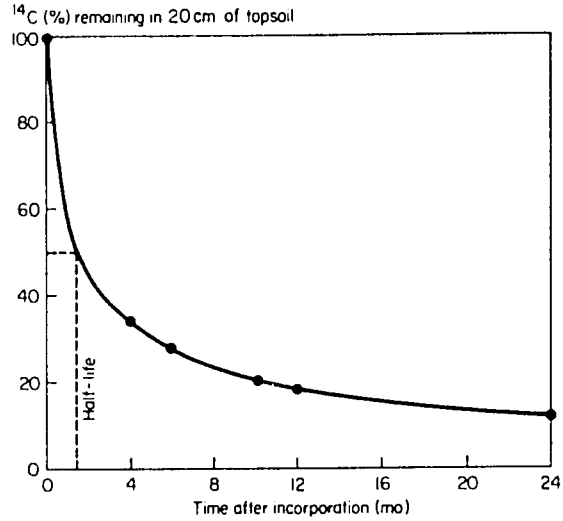
Straw was used with four management methods (removed, burned, long straw, and composted straw) on Maahas clay. The 22nd crop of IR52 and the 23rd crop of IR56 had higher straw and grain yields in the long-straw and compost treatments,



1. Activity of the soil solution after incorporation of ^{14}C-labeled rice straw to a depth of 5-10 cm. IRRI, 1983.



2. Formation of methane and CO_2 from ^{14}C-labeled rice straw. IRRI, 1983.



3. Decomposition of ^{14}C-labeled rice straw in a continuously submerged soil on the IRRI farm, 1983.

The highest increase of N and available P came from compost incorporation, and the greatest increase in exchangeable K came from burning (Table 2).

Water management studies in 3 soils (pH 4.8-7.5) in outdoor drums showed that flood fallowing produced higher straw and grain yields for the 35th and 36th crops. Submergence increased soil C by 0.5% and N by 0.06% over dry fallow.

Three water and 2 straw treatments on Maahas clay showed no significant differences in straw and grain yields in the 22d and 23d crops. Straw and grain yields were high in all treatments with means of 4.4 t/ha in DS and 3.5 t/ha in WS.

Table 1. Fate of ^{14}C-labeled rice straw in submerged Maahas clay, 1 yr after incorporation. 1983.

Depth (cm)	Distribution (%) of ^{14}C in soil when loss is				Av distribution (%)
	82.7%	79%	71.9%	72.1%	
0-5	5.4[a]	3.2	0.8	0.3	
5-10	6.1	4.5[b]	0.6	0.3	
10-15	2.0	6.0	9.5[c]	1.6	
15-20	1.1	3.8	10.3	18.2[d]	18.4
20-25	1.3	1.8	4.9	5.2	
25-30	0.8	0.8	1.0	1.1	
30-35	0.3	0.5	0.7	0.7	
35-40	0.3	0.4	0.3	0.5	23.6
Total	17.3	21.0	28.1	27.9	

[a]Depth of incorporation (DI) was 0-5 cm. [b]DI = 5-10 cm. [c]DI = 10-15 cm. [d]DI = 15-20 cm.

Table 2. Effects of 4 straw treatments on nutrient status of Maahas clay before the 23d WS crop, 1983.

Treatment	Total N (%)	Organic C (%)	Available P (mg/kg)	Exchangeable K (meq/100g)
Straw removed	0.17 c	1.6 b	7.3 c	1.14 b
Straw burned and ash mixed with the soil	0.17 c	1.7 b	10.3 b	1.52 a
Long straw added	0.18 b	1.9 a	8.9 bc	1.27 b
Straw compost added	0.21 a	2.0 a	20.2 a	1.14 b

Effect of different amounts of straw incorporation. Greenhouse studies investigated the effect of increasing amounts of incorporated straw on soil solution kinetics and growth of rice on Luisiana clay (pH 4.4), Maahas clay (pH 6.1), and San Manuel clay loam (pH 6.9). Straw was incorporated at 0%, 0.3%, 0.6%, and 0.9% by weight. IR26 was the test variety.

Aside from the beneficial effects of increasing NH_4^+ and K^+, Zn availability decreased markedly with increasing amounts of incorporated straw. This was probably caused by precipitation into $ZnCO_3$. The decrease in availability caused Zn deficiency in Maahas clay and San Manuel clay loam. In Luisiana clay, the decrease remained above the critical level. Since IR26 is susceptible to Zn deficiency, straw and grain yields decreased with increasing amounts of incorporated straw on Maahas clay and San Manuel clay loam. Yields increased on Luisiana clay (Table 3).

Table 3. Grain yield and Zn content of IR26 straw as affected by straw treatments. 1983.

Soil	pH	Straw addition (weight % of dry soil)	Grain (g/pot)	Zn ppm
Luisiana clay	4.4	0.0	42 fg	152 a
		0.3	93 bc	145 a
		0.6	113 b	125 b
		0.9	146 a	110 bc
Maahas clay	6.1	0.0	86 cd	101 cd
		0.3	68 de	71 ef
		0.6	23 g	58 fg
		0.9	42 fg	48 g
San Manuel clay	6.9	0.0	57 ef	87 de
		0.3	46 efg	71 ef
		0.6	37 fg	63 fg
		0.9	40 fg	54 fg

Another experiment showed no differences in grain yield of IR36 (tolerant of Zn deficiency) after incorporation of 0.25% straw.

AMELIORATION OF AN ACID SULFATE SOIL

Soil Chemistry/Physics Department

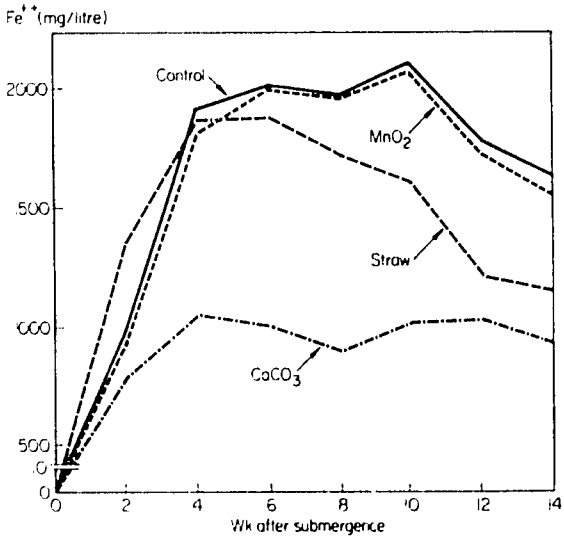
Effects of $CaCO_3$, MnO_2, and straw addition on soil solution kinetics and rice growth were studied in the greenhouse on an acid sulfate soil from Albay, Philippines. The application rate for straw was 0.25%; lime, 0.25%; and MnO_2, 0.005% by weight of air-dried soil. Fertilizer rates during the first crop were 50-25-25 kg NPK/kg soil. Four 3-wk-old IR26 seedlings were transplanted. Lime application immediately increased the pH from 3.2 to more than 4.5 and depressed excessive formation of Fe^{2+} and Al^{3+} in the soil solution. Straw application only slightly increased pH but markedly depressed Fe^{2+} concentration after 2 wk (Fig. 4) so that Fe toxicity symptoms occurred only during early growth. Other than on Mn content, MnO_2 application had no effect on the chemical kinetics of the soil solution.

Lime treatments resulted in the highest straw and grain yields for the first crop, followed by the straw and Mn treatments, and the control (Fig. 5).

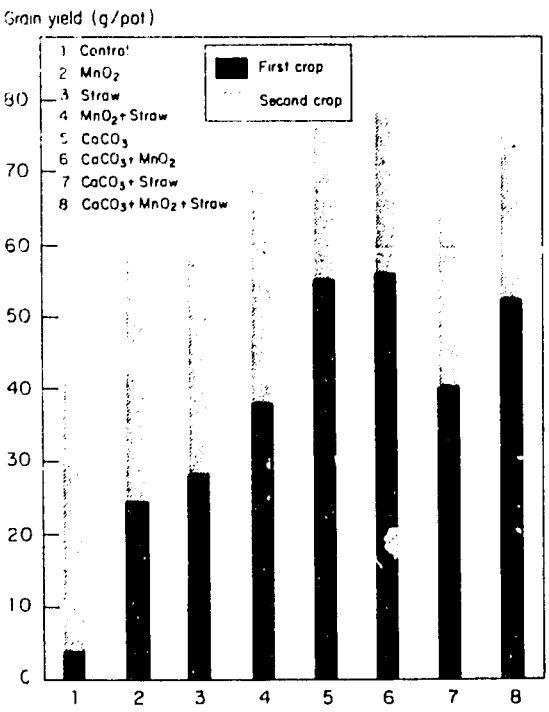
The soil was kept submerged and 50-25-25 mg NPK/kg soil was added before planting a second crop. Four WT, growth was depressed on soils that

were previously treated with lime and straw because of N deficiency. The control performed best (Fig. 5).

Topdressed N seems to be essential on ameliorated acid sulfate soils that have been kept submerged.



4. Effect of amendments on the kinetics of Fe in the soil solution of an acid sulfate soil from Albay, Philippines, 1983.



5. Effect of amendments on the yield of 2 successive IR26 crops on an acid sulfate soil from Albay, Philippines, 1983.

OPTIMAL SOIL ORGANIC MATTER CONTENT OF SUBMERGED SOILS

Soil Chemistry/Physics Department

The model, described in Annual Report for 1980, for tailoring N recommendation to soil and crop needs in submerged soil was developed further.

The bulk density of puddled and submerged soils is correlated to the OM content and consequently (because of the stable C:N of about 10) to the soil N content (Fig. 6).

The mass of soil (m_s in kg/ha) is therefore expressed as a function of the soil N content (% N_t) and the effective root depth (d_r in cm).

- $m_s = 10^5 (1.5095 - 3.8051\ N_t) \times d_r$

Philippine field trials without N fertilizer during the last 15 yr showed that one rice crop takes up 3.2% of total N.

Soil N uptake (SN_u in kg/ha) is calculated as

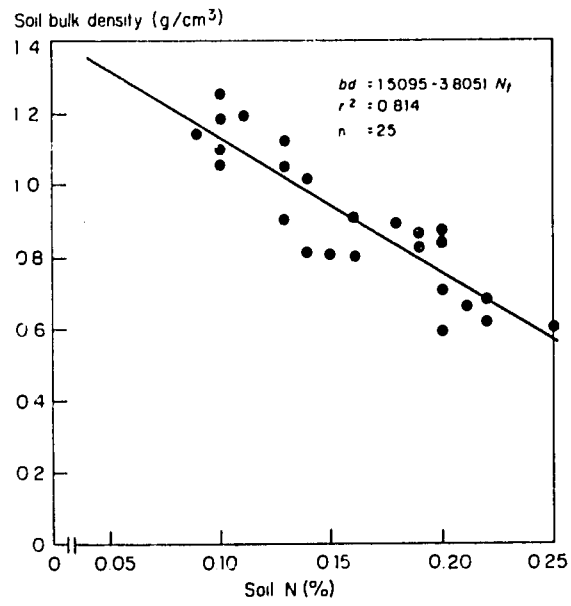
- $SN_u = 32\ N_t\ (1.5095 - 3.8051\ N_t) \times d_r$

Losses of N fertilizer (FN) may increase with higher rates. The remaining effective uptake of N fertilizer (FN_e in kg/ha) is estimated as

- $FN_e = 1.193 \cdot FN^{0.9}$

The weakening of yield response to N fertilizer (FN_u) *was found to be*

- $FN_u = -0.000225 \cdot FN_e^2$



6. Relationship between soil N content and soil bulk density in puddled and submerged soil. IRRI, 1983.

Experiments with ^{15}N fertilizer showed that application enhances uptake of soil N (SN_e), which is expressed by

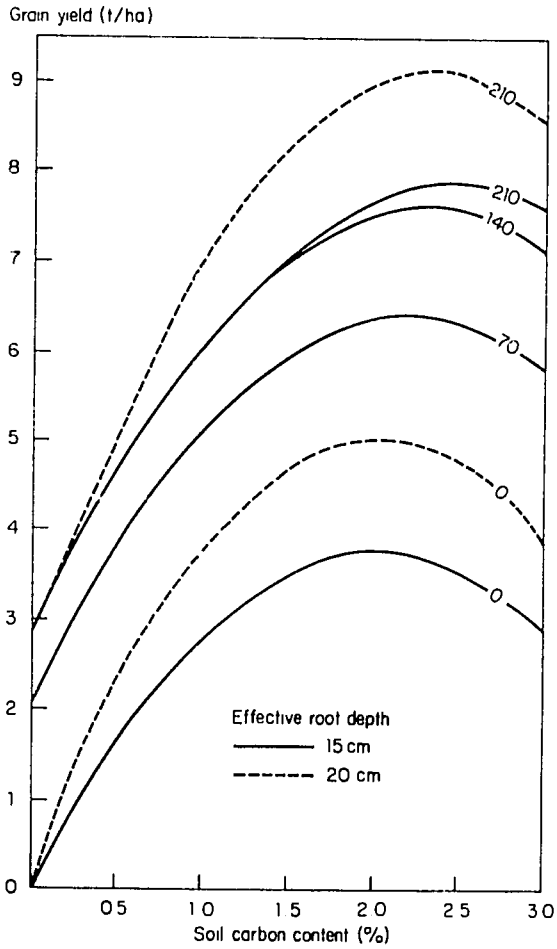
- $SN_e = FN_e \cdot N_t$

Since 20 kg of N uptake produces 1 t rice, the equation for yield targets (Y_t in kg/ha) is

- $Y_t = 0.05 \cdot FN_e - 0.000225 \cdot FN_e^2 + 0.05\, FN_e \cdot N_t + (2.4152\, N_t - 0.0882\, N_t^2) \cdot d_r$

Only effective root depth (mostly 15 cm), soil N content, and N fertilizer rate data are needed. The model worked satisfactorily for soils with an N range of 0.09 to 0.25% and an OM content range of 2 to 5%. The validity has not yet been evaluated for lower and higher contents.

The model predicts optimum yields for given soil N contents and fertilizer rates. It also identifies optimum soil N and C by comparing yields at different levels. For a maximum yield of 3.8 t/ha with zero N, optimum soil C should be 2.0%. For a yield of 7.9 t/ha with 210 kg N/ha, soil C should be 2.4%. Further increase of soil C does not produce higher yields. If the effective root depth, not just tillage depth, could be increased by 5 cm, grain yields of 5 t/ha without fertilizer N could be possible (Fig. 7).



7. Relationship between soil C content, N-fertilizer rate (0, 70, 140, 210 kg N/ha), and rice yield in puddled and submerged soil. IRRI, 1983.

SUPPLEMENTARY SOURCES OF NITROGEN FERTILIZERS IN LOWLAND RICE

Agronomy Department

Long-term studies on integrated N management using organic and inorganic fertilizers were initiated during the 1982 WS at IRRI and in a farmer's field in Laguna, Philippines.

Before trials began, soil analyses showed marked differences in total N, OM, and exchangeable NH_4^+-N (Table 4). First crop yields in the unfertilized control were higher in the farmer's field (4.0 t/ha) than at IRRI (3.1 t/ha) because the farmer's field had higher soil N (0.37% vs 0.17%) (Table 5). However, N response was greater at IRRI (1.6 t/ha vs 1.1 t/ha).

In both soils, azolla alone or combined with PU or deep-placed USG performed better than soil-incorporated fresh or composted rice straw. Yields from azolla-treated plots were comparable with those with either PU or USG. Fresh or composted rice straw was as good as the control.

Table 4. Characteristics of soils for the long-term trial on supplementary sources of fertilizer N in lowland rice at IRRI and in a farmer's field in Victoria, Laguna, Philippines, 1982 WS.

Soil property	IRRI	Victoria, Laguna
pH (1:1)	6.4	6.6
Total N (%)	0.17	0.37
OM (%)	3.1	6.7
Exchangeable NH_4^+-N (ppm)	28	46
Available P (Olsen, ppm)	24	6
Exchangeable cations (meq/100 g)		
K	1.33	0.72
Na	1.44	0.73
Ca	18	27
Mg	11	13
CEC (meq/100 g)	35	43
Available Zn (ppm, K & P)	1.4	0.16
Texture	Silty clay	Clay

In the farmer's field, combined N sources gave similar yields except for fresh rice straw with USG. With the same inorganic source added, fresh rice straw and rice straw compost were comparable to urea alone.

At IRRI, fresh rice straw and rice straw compost either with PU or USG were equally effective (Table 5).

The second (DS) and third (WS) consecutive crops at both sites were continued in 1983.

At both sites in DS, fresh soil-incorporated azolla alone or combined with PU or USG was comparable to PU alone. Soil-incorporated rice straw compost did not increase yield over the control. At IRRI, fresh soil-incorporated rice straw was as effective as PU or USG (Table 6). In the farmer's field, however, fresh soil-incorporated rice straw was no better than the unfertilized control (Table 7). PU or USG with fresh rice straw or rice straw compost usually gave higher yields than either rice straw or rice straw compost alone.

In WS, organic sources performed poorly at both sites. Combination treatments at IRRI were comparable to USG or PU alone and almost always superior to the control. Organic and inorganic fertilizers performed poorly in the farmer's field.

Table 5. Effect of supplementary N sources on grain yield of IR36. IRRI and a farmer's field in Victoria, Laguna, Philippines, 1982 WS.

N source[a]	Grain yield (t/ha)	
	IRRI	Victoria, Laguna
No fertilizer N (control)	3.1 d	4.0 ef
58 kg N/ha of single sources		
PU, split	4.7 a	5.0 ab
SCU	4.7 a	5.1 ab
Fresh azolla, soil incorporated	4.3 abc	5.2 a
Fresh rice straw, soil incorporated	2.9 d	3.9 f
Rice straw compost, soil incorporated	3.1 d	4.3 de
58 kg N/ha[b] of combined sources		
Fresh azolla + PU, split	4.5 ab	5.1 ab
Fresh rice straw + PU, split	4.1 bc	5.1 ab
Rice straw compost + PU, split	3.8 c	4.9 ab
Fresh azolla + USG	4.7 a	4.8 ab
Fresh rice straw + USG	4.0 c	4.5 cd
Rice straw compost + USG	4.3 abc	4.7 bc

[a]For split application, 2/3 urea was B&I at planting time, and 1/3 was topdressed 5-7 DBPI. [b]29 kg N/ha each of organic and inorganic sources combined.

Table 6. Effect of supplementary N sources on grain yield of IR36 rice. IRRI, 1983.

N source[a]	Grain yield (t/ha)	
	DS (second crop)	WS[b] (third crop)
No fertilizer N (control)	4.5 d	3.3 c
Single sources		
PU, best split	5.9 ab	4.1 a
USG	5.6 ab	4.0 ab
Fresh azolla, soil incorporated	5.5 ab	3.5 bc
Fresh rice straw, soil incorporated	5.2 bc	3.5 bc
Rice straw compost, soil incorporated	4.4 d	3.6 abc
Combined sources[c]		
Fresh azolla + PU, best split	5.8 ab	3.2 ab
Fresh rice straw + PU, best split	5.9 ab	4.0 ab
Rice straw compost + PU, best split	5.6 ab	3.8 ab
Fresh azolla + USG	5.8 ab	3.8 ab
Fresh rice straw + USG	4.6 cd	3.9 ab
Rice straw compost + USG	6.0 a	3.7 abc

[a]For best split application, 2/3 urea was B&I at planting time, and 1/3 was topdressed 5-7 DBPI. N rates = 58 kg N/ha in WS and 116 kg N/ha in DS. [b]No azolla application in WS. [c]For combined applications 29 kg N/ha each of organic and inorganic sources in WS, and 58 kg N/ha in DS.

Table 7. Effect of supplementary N sources on grain yield of IR36. Farmer's field, Victoria, Laguna, Philippines, 1983.

N source[a]	Grain yield (t/ha)	
	DS (second crop)	WS[b] (third crop)
No fertilizer N (control)	3.1 ef	3.2 c
Single sources		
PU, best split	5.5 bc	4.0 ab
USG	6.1 ab	4.4 a
Fresh azolla, soil incorporated	6.0 ab	3.6 bc
Fresh rice straw, soil incorporated	2.6 f	3.4 bc
Rice straw compost, soil incorporated	2.7 f	3.1 c
Combined sources[c]		
Fresh azolla + PU, best split	5.3 cd	3.4 bc
Fresh rice straw + PU, best split	4.6 d	3.4 bc
Rice straw compost + PU, best split	3.7 e	3.8 bc
Fresh azolla + USG	6.5 a	3.4 bc
Fresh rice straw + USG	5.1 cd	3.7 bc
Rice straw compost + USG	5.0 cd	3.4 bc

[a]For best split application, 2/3 urea was B&I at planting time, and 1/3 was topdressed 5-7 DBPI. N rates = 58 kg N/ha in WS and 116 kg N/ha in DS. [b]No azolla application during WS. [c]For combined applications, 29 kg N/ha each of organic and inorganic sources in WS and 58 kg N/ha in DS.

AZOLLA AS SOURCE OF SUPPLEMENTARY NITROGEN FERTILIZER FOR MEDIUM DEEPWATER RICE

Agronomy Department

An experiment was conducted to determine the supplementary effect of azolla when used with inorganic fertilizer sources (PU, SCU, and USG) and IR42. *Azolla pinnata* with 4% N (dry weight basis) was inoculated at 500 g/m² 1 DT, allowed to grow, and incorporated 30 DT. Water depth increased 5 cm daily after azolla incorporation and was maintained at 50 cm until harvest.

Yield increased significantly with fertilizer N compared with the unfertilized control (Table 8).

NITROGEN FIXATION BY *AZOLLA-ANABAENA* SYMBIOSIS

Soil Microbiology Department

Dual culture of rice and azolla by wide-row spacing. To see if azolla can substitute for chemical N fertilizer, the fern was grown in the rice canopy in wide or narrow row spacing and incorporated. AS in chemical-N treatments was applied 1/3 at basal, 1/3 at 14 DT, and 1/3 at 50 DT. The distance between narrow rows was 13.6 cm; between wide rows, 53 cm; and between hills on a row, 10 cm. Plant density was 30 hills/m². A mixture of *Azolla pinnata* and *A. caroliniana* was inoculated and one crop was grown before transplanting rice. The results of the seventh and eighth crops are shown in Table 9. Azolla alone produced yields similar to those obtained with chemical fertilizer.

Comparison of azolla grown in the field. Desirable azolla strains for future field propagation should have a higher multiplying capacity, less seasonal variability in growth, and higher biomass production. To screen for those traits, 10 strains were grown in the field during WS and DS. *A. nilotica* and *A. microphylla* #421 (Galapagos) were also tried, but they only grew for 2 wk in August.

Azolla was grown in 1-m² plots in an IRRI field. Each strain had three replications. Initial inoculum was 100 g fresh azolla/m². Fresh weight was determined weekly and about 10-20 g fresh azolla was removed for dry weight and N determination. Tests were conducted from August to January in WS and from March to June in DS.

In WS, one-half of the biomass was removed when the fresh weight exceeded 1,000 g/m² except during the last 2 wk. In DS, three-fourths was removed. In WS, *Azolla pinnata* var. *pinnata* #701 had the highest biomass production and the greatest number of harvests, followed by *A. microphylla*, and *A. caroliniana* (Table 10).

In the hot DS, only *A. microphylla* #418 grew well. *A. pinnata* had biomass of ≤40 g dry weight only (Table 11). *A. microphylla* #407 and #417 died after 8 wk. All strains except *A. microphylla* #418 and *A. caroliniana* #301 peaked in biomass production in April. Good growth of the mixture inoculum came from the predominance of *A. microphylla* #418. Results from both seasons show that *A. microphylla* #418 is the most promising.

Table 8. Effect of azolla as supplementary N source for medium deepwater (maximum water depth, 50 cm) rice (IR42).[a] IRRI, 1983 cropping season.

Nitrogen rates (kg/ha)	Grain yield (t/ha)	
	No azolla	With azolla
	DS	
0	3.6 b	3.4 b
58	4.3 a	3.7 a
116	4.3 a	4.6 a
	WS	
0	1.4 b	1.6 b
29	1.5 a	2.1 a
58	2.1 a	1.9 a

[a] Av of 3 replications and 3 N sources.

Table 9. Dual culture of rice and azolla. IRRI, 1982 WS and 1983 DS.

Trials sequence	Cropping duration and rice variety	Chemical N applied (kg/ha)	Azolla incorporation		Rice grain yield (t/ha)		
			No.	N content (kg N/ha)	No N	Chemical N	Azolla
7th	Sep-Dec 1982, IR56	60	5	57	3.6	5.0	4.5
8th	Jan-Apr 1983, IR56	100	5	83	2.6	3.9	4.0

Table 10. Azolla grown in WS, Aug 1982-Jan 1983 (20 wk).[a]

Azolla species	Acc. no.	Accumulated biomass			Harvests (av no.)
		Fresh weight (kg/m²)	Dry weight (g/m²)	N (g/m²)	
A. pinnata	5	3.67	178	6.3	5.3
A. pinnata	32	1.04	65	2.3	1.0
A. pinnata	40	0.81	48	1.5	0.3
A. pinnata	49	1.48	81	2.9	2.0
A. pinnata var. *pinnata*	701	5.90	331	10.7	9.3
A. caroliniana	301	3.60	196	6.9	4.7
A. caroliniana[b]	302	3.43	189	7.2	4.7
A. microphylla	407	3.74	218	7.0	5.7
A. microphylla[b]	417	4.16	228	7.6	5.7
A. microphylla[b]	418	3.97	227	8.6	5.3

[a]In the last 2 wk, 3/4 of biomass was removed when it was greater than 1 kg/m². [b]Species identification is tentative.

Response of azolla species to various temperatures. Five azolla strains (*A. pinnata* #2, Malaysia; *A. pinnata* var. *pinnata* #701, Australia; *A. caroliniana* #301; *A. microphylla* #417, Paraguay; *A. microphylla* #421, Galapagos) were inoculated (60 g fresh weight/m²) in a tray containing an N-free mineral medium. Plants were kept in growth cabinets with controlled temperature and light. Four conditions of day/night temperature — 23°/15° C, 26°/19° C, 33°/25° C, and 37°/29° C — were compared. Length of day and night was 12 h. Light intensity was 30 klx at the surface of the azolla plant. Fresh weight was measured and culture solution renewed at alternating 6- and 8-d intervals. Growth was continued until azolla reached its maximum value or showed senescence. Then it was harvested and subjected to chemical analyses.

Relative growth rate (g/g) was maximum in the first week except for that of #421 during the second week. The value was highest at 26°/18° C and 35°/25° C in all strains. At all temperature levels *Azolla microphylla* #417 showed highest relative growth rate (Table 12).

The maximum biomass and average N_2-fixing rate decreased at temperatures higher than 26°/18° C for all strains. Strains #421 and 301 were less tolerant of higher temperatures than strains #2, 701, and 417.

Relative growth rate, average N_2-fixing rate, N%, and field growth data show *Azolla pinnata* var. *pinnata* #701 and *A. microphylla* #417 as promising.

Survival of azolla at 40° C or higher temperature. Azolla fronds were treated at 40°, 44°, 48°, and 52° C for 0.5, 1 and 2 h. Two-hour exposure at 40° C retarded growth. After 2 h exposure at 44° C, plants of *A. pinnata* #5, *A. microphylla* #417 and 418, and *A. pinnata* var. *pinnata* #701 and 704 survived. After 30-min exposure at 48° C, ≤30% of these strains survived, but could not multiply any more.

Contribution of N_2 fixation to N nutrition of azolla grown in soil. In the field, azolla may partly depend on soil N. To assess the contribution of N_2 fixation to azolla's N nutrition, the ^{15}N dilution technique was applied. *Lemna minor* L. was used as a non-N_2-fixing aquatic plant. Because of N fixation, ^{15}N content in azolla must be lower than that in non-N_2-fixing *Lemna*.

Table 11. Azolla growth in DS, Mar-Jun 1983.

Azolla species	Acc. no.	Accumulated biomass			Harvests (no.)	Duration of growth (wk)
		Fresh weight (g/m²)	Dry weight (g/m²)	N (g/m²)		
A. pinnata	5	386	24	0.68	0	13
A. pinnata	32	442	30	0.86	0	12
A. pinnata	40	309	19	0.58	0	14
A. pinnata	49	369	24	0.74	0	12
A. pinnata var. *pinnata*	701	1042	40	1.11	0.3	12
A. caroliniana	301	1048	94	3.12	1	12
A. caroliniana	302	883	53	1.91	0.3	13
A. microphylla	407	333	17	0.63	0	8
A. microphylla	417	480	8	0.88	0	8
A. microphylla	418	3192	167	6.30	3	13
Mixture[a]	5, 301, 418	2211	105	3.60	1.7	10

[a]Initial inoculation was made 1 mo later.

Table 12. Maximum biomass, average N_2-fixing rate, and N content of harvest of azolla grown in controlled conditions. IRRI, 1983.

Temperature (°C)	Trait	*A. pinnata* 2	*A. pinnata* 701	*A. caroliniana* 301	*A. microphylla* 417	*A. microphylla* 421
23°/15°	Maximum biomass (g N/m²)	15.8	15.3	27.3	22.3	20.0
	Duration (d)	56	56	62	56	62
	Av N_2 fixation (g N/m² daily)	0.283	0.274	0.441	0.399	0.323
	% N (dry basis)	5.26	4.97	5.97	7.29	4.86
26°/18°	Maximum biomass (g N/m²)	16.9	18.3	22.6	19.9	16.4
	Duration (d)	48	56	56	48	48
	Av N_2 fixation (g N/m² daily)	0.352	0.327	0.404	0.414	0.341
	% N (dry basis)	5.45	4.94	6.08	7.37	5.31
33°/25°	Maximum biomass (g N/m²)	11.4	10.9	8.8	9.7	7.1
	Duration (d)	48	48	42	34	48
	Av N_2 fixation (g N/m² daily)	0.237	0.228	0.209	0.285	0.149
	% N (dry basis)	4.97	4.64	5.25	7.23	4.23
37°/29°	Maximum biomass (g N/m²)	4.7	10.7	3.33	7.2	2.4
	Duration (d)	28	34	28	28	28
	Av N_2 fixation (g N/m² daily)	0.169	0.135	0.119	0.258	0.087
	% N (dry basis)	4.07	3.64	3.32	5.98	2.90

Percent of N derived from N_2 fixation ($NdfN_2$) is calculated as follows:

$$\% \ NdfN_2 = \left(1 - \frac{^{15}N \text{ atom \% excess in azolla}}{^{15}N \text{ atom \% excess in } Lemna}\right) \times 100$$

^{15}N-labeled AS (1.48 g N/m²) was applied to soil in a 1-m² concrete pot and mixed well with soil. *Lemna* and *Azolla pinnata* were inoculated. After 15 d, *Azolla* and *Lemna* were harvested. $NdfN_2$ in azolla was 35%. To remove mineral N, rice plants were transplanted, and *Azolla* and *Lemna* were inoculated again. $NdfN_2$ in azolla was 86% after 28 d with both *Azolla* and *Lemna* growing well. After rice harvest, the two grew for 24 d, but *Lemna* growth was poor probably because of lack of available N. $NdfN_2$ in azolla was 75% or more.

Decomposition of azolla in flooded condition. Fresh and dried azolla were inoculated in soil (about 500 μg azolla N/g soil), flooded, and incubated. Ammonium was determined weekly for 10 wk at 30°C. Rapid ammonification from fresh azolla took place in the first and second weeks, followed by gradual ammonia formation. Ammonification from dried azolla showed 1- or 2-wk lag.

Maximum amount of mineralized N from fresh azolla was 40 to 43% of total N in azolla except for *A. microphylla* #417 which released 60% of azolla N as ammonium. This strain had the highest N content (6.3%). Accumulated N of *A. filiculoides* (N = 4.3%) was most resistant to mineralization.

AZOLLA INSECT PESTS

Entomology Department

About 30 species of insects have been recorded as pests of azolla. *Chironomus kiiensis* Tokunaga (Diptera, Chironomidae) and *Rhopalosiphum nymphaeae* (L.) (Homoptera, Aphididae) were identified. A webworm (Lepidoptera, Pyralidae), probably a new species, was found.

The caseworm *Nymphula enixalis* (Swinhoe) and the webworm have been found in Luzon, Leyte, and Mindanao (South Cotabato) in the Philippines (Fig. 8).

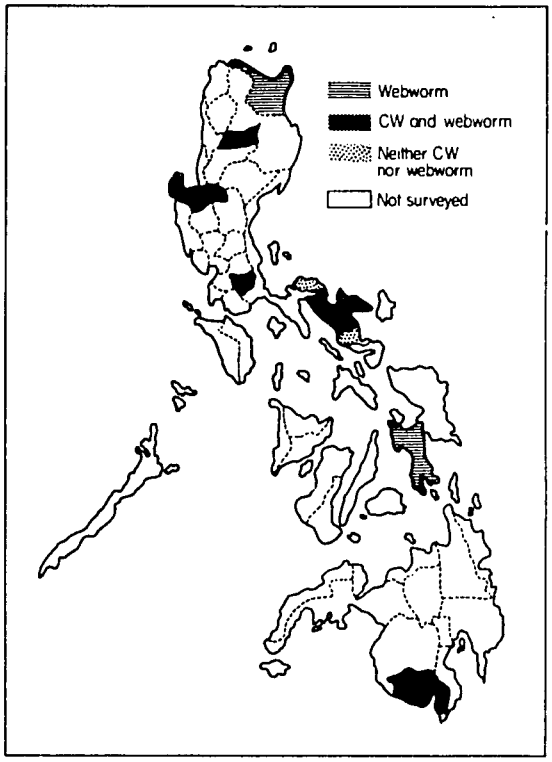
The fully grown larva of the webworm is about 8-12 mm long with a light brown body and dark head. During the 15-d larval stage, larvae make tunnels of azolla fronds bound together. The tunnel appears as a white line, especially when azolla changes from green to brown from heavy infestation. The larval stage lasts about 15 d.

A preliminary experiment showed that carbofuran 3G and monocrotophos 30EC are effective when applied to azolla inoculum.

CURRENT STATUS OF AZOLLA CULTIVATION IN SOUTH COTABATO AND LEYTE, PHILIPPINES

Soil Microbiology Department

To test for adaptability, four species/strains of azolla were introduced to South Cotabato in addition to the existing *A. pinnata* Bangkok strain.



8. Distribution of CW and webworm on azolla in the Philippines, 1983.

They were *A. caroliniana* 301, *A. pinnata* var. *pinnata* Australia, *A. microphylla* 407, and *A. microphylla* 417.

Of these, only *A. pinnata* Bangkok strain and *A. microphylla* survived the long drought.

In South Cotabato, where the drought lasted for 8 mo and where farmers had previously used azolla, most rice fields were planted to upland crops, causing azolla to disappear.

By late 1983, however, azolla had returned to the irrigated rice areas of the Koronadal Valley, mostly as *A. pinnata* and *A. microphylla*. Although not covering as extensive an area, azolla was clearly spreading again through irrigation water and manual distribution, and farmers were again using it as an organic manure. The Ministry of Agriculture encouraged farmers to make at least 5 azolla multiplication ponds of 400-500 m^2 area in each village for easy distribution to farmers' fields.

Because of strong positive results from the nationwide azolla adaptability tests, Leyte was identified for more intensive study during 1983. A native strain of azolla was found growing freely in parts of Leyte; however, active use of azolla by farmers is limited.

Presently, azolla cultivation remains confined to maintenance nurseries of the Ministry of Agriculture Research Stations. These nurseries are small and few and require very intensive and careful management. From them, interested farmers can obtain propagation materials and information from technicians.

Insect pests of azolla are found in South Cotabato and Leyte, but their impact is not serious.

The monitoring of azolla adaptation and use by Filipino farmers is continuing.

Soil and crop management

Management of other nutrients

Agronomy Department and IRRI-International Fertilizer Development Center (IFDC) Cooperative Experiments

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LONG-TERM FERTILITY EXPERIMENTS

Agronomy Department

IRRI. The 38th (DS) and 39th (WS) consecutive crops were grown in long-term fertility experiments using IR8, IR36, and IR42. In DS, all test varieties had highly significant yield increases with 140 kg added N/ha. Yields from plots with N fertilizer alone were comparable with those in plots receiving N combined with P or K or both (Table 1). Plots receiving either P or K alone had yields comparable to those in control plots. In complete fertilizer treatments (NPK), where part of the N came from compost, yield was statistically comparable with those where N came only from inorganic sources.

During WS, RTV damaged IR8. There were minimal yield increases from 60 kg added N/ha, alone or combined with P or K. P- or K-treated plots consistently had yields comparable to those of the control plots (Table 1).

BPI stations. During DS, NPK substantially increased yields of all test varieties in Maligaya and Bicol. When combined with N and P, K which was increased to 90 kg K_2O/ha and applied in split doses did not increase yields further. N combined with P gave better yields than N alone or combined with K (Table 2). The Visayas trial was discontinued because of drought.

During WS in Maligaya, yields of all three varieties with an N and P combination were comparable to those with NPK (Table 3). Although the N and K combination increased yield, the yield was lower than that with N alone. Yield trend in Bicol, except for IR8 which had some RTV infection, was similar to that in Maligaya.

Farmers' fields. The 14th and 15th crops in Luisiana, Laguna, and the 12th and 13th in Tanay, Rizal, continued in 1983.

IR36 yields from a single application of N, P, or K on both Luisiana and Tanay soils were no better than the control (Table 4, 5). In both seasons, however, IR42 showed a significant P response on Luisiana soil and a significant N response on Tanay soil (pH 7.1).

Table 1. Effect of NPK fertilizers on grain yields of IR8, IR36, and IR42 in the 38th (DS) and 39th (WS) consecutive crops. IRRI, 1983.

Fertilizer (kg/ha)			Yield (t/ha)		
N[a]	P_2O_5	K_2O	IR8	IR36	IR42
			DS		
0	0	0	4.2 c	4.3 b	3.8 c
140	0	0	7.4 ab	7.3 a	6.5 b
0	30	0	4.5 c	4.4 b	3.9 c
0	0	30	4.3 c	4.3 b	4.3 c
140	30	0	7.1 ab	7.1 a	6.9 ab
140	0	30	6.9 b	6.9 a	6.7 ab
140	30	30	7.8 a	7.0 a	7.0 ab
140[b]	30	30	7.1 ab	6.9 a	7.4 a
			WS		
0	0	0	–	3.2 c	2.4 c
60	0	0	–	4.0 abc	3.5 ab
0	30	0	–	3.5 abc	3.0 bc
0	0	30	–	3.3 bc	2.4 c
60	30	0	–	4.5 a	4.2 a
60	0	30	–	3.9 abc	3.3 abc
60	30	30	–	4.4 ab	3.9 ab
60[b]	30	30	–	4.2 abc	3.9 ab

[a]All N treatments except the control include 40 kg N/ha topdressed 5-7 DBPI during DS and 20 kg N/ha topdressed 5-7 DBPI during WS. [b]24 kg N/ha coming from compost.

Table 2. Effect of NPK fertilizers on yields of IR8, IR36, and IR42 in the 31st crop (DS) in the long-term fertility trials at Maligaya Rice Research and Training Center and Bicol Experiment Station, Philippines. 1983 DS.

Fertilizer (kg/ha)			Yield (t/ha)					
			Maligaya			Bicol		
N[a]	P_2O_5	K_2O	IR8	IR36	IR42	IR8	IR6	IR42
0	0	0	3.8 bcd	3.3 d	4.4 bcd	2.5 f	2.6 f	2.6 f
140	0	0	4.7 bcd	3.9 bcd	4.4 bcd	2.7 f	2.9 f	3.3 ef
140	60	0	7.0 a	5.4 b	4.8 bcd	4.3 cdef	6.7 ab	5.9 abcd
140	0	60	5.4 b	4.3 bcd	4.5 bcd	2.7 f	4.1 def	4.5 cdef
140	60	60	8.1 a	7.9 a	8.0 a	5.1 bcde	7.1 a	6.8 ab
140	60	60 + 30	8.1 a	8.1 a	7.8 a	5.4 abcd	6.6 ab	6.1 abc

[a]All N treatments except the control include 40 kg N/ha topdressed 5-7 DBPI.

Table 3. Effect of NPK fertilizers on IR8, IR36, and IR42 yields in the 32nd crop (WS) in the long term fertility trials at Maligaya Rice Research and Training Center and Bicol Experiment Station and in the 16th crop (WS) at Visayas Experiment Station, Philippines, 1983.

Fertilizer (kg/ha)			Yield (t/ha)								
			Maligaya			Bicol			Visayas		
N[a]	P_2O_5	K_2O	IR8	IR36	IR42	IR8	IR36	IR42	IR8	IR36	IR42
0	0	0	1.9 i	2.7 g--i	2.3 hi	1.6 h	3.8 de	2.1 gh	2.8 cd	2.3 d	2.8 cd
70	0	0	3.0 f--h	3.4 d--g	3.4 d--g	2.8 fg	4.4 b--d	2.9 fg	3.8 bc	3.1 cd	3.3 cd
70	60	0	3.8 d--f	5.6 a	4.7 a--c	4.0 de	4.6 b--d	5.1 ab	5.2 a	4.9 a	4.5 ab
70	0	60	2.6 g--i	3.2 c--h	2.9 e--h	4.2 cd	4.4 b--d	3.3 ef	3.5 c	3.0 cd	3.0 cd
70	60	60	4.2 b--d	4.8 a--c	5.6 a	4.9 a--c	5.1 ab	5.6 a	5.5 a	5.0 a	4.5 ab
70	60	60 + 30	4.0 c--e	5.0 ab	5.3 a	4.1 c--e	5.5 a	5.6 a	5.2 a	4.8 a	4.8 a

[a]All N treatments except the control include 20 kg N/ha topdressed 5-7 DBPI.

Table 4. Effects of NPK on yield of IR36 and IR42 in the 14th (DS) and the 15th (WS) consecutive crops, on Luisiana silty clay. Luisiana, Laguna, Philippines, 1983.

Fertilizer treatment[a]	Yield (t/ha)			
	DS		WS	
	IR36	IR42	IR36	IR42
Control	3.0 cd	2.8 d	2.9 bc	2.4 c
N	3.2 cd	2.8 d	2.5 cd	2.7 bc
P	2.9 d	3.7 c	2.4 d	3.0 b
K	2.8 d	2.8 d	2.4 d	2.5 c
NP	4.0 b	4.8 b	3.5 a	2.7 bc
PK	3.3 c	3.6 c	2.5 cd	2.4 c
NK	3.3 c	3.7 c	3.0 b	2.3 c
NPK	5.0 a	6.0 a	3.7 a	3.8 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 = 6.9% for DS and 9.9% for WS.

Table 5. Effects of NPK on yield of IR36 and IR42 in the 12th (DS) and the 13th (WS) consecutive crops on Bay clay. Tanay, Rizal, Philippines, 1983.

Fertilizer treatment[a]	Yield (t/ha)			
	DS		WS	
	IR36	IR42	IR36	IR42
Control	3.6 cde	3.6 b	2.6 bc	2.3 d
N	3.9 bcd	4.9 a	2.7 bc	3.2 bc
P	3.3 de	3.3 b	3.2 b	3.1 bc
K	3.0 e	3.4 b	2.5 b	2.4 d
NP	4.3 ab	4.6 a	3.2 b	4.2 a
PK	3.2 de	3.7 b	2.5 c	2.9 cd
NK	4.3 ab	4.7 a	2.8 bc	3.0 bc
NPK	4.5 a	4.9 a	3.9 a	3.6 ab

[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 = 9.9% for DS and 13.7% for WS.

Combined applications of NPK brought a significant response in Luisiana soil in DS. In WS, response was more consistent with IR36 in Tanay.

Continuous croppings increase the need for higher rates of NPK.

PHOSPHORUS AND NITROGEN-PHOSPHORUS FERTILIZER SOURCES

Agronomy Department

Experiments in farmers' fields in 1983 evaluated direct and residual effects of P and NP fertilizers in lowland rice. DS trials to study direct effects were installed in three sites: Pili, Camarines Sur; Gen. Natividad, Nueva Ecija; and Famy, Laguna. In WS, only Pili and Famy were used to study residual effects because a water problem existed.

Table 6 shows the characteristics of soils before trials began.

At Pili, all P sources at all rates of fresh application increased yields significantly over the control (Table 7). The same trend occurred with NP fertilizer sources at Famy (Table 8). At Pili, a response of 3 t/ha was obtained with single superphosphate (SSP) and PAPR-30 (partially acidulated phosphate rock, 30% acidulation) at 80 kg P/ha (Table 7). At Gen. Natividad, however, 40 and 80 kg P/ha as SSP increased yield by 1.5 t/ha. The same response was obtained with urea + triple

Table 6. Characteristics of soils for P and NP sources trials in Pili, Camarines Sur; Gen. Natividad, Nueva Ecija; and Famy, Laguna, Philippines, 1983.

Soil property	Pili, Camarines Sur	Gen. Natividad, Nueva Ecija	Famy, Laguna
pH (1:1)	5.0	5.3	4.8
Total N (%)	0.190	0.050	0.163
Exchangeable K (meq/100 g)	0.04	0.05	0.14
Total P (ppm)	188	69	650
Available P (ppm)			
Bray 2	6	4	11
Olsen	1.6	1.8	7.4
CEC (meq/100 g)	22	6	25
Exchangeable Ca (meq/100 g)	7.6	2.4	9
Exchangeable Zn (ppm)	0.4	0.6	3.5
Particle size (%)			
Sand	15	52	12
Silt	41	35	48
Clay	44	13	40
Texture	Silty clay	Loam	Silty clay

Table 7. Yield of IR36 with different P fertilizers and residual effects on IR58. Pili, Camarines Sur, and Gen. Natividad, Nueva Ecija, Philippines, 1983.

Source[a] (kg P/ha)	Yield (t/ha)		
	Fresh applications in DS		Residual in WS
	Pili	Gen. Natividad	Pili
No P	3.6 g	5.2 d	3.7 b
SSP			
10	5.7 cde	6.0 abcd	4.1 ab
20	6.0 abcd	6.1 abcd	4.1 ab
40	6.0 abcd	6.7 a	4.5 a
80	6.6 a	6.7 a	4.3 ab
PAPR-30			
10	5.6 cde	6.1 abcd	3.9 ab
20	5.8 bcde	5.9 bcd	4.0 ab
40	6.1 abcd	6.2 abcd	4.1 ab
80	6.6 a	6.6 ab	4.2 ab
PAPR-15			
10	5.2 ef	5.6 cde	3.9 ab
20	5.3 de	5.5 de	3.9 ab
40	6.0 abcd	6.2 abcd	4.0 ab
80	6.2 abc	6.4 abc	4.2 ab
PR			
10	4.9 f	5.7 cde	3.9 ab
20	5.7 bcde	5.8 cd	4.0 ab
40	5.9 bcd	6.0 abcd	4.4 a
80	6.4 ab	6.4 abc	4.5 a
TSP			
10	–	–	4.1 ab
40	–	–	4.1 ab
80	–	–	4.2 ab

[a]SSP = single superphosphate; PAPR – 30 = partially acidulated phosphate rock, 30% acidulation; PAPR – 15 = partially acidulated phosphate rock, 15% acidulation; PR = phosphate rock; TSP = triple superphosphate.

superphosphate (TSP) at 80 kg P/ha in Famy (Table 8).

Grain yields differed significantly between rates but not between sources. In WS, the trials showed minimal residual effects. Fresh applications of TSP were as good as the control.

In addition to site selections, more croppings are needed to critically evaluate direct and residual effects of P fertilizers.

PHOSPHORUS FOR LOWLAND RICE

Agronomy Department and IRRI-International Fertilizer Development Center (IFDC) Cooperative Experiments

Source, time, and method of application for lowland rice. *IRRI-IFDC Cooperative Experiments.* Many farmers apply fertilizer P after transplanting. It is believed that P should be

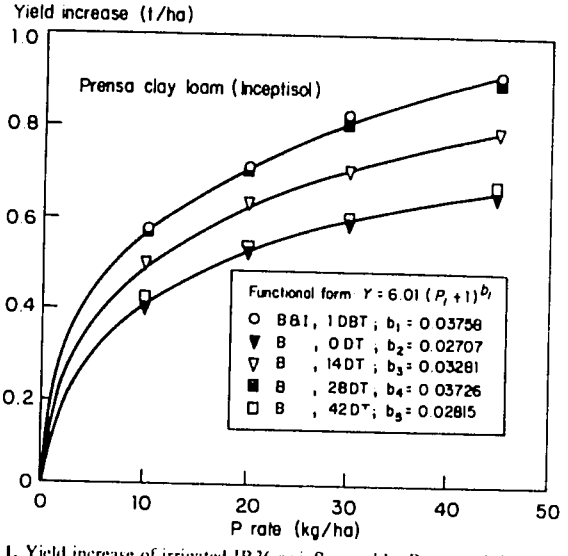
Table 8. Yield of IR58 with different sources of NP fertilizers, and the residual effects. Famy, Laguna, Philippines, 1983.

Source[a] (kg P/ha)	Yield (t/ha)	
	Fresh application 1983 DS	Residual 1983 WS
No P	4.3 de	3.6 ab
TSP + urea		
10	4.8 cd	3.5 b
20	5.5 abc	3.6 ab
40	5.3 abc	4.1 a
80	5.8 a	3.9 ab
UP		
10	5.0 bc	4.1 a
20	5.0 bc	3.8 ab
40	5.3 abc	4.0 ab
80	5.2 abc	3.6 ab
DP		
10	4.9 c	3.6 ab
20	5.2 abc	3.9 ab
40	5.2 abc	3.8 ab
80	5.7 ab	3.9 ab
TSP		
10	4.9 c	3.6 ab
20	5.3 abc	3.7 ab
40	5.2 abc	4.1 a
80	5.3 abc	3.9 ab
TSP[b]		
10	–	3.8 ab
40	–	3.9 ab
80	–	4.1 a

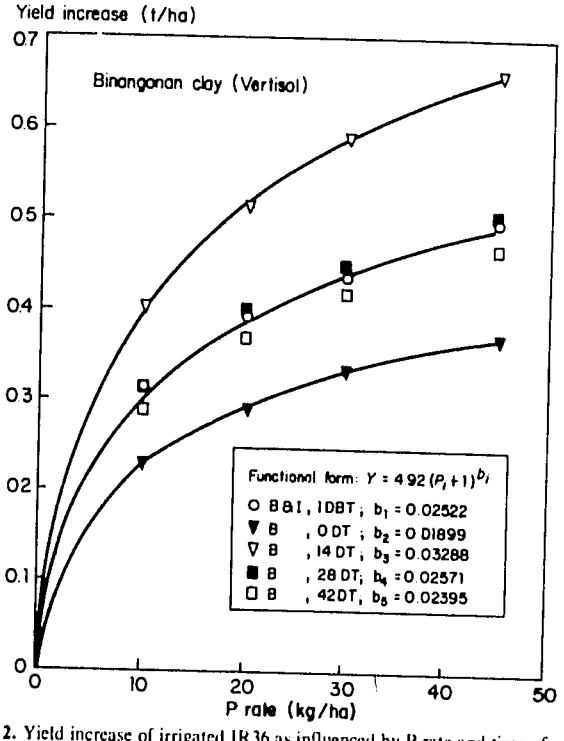
[a]TSP = triple superphosphate, UP = urea phosphate, DP = diurea phosphate. [b]TSP applied in WS.

applied before tillering to be effective, but little field data are available. The effect of time of fertilizer P application for irrigated IR36 was investigated at Llanera, Nueva Ecija (Inceptisol, pH 5.6); Teresa, Rizal (Vertisol, pH 6.8), and Pangil, Laguna (Inceptisol, pH 4.9). Application times were B&I 1 DBT, broadcast after transplanting on the same day, and 14, 28, and 42 DT. SSP was B&I 1 DBT and broadcast without incorporation at other times. P rates were 0, 5, 15, and 45 kg/ha. Maximum yield responses to P at Llanera in 1983 DS and Teresa in 1982 WS were 15% over the control. All application times had similar (P = 0.05) yield responses (Fig. 1, 2). In Teresa during 1983 DS, yield responses to residual P were similar to those to fresh applications (Fig. 3). Maximum responses were 15% over the control. Accumulated yield responses during two seasons at Teresa (Fig. 4) were similar for all times of P application. At Pangil, maximum yield responses were 31% over the control and P applied at 42 DT increased yield significantly less than at other application times (Fig. 5). During 1983 DS, responses to residual P were similar to those for fresh applications, and maximum yield response was 22% over the control (Fig. 6). The same pattern of responses to application time occurred for accumulated yield responses over two seasons (Fig. 7).

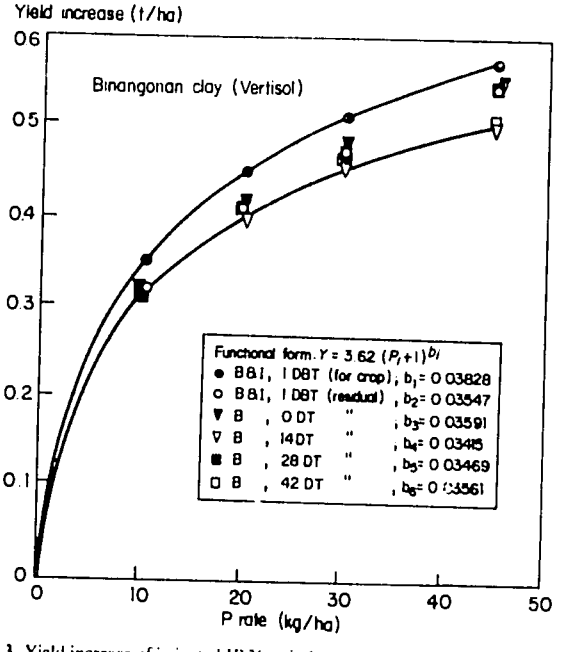
Diammonium phosphate (DP) and urea phosphate (UP) were compared with TSP at Famy, Laguna (Inceptisol, pH 4.8). Two other experi-



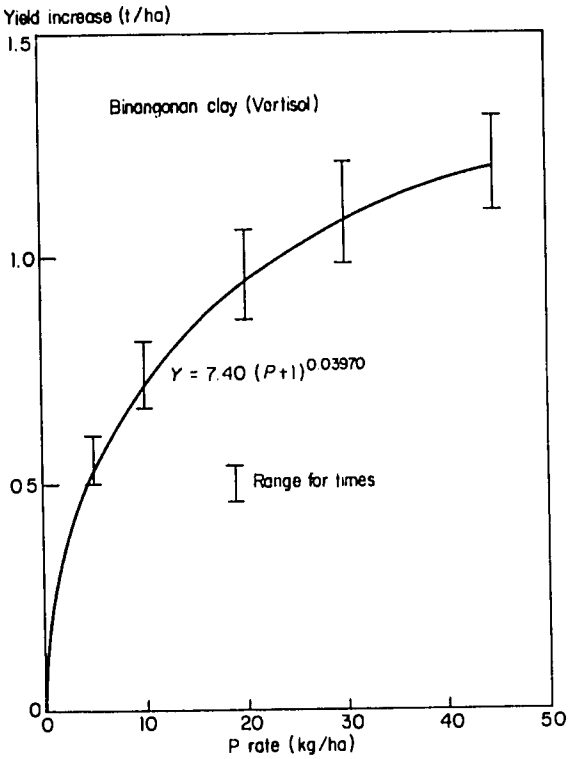
1. Yield increase of irrigated IR36 as influenced by P rate and time of application. Llanera, Nueva Ecija, Philippines, 1983 DS. B = broadcast.



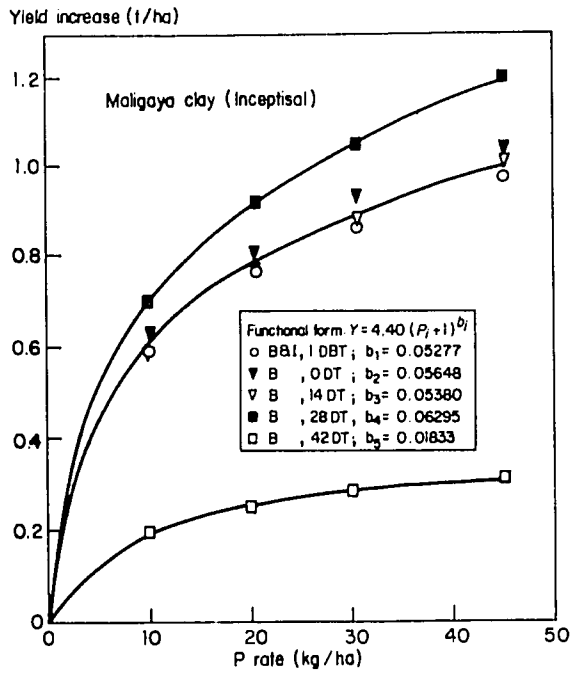
2. Yield increase of irrigated IR36 as influenced by P rate and time of application. Teresa, Rizal, Philippines, 1982 WS. B = broadcast.



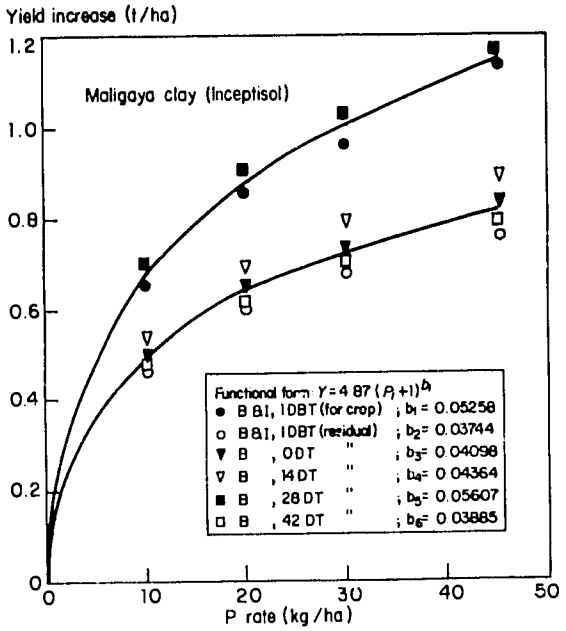
3. Yield increase of irrigated IR36 as influenced by rate of P as residual and fresh applications. Teresa, Rizal, Philippines, 1983 DS. B = broadcast.



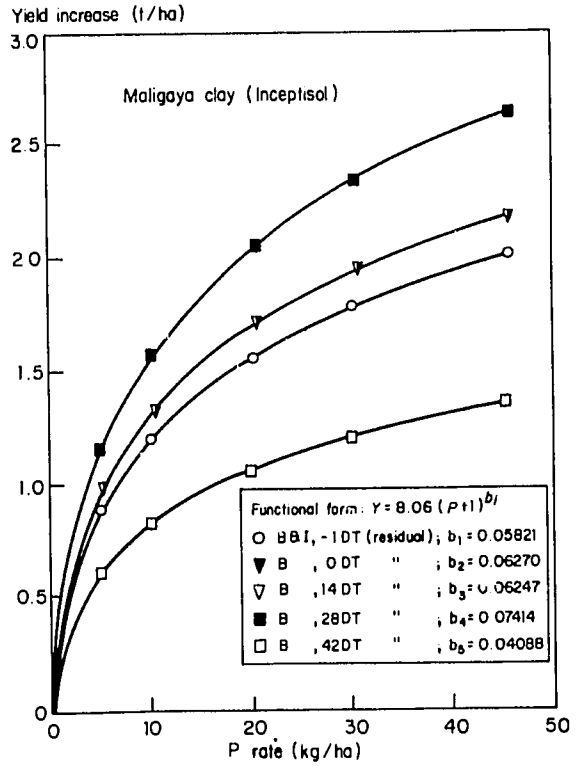
4. Range of accumulative yield increase for 2 crops of irrigated IR36 as influenced by P rates and times of application (first crop only). Teresa, Rizal, Philippines, 1982 WS and 1983 DS.



5. Yield increase of irrigated IR36 as influenced by P rate and time of application. Pangil, Laguna, Philippines, 1982 WS. B = broadcast.



6. Yield increase of irrigated IR36 as influenced by rate of P as residual and fresh applications. Pangil, Laguna, Philippines, 1983 DS. B = broadcast.

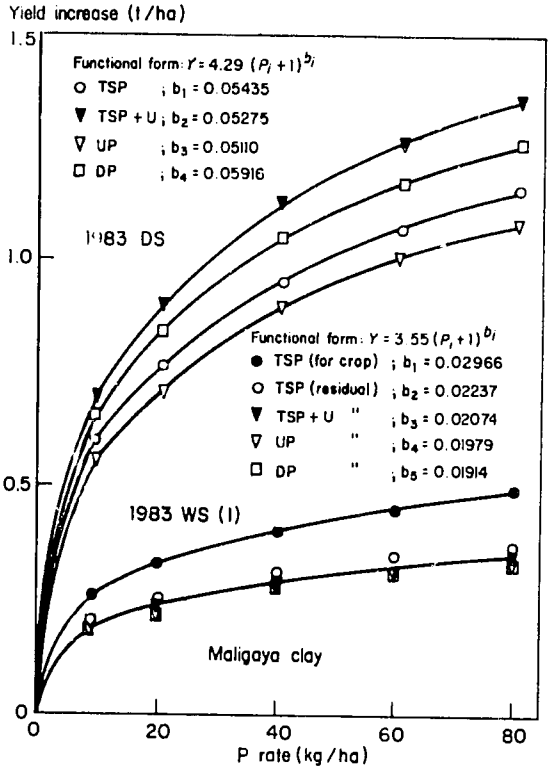


7. Accumulative yield increase of 2 crops of irrigated IR36 as influenced by P rates and times of application (first crop only). Pangil, Laguna, Philippines, 1982 WS and 1983 DS. B = broadcast.

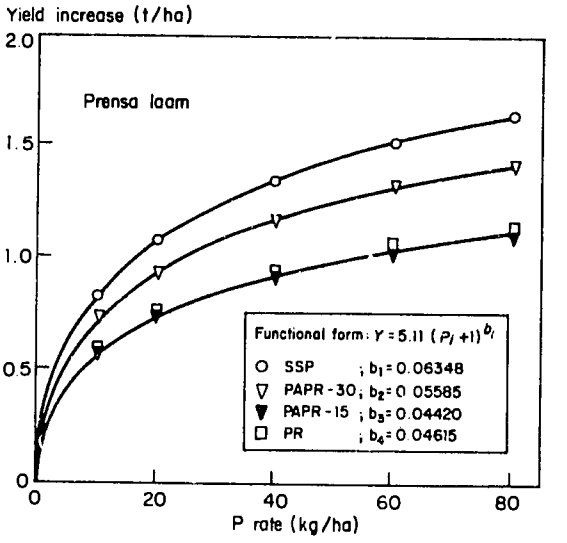
ments that were established were lost because of lack of irrigation water. P sources were B&I at rates of 0, 10, 20, 40, and 80 kg P/ha.

In 1983 DS, maximum yield response was 30% over the control and sources had similar yield responses (Fig. 8). With maximum yield response of 14% over the control during 1983 WS, residual P and fresh applications had similar yields.

Phosphate rock (PR) and partially acidulated PR (PAPR) are potentially lower cost sources of fertilizer P than soluble sources. PR and two levels of partial acidulation (15% sulfuric acid required to produce SSP — PAPR-15 and 30% to produce PAPR-30) were compared with SSP in experiment at Gen. Natividad, Nueva Ecija (Inceptisol, pH 5.3), and Pili, Camarines Sur (Vertisol, pH 5.0). Sources were B&I at rates of 1, 10, 20, 40, and 80 kg P/ha. Maximum yield responses were 28% over the control at Gen. Natividad and 82% at Pili. SSP and PAPR-30 had similar yields and were superior



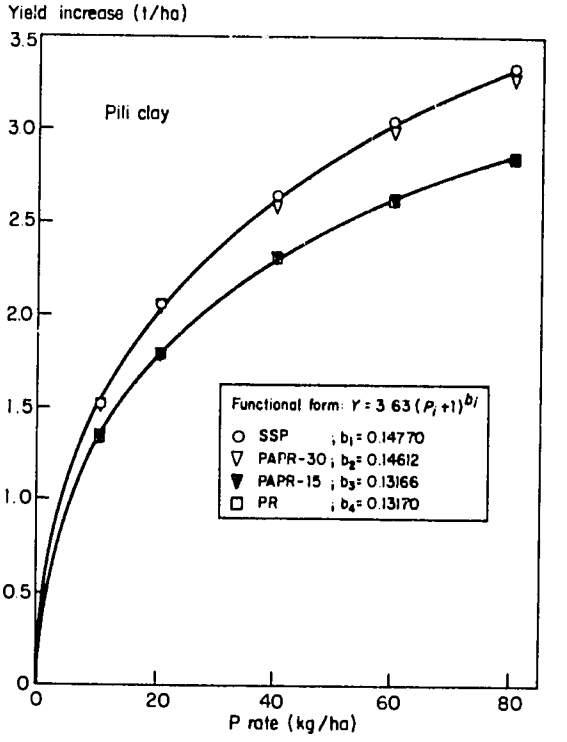
8. Yield increase of irrigated IR36 as influenced by P rate and source (1983 DS) and by rate, residual, and fresh applications (1983 WS) at Famy, Laguna, Philippines. For TSP, a basal 56 kg N/ha was DPP and 72 kg N/ha was broadcast 5-7 DBPI. TSP + UP means that urea was B&I at N rates equivalent to those of DP and UP (N:P = 0.9:1.0). In addition, 56 kg N/ha was broadcast 5-7 DBPI for TSP + U, DP, and UP.



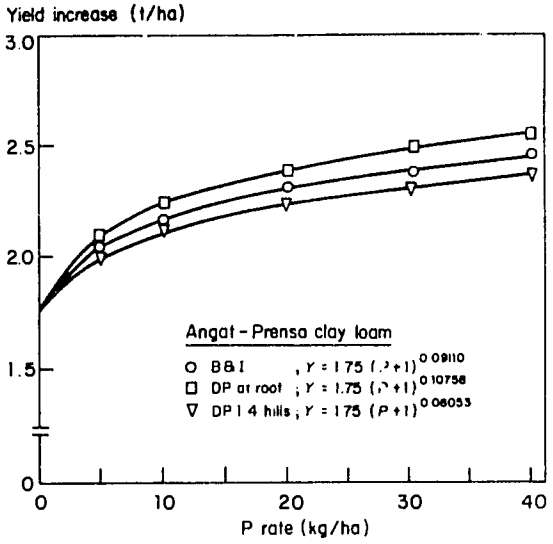
9. Yield increase of irrigated IR36 as influenced by P rate and source. General Natividad, Nueva Ecija, Philippines, 1983 DS.

(P = 0.05) to PAPR-15 and PR on both soils (Fig. 9, 10).

Fertilizer P placement may influence response of rainfed rices, particularly if the soil surface is dry for long periods. During 1982 WS, B&I, deep-



10. Yield increase of irrigated IR36 as influenced by P rate and source. Pili, Camarines Sur, Philippines, 1983 DS.



11. Yield increase of rainfed IR36 as influenced by method of placement. Angat, Bulacan, Philippines, 1982 WS.

point placement (DPP) with seedlings, and DPP between alternate 4 hills were compared at 0, 5, 10, 20, 30, and 40 kg P/ha at Angat, Bulacan (Inceptisol, pH 6.0). Maximum yield response was 50% over the control and placement methods gave similar yield response (Fig. 11). During 1983 WS, B&I, broadcast without incorporation, and DPP with seedlings were compared at 0, 5, 15, 30, and 60 kg P/ha at Pamukid, Camarines Sur (Inceptisol, pH 5.4). Maximum yield response was 14% over the control and placement methods had similar yields.

Production was less than 30 kg grains/kg P during WS and more than 30 kg grains/kg P during DS.

P extractions of aerobic soils by Bray 2 and Olsen methods were not good indications of yield responses to fertilizer P (Fig. 12).

On moderately P-deficient soils,

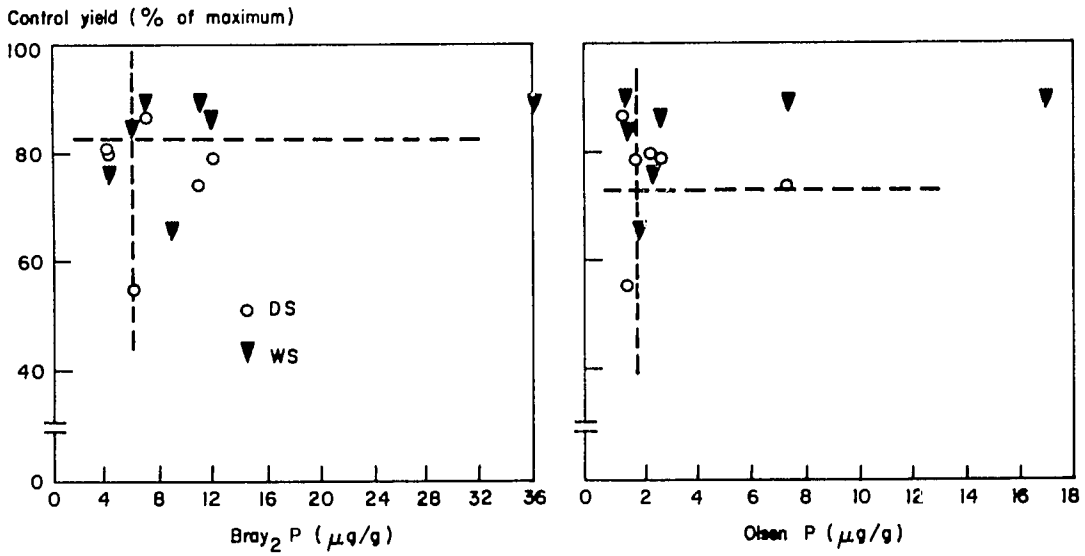
- fertilizer P may be applied to irrigated IR36 until PI stage without affecting yield response; later application has less response;
- more than 15% acidulation is needed for moderately reactive PR to be as effective as highly soluble P for irrigated IR36 rice, particularly for the immediate crop; and
- B&I, broadcast, and DPP with seedlings were similarly effective for rainfed rice.

PHOSPHORUS SOURCES FOR LOWLAND RICE

Agronomy Department

The evaluation of three P sources used in lowland rice in Teresa and in Lucban was continued in 1983 after testing the residual effects for six continuous plantings.

In DS, significant P response was observed with all sources and application rates in both soils (Table 9). Local PR and SSP had comparable yields.



12. Relationships between yield response and Bray 2 or Olsen soil P in 13 field experiments, Philippines.

In WS, calcined iron aluminum phosphate and imported PR (both highly reactive) had similar yields as the control (Table 9). SSP had higher yields than the control while local PR had yields similar to those with SSP.

DRILLING OF LIME AND PHOSPHORUS ON ACID SULFATE SOILS

Agronomy Department and Thai-IRRI Collaborative Project

Deepwater rice RD19 was drilled in rows 18 cm apart, at 125 kg seed/ha, on acid sulfate soils (pH 4.3) at Prachinburi, Thailand. Finely ground lime (100 mesh) and TSP were either drilled with the seed or broadcast after seeding (Table 10). All plots received 75 kg N/ha.

Floodwater rose 2.3 cm/d during August and reached a maximum depth of 110 cm. Despite the response to P ($p < 0.01$), yields were lower than in previous years. Lime did not significantly increase yields.

In a second experiment, three P rates were used, either drilled with seed or broadcast afterwards. All plots received 75 kg N/ha. Maximum water depth was 94 cm. Drilling, which concentrated the fertilizer near the seed, produced higher yields than broadcasting ($p < 0.01$) (Table 11).

Table 9. Yield of IR36 as affected by different P sources on Binangonan clay (Teresa, Rizal) and Luisiana silty clay (Lucban, Quezon), Philippines, 1983.

Treatment (source, kg P_2O_5/ha	Yield (t/ha)			
	Binangonan clay		Luisiana silty clay	
	DS	WS	DS	WS
No fertilizer P (control)	3.3 e	3.7 e	3.2 e	2.1 e
SSP				
20	4.3 bc	3.7 de	4.5 cd	2.9 bc
40	4.4 bc	4.2 abc	5.0 abc	3.4 ab
60	4.8 a	4.2 abcd	5.4 a	4.0 a
PR[a]				
20	4.1 d	3.7 cde	4.2 d	2.2 de
40	4.2 cd	3.9 bcde	4.4 d	2.5 cde
60	4.3 bc	4.0 abcde	4.6 bcd	2.6 cde
Guano				
40	4.2 cd	4.4 abcd	4.3 d	2.8 bcd
80	4.5 b	4.4 a	5.1 ab	3.4 ab
120	4.7 a	4.3 ab	5.4 a	3.7 a

[a]Calcined iron aluminum phosphate (highly reactive) Binangonan clay and imported PR (high reactive).

Table 10. Yields of RD19 with drilled or broadcast lime and P. Prachinburi, Thailand, 1983.

Lime (kg/ha)	Av yield (t/ha)			Mean yield (t/ha)
	No P_2O_5	40 kg P_2O_5/ha, drilled	40 kg P_2O_5/ha, broadcast	
0	0.69	1.36	1.41	1.15
300, drilled	0.93	1.39	1.25	1.19
300, broadcast	0.97	1.48	1.64	1.36
	0.86 b	1.41 a	1.43 a	1.23

SULFUR STATUS OF SOME PHILIPPINE RICE SOILS

Agronomy Department

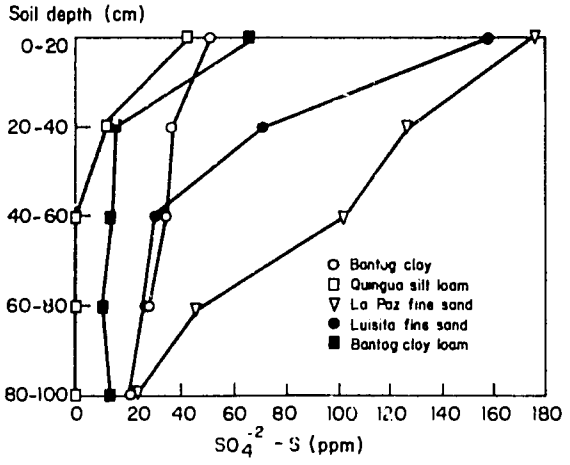
Preliminary survey. To identify potential S-deficient rice areas in the Philippines, soil samples at different depths were collected in 167 sites in 19 provinces of Luzon and 2 in the Visayas. The samples were analyzed for SO_4^{-2}-S, total S, and other soil characteristics. Preliminary results of SO_4^{-2}-S analysis showed that at least 50 sites can be considered potentially S-deficient based on the critical level of 9 ppm SO_4^{-2}-S established by Islam and Ponnamperuma (1981).

SO_4^{-2}-S content varied according to soil type and sampling depth. Values ranged from < 1 to >1,000 ppm, generally decreasing with increasing sampling depth (Fig. 13). A few sites showed increasing SO_4^{-2}-S accumulation (Fig. 14). Initial total S analysis showed a similar trend.

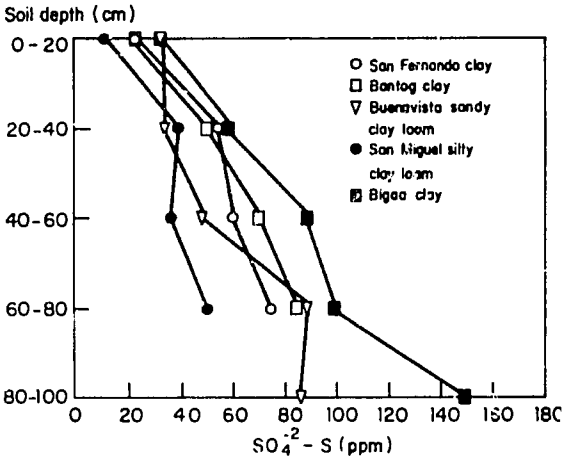
Greenhouse experiments. Six Luzon soils suspected to be S deficient were tested for S response in the greenhouse. Their chemical characteristics are presented in Table 12. Only Bankal loam in Botolan, Zambales, and San Manuel sandy loam

Table 11. Yields of RD19 with 3 rates of P drilled or broadcast. Prachinburi, Thailand, 1983.

	Av yield (t/ha)			
	24 kg P_2O_5/ha	48 kg P_2O_5/ha	72 kg P_2O_5/ha	Mean yield (t/ha)
Drilled	1.62	1.96	1.84	1.81 a
Broadcast	1.53	1.44	1.71	1.56 b
	1.58	1.70	1.78	1.56



13. Representative soil types with decreasing SO_4^{-2}-S content. 1983.



14. Representative soil types with increasing SO_4^{-2}-S content. 1983.

in Bacnotan, La Union, had significant yield responses to applied S (Table 13).

The experiment continued until the third crop to evaluate residual effects of added S. Responses to residual S were significant only in San Manuel sandy clay loam and Maahas silty clay loam (Block 421, IRRI farm). Yield increased with increased S. No significant effects were obtained with four other soils until the second residual crop (Table 14).

The influence of water management on S availability was evaluated in Bankal loam where yield of the first residual crop was practically zero. Allowing the soil to dry before subjecting it to prolonged submergence produced beneficial effects. Irrespective of the amount of added S, yield increases were extremely high, significantly higher than in the three other soils which were continuously submerged.

Table 12. Chemical characteristics of soils studied in the greenhouse. IRRI, 1983.

Site	Soil type	pH (1:1)	Organic C (%)	Total N (%)	CEC (meq/100 g)	Available Zn (ppm)	Available S (ppm)
Muñoz, Nueva Ecija	Maligaya silty clay	6.1	1.10	0.138	26.9	0.5	36
Candelaria, Zambales	Quingua clay loam	6.6	1.37	0.148	38.4	nil	25
Talavera, Nueva Ecija	Quingua loam	6.7	1.16	0.119	20.3	0.5	10
Botolan, Zambales	Bankal loam	6.8	0.72	0.080	14.5	0.3	5
Bacnotan, La Union	San Manuel sandy loam	6.1	0.50	0.050	13.6	0.8	7
Block 421, IRRI farm	Maahas silty clay loam	6.2	1.40	0.120	32.6	0.4	40

Table 13. Response to applied S of 2 rice varieties in 6 Luzon soils. IRRI, 1983.

Site	SO_4^{-2}-S (ppm)	Yield[a] (g/pot)		
		No S	20 kg S/ha	40 kg S/ha
Botolan, Zambales[b]	5	7.4 f	53.2 e	54.9 de
Candelaria, Zambales[b]	25	63.2 bcd	53.9 de	56.0 cde
Muñoz, Nueva Ecija[b]	36	76.3 a	67.3 ab	70.7 ab
Talavera, Nueva Ecija[b]	10	64.9 bc	69.2 ab	67.4 ab
Bacnotan, La Union[c]	7	15.2 d	60.4 a	52.5 bc
Block 421, IRRI farm[c]	40	59.3 a	56.0 ab	48.4 c

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. [b]BG 400-1 was test variety. [c]IR50 was test variety.

Table 14. Effect of residual S on rice yield. IRRI, 1983.

Site	Yield[a] (g/pot)					
	No S		20 kg S/ha		40 kg S/ha	
	Crop 1	Crop 2	Crop 1	Crop 2	Crop 1	Crop 2
Botolan, Zambales	0.0 d	86.6 a	0.0 d	76.5 a	0.1 d	84.6 a
Candelaria, Zambales	61.6 abc	38.3 bc	66.6 ab	49.3 b	56.2 c	48.1 b
Muñoz, Nueva Ecija	62.0 abc	45.8 bc	60.1 abc	51.4 b	59.3 ab	48.3 b
Talavera, Nueva Ecija	60.6 abc	29.5 c	70.1 a	40.2 bc	69.4 ab	52.4 b
Bacnotan, La Union	16.2 e		58.2 cd		77.9 ab	
Block 421, IRRI farm	41.9 d		68.4 bc		92.3 a	

[a]Separation of means in a row by Duncan's multiple range test at the 5% level.

In another experiment on an S-deficient Bankal loam where S response was highest, 11 varieties and lines of rice were tested for tolerance to S deficiency. By appearance and magnitude of S response, no varieties were tolerant of low S (Table 15).

Table 15. Response of 11 varieties and lines of rice tested in S-deficient Bankal loam. Botolan, Zambales, Philippines, 1983.

Variety	Grain yield (g/pot)		% yield increase
	With S	Without S	
IR8	54.2 a	3.1 g	1648
IR32	44.5 cde	4.7 g	847
IR36	42.5 def	5.2 g	717
IR42	48.1 abcd	3.8 g	1166
IR50	51.4 ab	4.0 g	1185
IR52	47.1 bcd	1.2 g	3825
IR54	47.4 bcd	3.4 g	1294
IR56	38.1 f	0.9 g	3720
IR9752-71-3-2	39.4 ef	3.3 g	1094
IR21820-154-3-2-2-3	52.0 ab	4.8 g	983
C4-137	48.8 abc	2.1 g	2224

Field experiments. During 1983 DS, a trial determined the response of IR50 to applied Zn in two forms and to S in two farmers' fields in Aguilar, Pangasinan. Physical and chemical characteristics of the test sites are given in Table 16.

In site 1, NPK alone brought a significant yield increase of 2.28 t/ha (Table 17). Added Zn (ZnO) improved yield significantly over NPK, but not when $ZnSO_4$ was used. There was practically no response to S (NPK + Zn + S vs NPK + Zn).

In site 2, NPK alone brought a marked decline in yield. Addition of 40 kg S/ha reduced it even more. When Zn instead of S was applied with NPK, grain yield significantly increased. ZnO increased yield by 2.35 t/ha, and $ZnSO_4$ at 4 kg Zn/ha increased yield by 1.70 t/ha (Table 17).

Zn is a limiting factor and root dip in a 4% ZnO solution is a better source of Zn than broadcast $ZnSO_4$.

Management of sulfur fertilizer for rice. IRRI Agronomy Department collaborated with Don Mariano Marcos Memorial State University to

Table 16. Physical and chemical characteristics of soils in 2 farmers' fields. Sitio Tambogan, Aguilar, Pangasinan, Philippines, 1983 DS.

Depth of sample (cm)	pH (1:1)	Organic C (%)	Total N (%)	CEC (meq/100 g)	Available Zn (ppm)	Available S (ppm)	Soil texture
				Site 1			
0-20	6.3	0.52	0.095	13.6	0.8	14	Sandy loam
20-40	6.6	0.15	0.024	12.1	0.5	18	Loamy sand
40-60	6.6	0.16	0.021	20.9	0.2	6	Sandy loam
				Site 2			
0-20	6.3	0.55	0.058	14.2	0.7	15	Sandy loam
20-40	6.5	0.19	0.026	11.7	0.6	12	Loamy sand
40-60	6.6	0.17	0.021	15.5	0.5	8	Sandy loam

Table 17. Response of IR50 to added Zn and S. Aguilar, Pangasinan, Philippines, 1983 DS.

Treatment[a]	Yield (t/ha)	
	Site 1	Site 2
Unfertilized control	1.89 d	2.67 b
NPK only	4.17 bc	1.54 c
NPK + S (40 kg/ha)	4.07 c	0.18 d
NPK + ZnO[b]	5.01 a	5.02 a
NPK + ZnO[b] + S (20 kg/ha)	4.78 ab	5.10 a
NPK + ZnO[b] + S (40 kg/ha)	5.09 a	4.65 a
NPK + $ZnSO_4$[c] (4 kg Zn/ha)	4.79 ab	4.37 a
NPK + $ZnSO_4$[c] + (20 kg/ha)	4.63 abc	4.62 a
NPK + $ZnSO_4$[c] + S (40 kg/ha)	4.86 a	4.94 a
CV (%)	9.20	17.40

[a]S is in the form of ammonium sulfate. [b]Root dip in 4% ZnO solution. [c]Broadcast and incorporated.

Table 19. Management of S fertilizer for irrigated rice. Bacnotan, La Union, Philippines, 1983 DS.

S source	S rate (kg/ha)	Yield (t/ha)
Unfertilized control	–	4.48 b
AS	20	6.00 ab
AS	40	5.78 ab
S	20	5.64 ab
S	40	5.50 ab
$CaSO_4$	20	5.72 ab
$CaSO_4$	40	4.60 ab
SCU	20	5.25 ab
SCU	40	6.83 a
CV (%)		20.70

conduct trials on an apparently S-deficient field in Bacnotan, La Union, to test S response in the field. The physical and chemical characteristics of the soil before planting are given in Table 18.

Of the 4 S fertilizers tested during DS, only SCU at the highest rate yielded significantly higher (an increase of 2.35 t/ha) than the control (Table 19). No significant differences were found among S sources and rates.

During WS, additional field tests were done in Botolan (Zambales) and Aguilar (Pangasinan). Soil chemical and physical characteristics are in Table 20. The two sites showed no significant response to S (Table 21). In Bacnotan, yield could be increased significantly to as high as 1.70 t/ha with NPK fertilizers alone. Different forms and amounts of added S made no differences.

The nonresponse to S could be caused by

- prolonged nonsubmergence period during DS, which might have enhanced mineralization of native S (especially in La Union);
- intermittent wetting and drying during WS, because of erratic and inadequate rainfall; and
- appreciably high concentrations of sulfate S in the irrigation water during DS.

Long-term fertility experiment for irrigated rice. The long-term IRRI experiment to evaluate effects of continuous application of high analysis fertilizers (urea and TSP) to irrigated rice was continued during the 1983 DS and WS (second and third crop).

During the second crop, N alone or combined with P or K, or P and K, and S produced significant yield increases over the control (Table 22). P and K did not appear to be limiting when applied singly or even when combined. Zn, shown deficient in soil analysis, did not increase yields significantly. Although not significant, added S (40 kg AS/ha) increased yield 0.83 t/ha over NPK only. Supplementing the inorganic fertilizer N with

Table 18. Physical and chemical characteristics of an S-deficient field. Bacnotan, La Union, Philippines, 1983.

Sample depth (cm)	pH (1:1)	Organic C (%)	Total N (%)	CEC (meq/100 g)	Available Zn (ppm)	SO_4^{-2}-S (ppm)	Soil texture
0-20	6.1	0.50	0.05	13.6	0.8	7	Sandy loam
20-40	6.5	0.10	0.02	9.9	0.5	2	Loamy sand
40-60	6.8	0.08	0.01	10.8	0.4	4	Loamy sand
60-80	6.8	0.24	0.02	22.7	0.3	4	Sandy loam

Table 20. Physical and chemical characteristics of the soil in Botolan, Zambales, and Aguilar, Pangasinan, Philippines, 1983 WS.

Sample depth (cm)	pH (1:1)	Organic C (%)	Total N (%)	CEC (meq/100 g)	Available Zn (ppm)	SO_4^{-2}-S	Soil texture
			Botolan, Zambales				
0-20	6.8	0.72	0.080	14.5	0.30	5	Loam
20-40	6.7	0.80	0.079	33.0	0.03	5	Clay loam
40-60	6.8	0.45	0.051	48.3	0.20	4	Clay
60-80	6.8	0.28	0.035	41.4	0.00	6	Clay
			Aguilar, Pangasinan				
0-20	6.9	0.98	0.078	23.3	0.09	12	Silty clay loam
20-40	7.0	0.74	0.051	30.5	0.01	5	Silty clay
40-60	6.8	0.65	0.045	25.3	0.05	13	Silty clay
60-80	7.0	0.47	0.033	27.1	0.00	4	Silty clay loam

Table 21. Management of S fertilizer in rainfed lowland rice at 3 Philippine sites, 1983 WS.

Treatment	S rate (kg/ha)	Yield (t/ha)		
		Bacnotan, La Union	Botolan, Zambales	Aguilar, Pangasinan
Unfertilized control	–	1.84 b	0.81 b	1.01 b
NPK only	–	3.58 a	2.67 a	2.88 a
AS	20	3.73 a	2.98 a	2.95 a
AS	40	3.50 a	2.86 a	2.87 a
S	20	3.31 a	2.95 a	2.82 a
S	40	3.53 a	2.79 a	3.24 a
$CaSO_4$	20	3.36 a	3.09 a	2.81 a
$CaSO_4$	40	3.43 a	3.09 a	2.69 a
S bentonite	20	3.22 a	3.02 a	2.92 a
S bentonite	40	3.34 a	2.91 a	3.01 a
CV (%)		9.80	10.90	13.2 a

Table 22. Yield of 14 treatments in the long-term fertility trial in irrigated rice. IRRI, 1983 cropping seasons.

Treatment	Yield (t/ha)	
	DS	WS
Control	2.60 b	4.22 abc
Zn[a] alone	2.76 b	3.87 bc
N + Zn	4.41 a	4.26 abc
P + Zn	2.94 b	4.05 abc
K + Zn	2.57 b	3.71 c
NP + Zn	5.00 a	4.42 abc
NK + Zn	4.25 a	4.55 ab
PK + Zn	2.95 b	4.43 abc
NPK + Zn	5.03 a	4.26 abc
NPK only	4.30 a	4.37 abc
NPK + S[b]	5.13 a	4.09 abc
NPK + Zn + S[b]	4.62 a	4.72 a
NPK + azolla + Zn	4.31 a	4.75 a
NPK + straw + Zn	4.74 a	4.65 ab
CV (%)	15.60	10.80

[a]Root dip in 4% ZnO solution. [b]In the form of AS at 40 kg S/ha.

organic fertilizers (azolla and straw) might prove economical.

Yields increased significantly from added elements during DS but not during WS. A typhoon during the third crop caused severe flooding 2 d after fertilizer application, and heavy lodging occurred 2 wk before harvest in all N-treated plots.

Soil and crop management

International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)

Agronomy Department

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NITROGEN FERTILIZER EFFICIENCY FIELD TRIALS

Irrigated. *IRRI farm.* The fifth international trial on N fertilizer efficiency in irrigated rice was continued at IRRI in 1983. Split-applied urea, SCU, B&I, and point-placed USG were compared at four application rates using medium-maturing IR56.

With increasing N rates in DS, yields of IR56 were 2 t/ha more than the control (Table 1). They were significantly higher with deep-placed USG and B&I SCU than split-applied PU at 58 and 87 kg N/ha. Deep-placed USG with topdressed urea during P_I did not increase yield over deep-placed USG applied 1 DT.

Table 1. Effects of forms, rates, and methods of urea application on IR56 yield. Fifth INSFFER trial, IRRI, 1983 DS and WS.

Treatment	Yield (t/ha)	
	DS	WS
No fertilizer N	2.8 f	3.7 d
29 kg N/ha		
PU, split application[a]		4.4 abcd
Ordinary SCU, B&I		4.2 bcd
USG, placement		4.5 abc
58 kg N/ha		
PU, split application[a]	4.5 e	4.6 abc
Ordinary SCU, B&I	5.4 bcd	5.0 ab
USG, placement	5.4 bcd	5.0 ab
USG, placement + urea top-dressed[b]	5.0 cde	
87 kg N/ha		
PU, split application[a]	4.9 de	4.8 ab
Ordinary SCU, B&I	5.8 ab	3.8 cd
USG, placement	5.1 cde	4.9 ab
USG, placement + urea top-dressed[b]	5.9 ab	
116 kg N/ha		
PU, split application[a]	5.9 ab	4.0 cd
Ordinary SCU, B&I	5.9 ab	3.8 cd
USG, placement	5.8 ab	5.2 a
USG, placement + urea top-dressed[b]	5.5 abc	
174 kg N/ha		
PU, split application[a]	5.9 ab	
Ordinary SCU, B&I	6.0 ab	
USG, placement	6.2 a	
USG, placement + urea top-dressed[b]	6.2 a	

[a]Two-thirds B&I at planting, 1/3 topdressed 5-7 DBPI.
[b]Two-thirds supergranule placement, 1/3 urea top-dressed 5-7 DBPI.

The WS experiment continued with three sources of urea at four application rates. IR56 did not respond significantly to increasing N rates. Results were modified by 2 typhoons that hit the field 1 mo after transplanting and during heading and flowering stages.

Farmers' fields. N fertilizer efficiency tests were continued in farmers' irrigated fields under the INSFFER program.

Soils were analyzed before trials began (Table 2). IR36 showed significant response to all N sources (Table 3). DS yields consistently increased as the N rate of all sources increased. Although significant differences were observed at 174 kg N/ha in Calauan soil, 116 kg was optimum in both seasons. N response was 6.4 t/ha in Calauan soil (0.26% total N) at 174 kg N/ha as USG plus PU, and 4.0 t/ha in Famy soil (0.188% total N) at 174 kg N/ha as USG only.

In WS, the highest response of 1.4 t/ha was obtained with PU at 116 kg N/ha.

Medium-deepwater rice. An INSFFER trial was conducted during the 1983 DS at IRRI as part of the third international trial on N fertilizer efficiency in deepwater rice. IR42, a semi-medium deepwater rice, was used at 50-cm water depth.

Regardless of N sources, application increased IR42 yield by 1.1 t/ha over the nonfertilized control (Table 4). At 58 kg N/ha almost all N sources yielded significantly higher than the control, but there were no differences among sources and among rates. Urea foliar spray 5-7 DBPI had no advantage over PU B&I.

Table 2. Characteristics of soils for INSFFER trials, farmers' fields in Calauan and Famy, Laguna, Philippines, 1983.

Soil property	DS		WS
	Calauan	Famy	Calauan
pH (1:1)	6.3	5.0	6.4
Total N (%)	0.26	0.19	0.11
OM (%)	4.2	3.1	1.6
Available P (ppm)	13	5	22
Exchangeable K (meq/100 g soil)	0.73	0.07	0.94
Exchangeable Ca (meq/100 g soil)	15	7	17
CEC (meq/100 g soil)	37	24	39
Available Zn (ppm)	nil	4	0.1
Texture	Silty clay	Silty clay	Silty clay

Table 3. Effect of sources, rates, and methods of N fertilizer application on grain yield of IR36 on Calumpang silty clay in Calauan, Laguna, and Maligaya silty clay in Famy, Laguna, Philippines. International trials on nitrogen fertilizer efficiency in irrigated rice, 1983.

Treatment[a]	Grain yield (t/ha)		
	DS		WS
	Calauan	Famy	Calauan
No fertilizer N	3.4 g	2.9 h	4.2 d
	58 kg N/ha		*29 kg N/ha*
PU, split	6.1 f	4.7 g	5.1 bc
SCU	6.7 ef	5.4 def	5.0 bc
USG	6.3 ef	5.2 defg	4.9 bc
USG + PU, split	7.2 e	5.1 efg	–
	87 kg N/ha		*58 kg N/ha*
PU, split	6.8 ef	4.9 fg	4.7 c
SCU	7.2 de	5.5 def	5.1 bc
USG	8.2 bcd	5.9 bcd	5.2 bc
USG + PU, split	8.3 bc	5.7 cde	–
	116 kg N/ha		*87 kg N/ha*
PU, split	7.1 ef	5.8 bcde	5.0 bc
SCU	7.3 cde	6.8 a	5.2 bc
USG	9.0 ab	6.5 ab	4.9 bc
USG + PU, split	9.0 ab	6.4 abc	–
	174 kg N/ha		*116 kg N/ha*
PU, split	8.5 b	6.3 abc	5.6 a
SCU	8.6 b	6.9 a	5.0 bc
USG	9.3 ab	7.0 a	5.3 ab
USG + PU, split	9.8 a	6.9 a	–

[a]For split application, 2/3 urea was B&I at planting time, and 1/3 topdressed 5-7 DBPI.

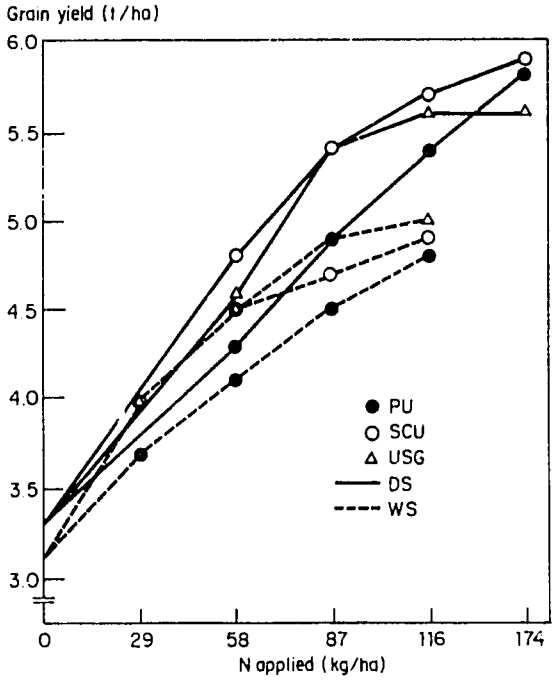
Table 4. Effects of sources and methods of N application on yield of medium deepwater rice IR42. IRRI, 1983 DS.

Treatment	Grain yield (t/ha)
No fertilizer N	0.8 c
58 kg N/ha	
PU, B&I	2.1 ab
2/3 PU, B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	2.0 ab
SCU, B&I	2.0 ab
USG, 10-12 cm deep placement	2.0 ab
87 kg N/ha	
PU, B&I	1.7 b
2/3 PU, B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	1.7 b
SCU, B&I	2.3 ab
USG, 10-12 cm deep placement	2.3 ab
116 kg N/ha	
PU, B&I	2.2 ab
2/3 PU, B&I fb 1/3 foliar spray of urea solution 5-7 DBPI	1.8 ab
SCU, B&I	2.4 a
USG, 10-12 cm deep placement	2.2 ab

INTERNATIONAL TRIALS

In 1983, 39 collaborating scientists submitted results from 93 trials conducted in 1982 in 63 sites in 11 countries. Most trials were on N fertilizer efficiency in irrigated rice. In 1983, 215 sets of materials and fieldbooks were sent to 60 collaborating scientists in 17 countries.

Fifth international trial on nitrogen fertilizer efficiency in irrigated lowland rice. Of the 46 trials conducted in 8 countries, one from Burma and one in the Philippines did not respond significantly to N. Average yield responses were higher during DS than during WS (Fig. 1). Yield increases ranged from 0.1 to 2.6 t/ha in DS and from 0.6 to 1.9 t/ha in WS. Regardless of form, response increased with N rate. Yield differences between SCU or USG and PU were highest at the medium rate in both seasons. The advantages of SCU and USG over PU were more apparent at the lower N rates (Fig. 2-5). At high N rates in some sites, USG or SCU yielded significantly lower than PU.



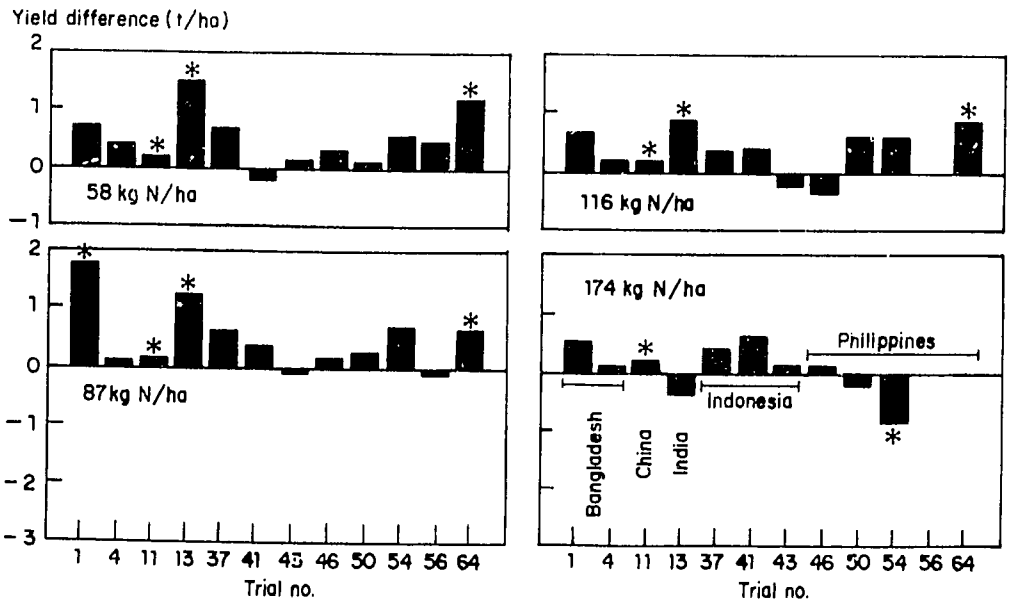
1. Rice response to N in different forms of urea and different application rates. Data are averages of 12 DS and 34 WS trials. The fifth international trial on nitrogen fertilizer efficiency in rice, INSFFER, 1982.

The effects of SCU and USG were variable among sites and inconsistent at all N rates. While SCU consistently outyielded PU significantly at all N rates in only one trial (trial #11, Fig. 2), USG outyielded PU in 3 trials: trials #10 and 11 in China and #15 in India (Fig. 4, 5).

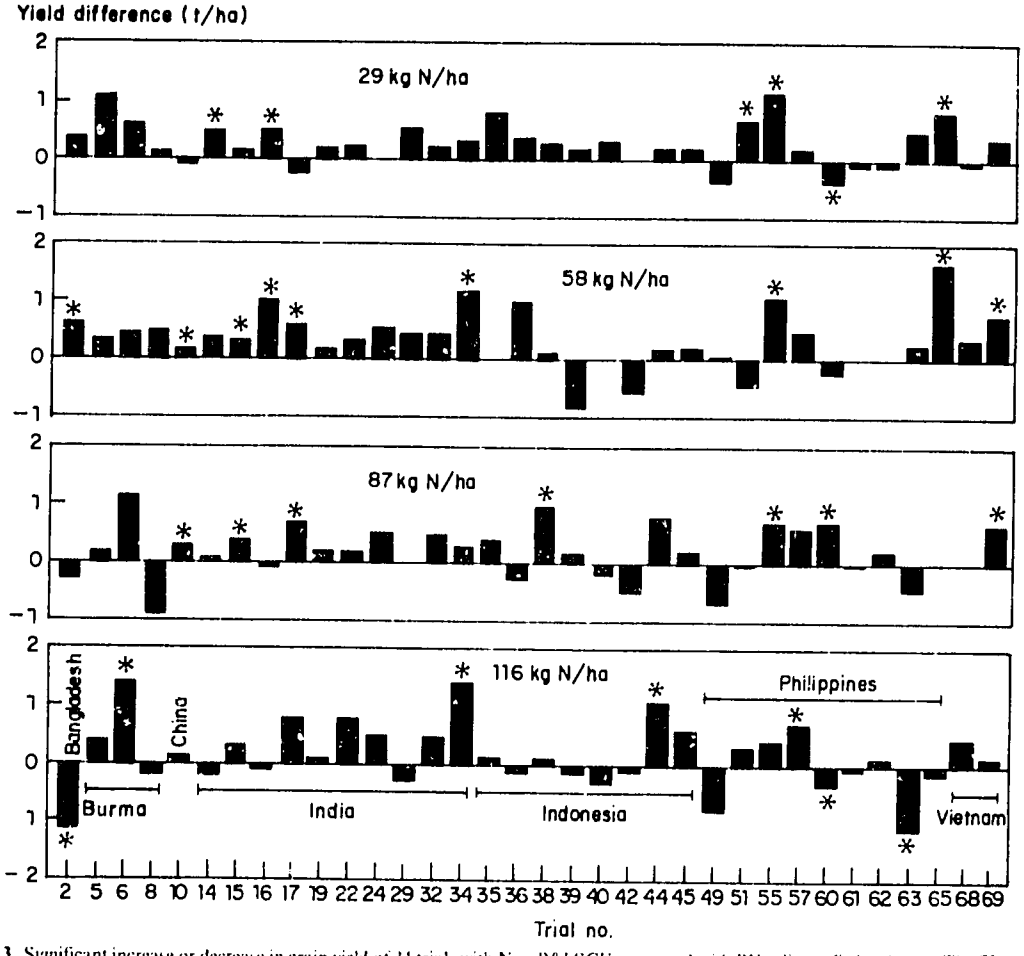
Ludhiana site, India (#22), consistently produced lower yield from USG than PU at all N rates because of the very high percolation and low CEC of the soil. The advantage of SCU and USG over PU were observed in several sites only at certain N rates.

The technical and economic efficiency of N sources included in INSFFER N-fertilizer efficiency experiments were evaluated using multi-fertilizer response models. Based on the results of the third to fifth N efficiency trials in irrigated rice, a trend emerged: SCU and USG were 25-30% technically more input efficient than PU. Yield (output) efficiency of SCU and USG was 1.3 to 1.4 higher than that of PU. However, there were large differences in results between sites, some caused by poor performance of USG at sites with high percolation losses. Other differences in response between locations are being explored.

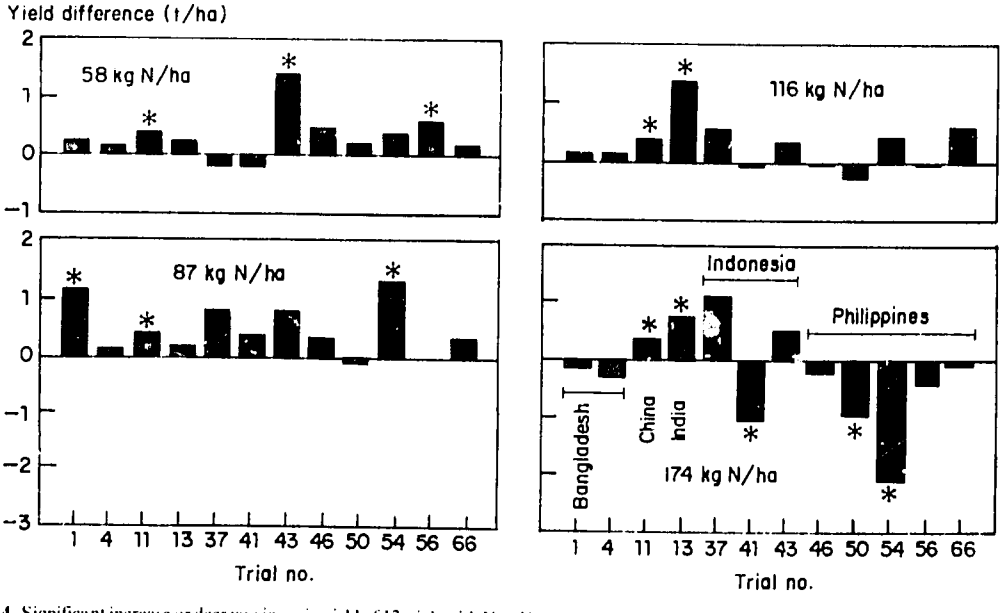
N sources were economically analyzed based on the percent increase in the price of SCU and USG that would yield the same profit as PU at its current price. This adjusted approach was used because SCU and USG are not yet commercially available and they have no market price. At about half the South and Southeast Asia INSFFER sites, modified N sources were more profitable than PU, even



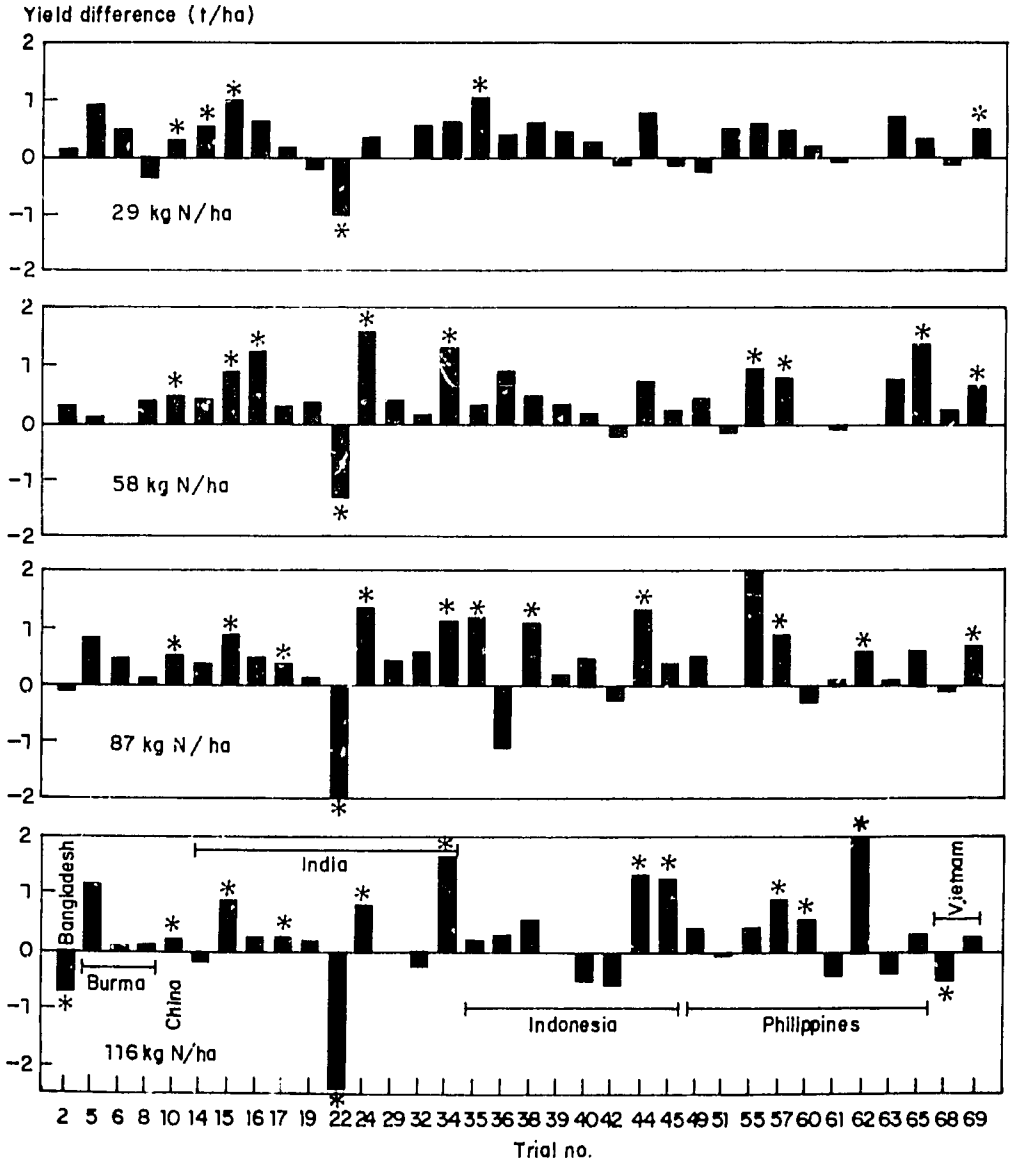
2. Significant increase or decrease in grain yield of 12 trials with N as B&I SCU compared with PU. The fifth international trial on nitrogen fertilizer efficiency in rice, INSFFER, 1982 DS.



3. Significant increase or decrease in grain yield of 34 trials with N as B&I SCU compared with PU split-applied at 4 rates. The fifth international trial on nitrogen fertilizer efficiency in rice, INSFFER, 1982 WS.



4. Significant increase or decrease in grain yield of 12 trials with N as USG, deep point-placed with PU. The fifth international trial on nitrogen fertilizer efficiency in rice, INSFFER, 1982 DS.



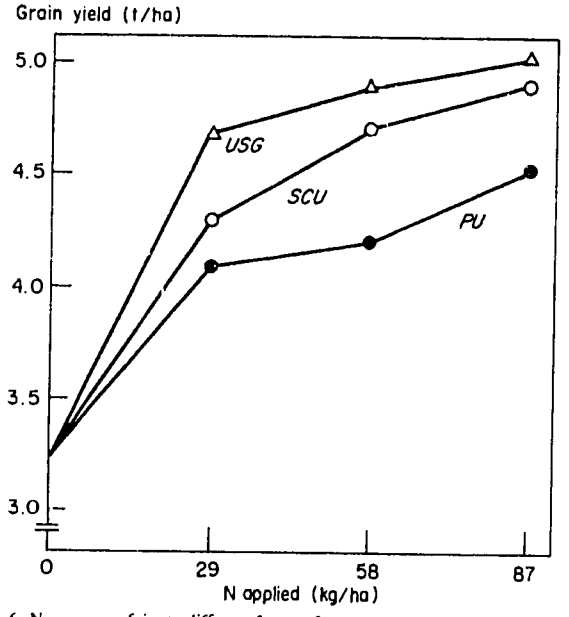
5. Significant increase or decrease in grain yield of 34 trials with N as USG deep point-placed compared with PU split-applied at 4 rates. The fifth international trial on nitrogen fertilizer efficiency in rice, INSFFER, 1982 WS.

when their cost is more than one-third higher than the current price of PU. As the price of PU increases, the profitability of using deep-placed SCU or USG increases.

Third international trial on nitrogen fertilizer efficiency in rainfed rice. All 13 trials conducted at 12 sites in 6 countries responded significantly to N. Based on average yields, USG and SCU consistently outyielded PU at all N rates. Average yield differences between USG or SCU and PU were greatest at 58 kg N/ha (Fig. 6) when SCU was higher by 0.5 and USG by 0.7 t/ha.

B&I SCU yielded significantly higher than PU best split in three trials at the low and medium rates and in five trials at the high rate (Fig. 7). Only trial #10 from Mithapur, India, produced significant yield differences between SCU and PU at all N rates.

Although 4 trials showed significant yield differences between USG and PU at 87 kg N/ha,

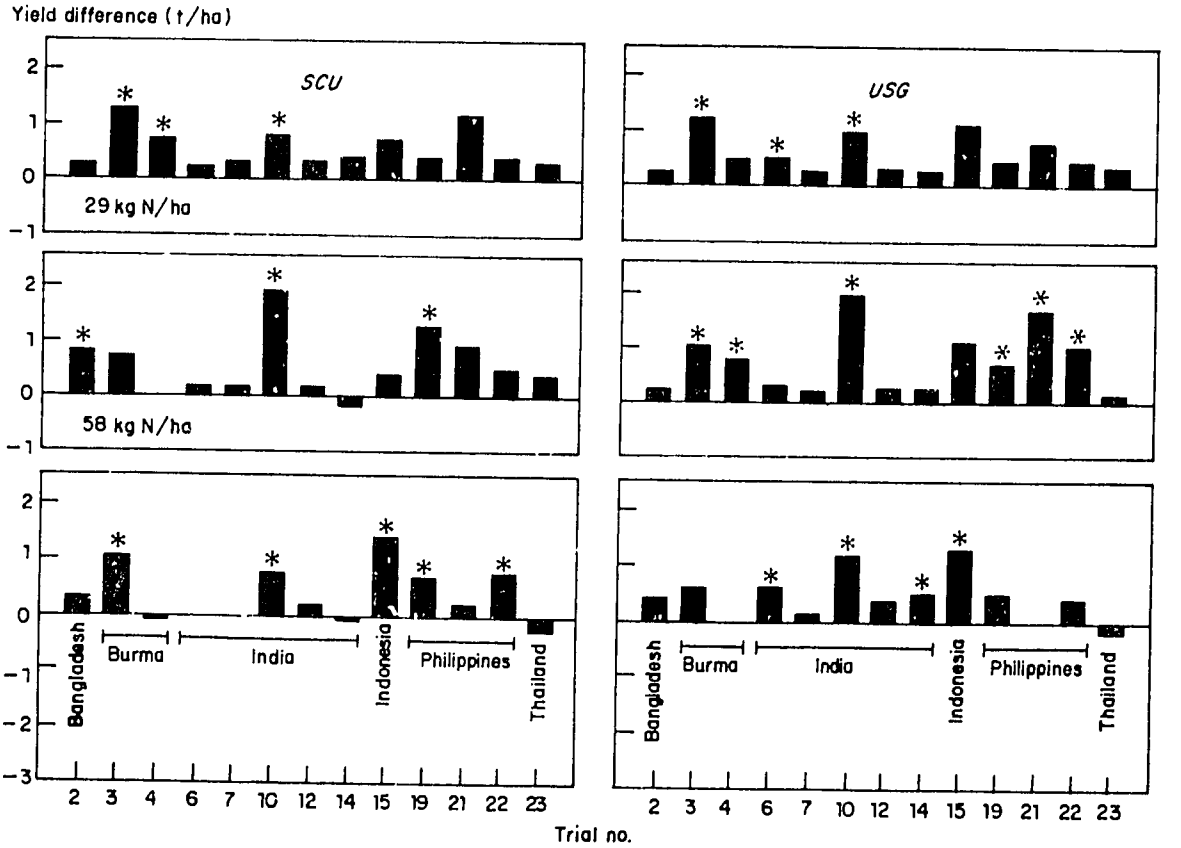


6. N response of rice to different forms of urea and application rates. The third international trial on nitrogen fertilizer efficiency in rainfed wetland rice, INSFFER, 1982.

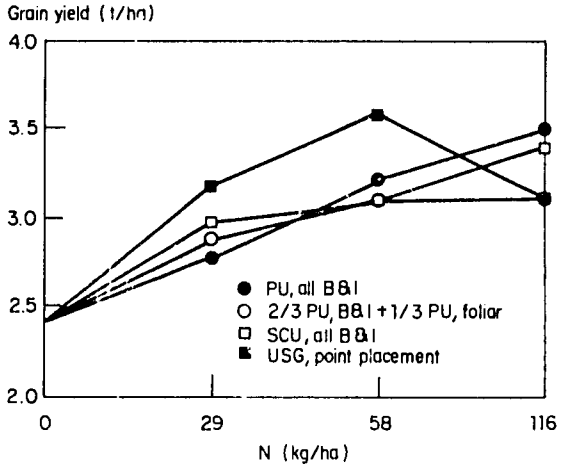
greater yield differences were observed in 6 trials at 58 kg N/ha. Like SCU, USG showed significant yield differences over PU at all N rates in trial #10.

Second international trial on nitrogen fertilizer efficiency in deepwater rice. Average yields of 5 N trials conducted in India, Philippines, and Thailand showed increases of 0.4-1.2 t/ha. PU in both methods of application (basal and split) yielded similarly at low and medium N rates (Fig. 8). Basally applied PU and SCU had similar yields at 58 and 116 kg N/ha. Deep-placed USG outyielded other urea forms at low and medium rates (Fig. 8). At 116 kg N/ha, USG yielded 0.3 t/ha lower than PU and 0.2 t/ha lower than SCU.

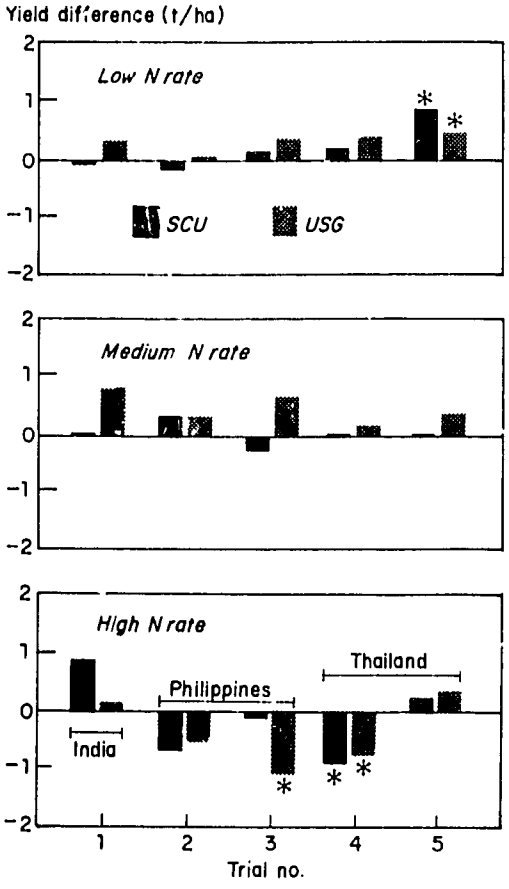
The SCU yield increase over best split urea was significant in trial #5 (Rangsit, Thailand) (Fig. 9) at the low N rate. At high N rate, however, SCU yielded significantly less than PU in Klong Luang (trial #4) where a yield reduction of 0.8 t/ha was noted.



7. Significant increase or decrease in grain yield of 13 trials with N as B&I SCU and deep-placed USG compared with PU split-applied at 3 rates. The third international trial on nitrogen fertilizer efficiency in rainfed wetland rice, INSFFER, 1982.



8. N responses of rice to different forms of urea and rates of application. The second international trial on nitrogen fertilizer efficiency in deepwater rice, INSFFER, 1982.



9. Significant increase or decrease in grain yield of 5 trials with N as B&I SCU and point-placed USG compared with split-applied PU. The second international trial on nitrogen fertilizer efficiency in deepwater rice, INSFFER, 1982.

USG also yielded significantly more than PU in trial #5 at the low N rate. At the high N rate, however, it yielded significantly less than PU in two trials. Trial #3 (Los Baños) showed a significant yield reduction of 1.0 t/ha; trial #4 in Klong Luang, 0.7 t/ha.

Azolla use in rice. The 1982 results from 18 sites in 8 countries showed that fresh azolla incorporated

Table 5. Grain yield response to fertilizer N and to azolla application in irrigated rice in 8 countries. INSFFER, 1982.

Treatment	Grain yield[a] (t/ha)	
	Mean of 18 sites	Mean of 13 N-responsive sites
Control	2.89	2.68
60 kg N/ha from PU, applied in 3 splits	4.20	4.24
2 t fresh azolla/ha incorporated before transplanting + 30 kg N/ha from urea	4.16	4.18
Azolla grown before and after transplanting, incorporated after full cover	4.03	4.00
Azolla grown twice after transplanting, each crop incorporated when full cover	3.87	3.94

[a]Values for the N and azolla treatment are averages of 2 plant spacings (20 X 20 cm and 10 X 40 cm) and are not significant.

Table 6. Mean yield response to different P sources in 93 trials at 25 sites in 11 countries. International trial on sources of phosphorus in flooded rice, INSFFER, 1983.

Treatment		Mean grain yield (t/ha)			
		All sites		P-responsive sites	
P source[a]	Rate (kg/ha)	WS (58 trials)	DS (35 trials)	WS (51 trials)	DS (31 trials)
Check		3.23	4.18	3.09	3.85
SP	9	3.67	4.69	3.58	4.44
	18	3.81	5.10	3.74	4.92
	26	3.86	5.27	3.80	5.14
HRP	9	3.70	4.49	3.63	4.22
	18	3.82	4.83	3.76	4.60
	26	3.82	5.03	3.76	4.81
LRP	18	3.84	4.47	3.76	4.39
	35	3.89	4.86	3.80	4.82
	53	3.93	4.88	3.85	4.84

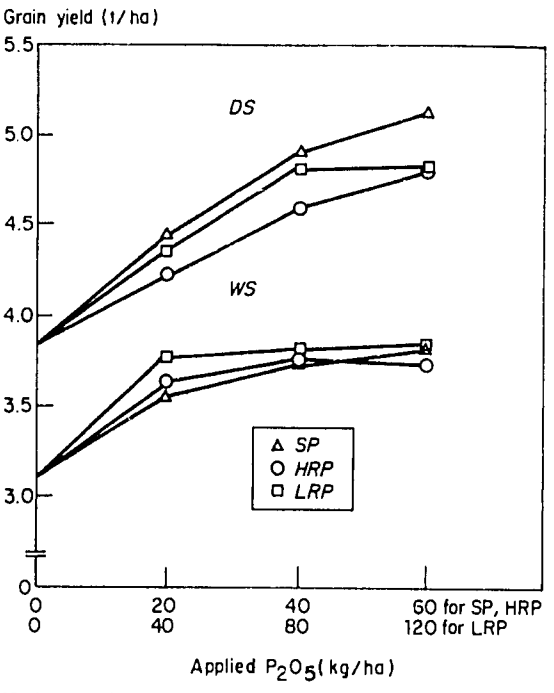
[a]SP = superphosphate, HRP = highly reactive rock phosphate, LRP = low reactive rock phosphate.

at 2 t/ha plus basal application of 30 kg N/ha as PU produced yields comparable to those of urea split application at 60 kg N/ha (Table 5). Azolla alone, applied before and after transplanting or twice after transplanting, yielded less than split doses of urea alone or azolla plus 30 kg N/ha of urea. However, the differences were not significant because azolla biomass was far lower than the 40 t/ha which is equivalent to 60 kg N/ha from urea. Azolla alone yielded a ton or more of grain above the control plot.

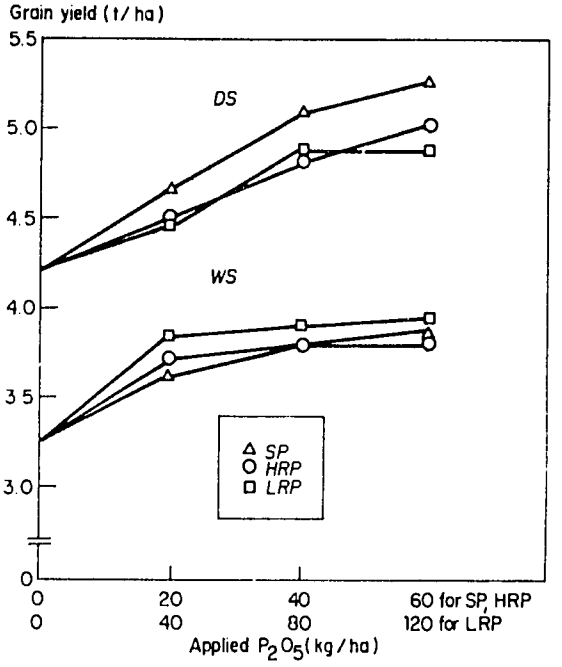
Sources of phosphorus in flooded rice. Since 1977, research on P sources in flooded rice have been conducted at 25 sites in 11 countries. Results of nine trials in five locations were reported in 1983.

Of 93 trials, 11 did not show significant differences among treatments. On the average, yields increased more than 0.5 t/ha from all P sources (Table 6). P response during DS was higher than during WS (Fig. 10, 11). During DS, greater yield responses were obtained from SP than from less soluble P sources but there were no differences during WS (Table 7).

Residual P after 5 seasons of continuous application in 4 sites increased yields 1.5 t/ha in DS and 0.8 t/ha in WS.



10. Average yield response of rice to different P sources in 93 trials. International trial on sources of phosphorus in flooded rice, INSFFER, 1983.



11. Average yield response of rice to different P sources in 82 trials. International trial on sources of phosphorus in flooded rice, INSFFER, 1983.

Long-term fertility trial. Since 1976, 80 long-term fertility trials have been conducted at 10 sites in 7 countries. Results from 11 trials at 4 sites in 2 countries were reported in 1983. After 10 crops, one Indonesian site showed response to N or P alone or N and P combined. The other site responded to N only after eight croppings (Table 8). Yield differences were more pronounced in DS.

Table 7. Mean yield differences between P sources and control. International trial on sources of phosphorus in flooded rice, INSFFER, 1983.

Treatment[a]	Yield differences (t/ha)			
	All sites		P-responsive sites	
	WS (58 trials)	DS (35 trials)	WS (51 trials)	DS (31 trials)
SP over check	0.56	0.84	0.62	0.98
HRP over check	0.55	0.60	0.63	0.69
LRP over check	0.66	0.56	0.71	0.83

[a]SP = superphosphate, HRP = highly reactive rock phosphate, LRP = low reactive rock phosphate.

Table 8. Mean yield of 9 treatments by location and season in Indonesia. International long-term fertility trial in rice, INSFFER, 1977-82.

Treatment	Mean grain yield (t/ha)			
	Lanrang		Maros	
	DS (5 trials)	WS (5 trials)	DS (5 trials)	WS (3 trials)
Check	3.0	2.2	3.3	3.2
N	3.8	2.6	5.1	4.1
P	4.0	2.3	3.9	3.4
K	3.3	2.5	3.6	3.2
NP	4.3	3.2	5.2	3.9
PK	3.3	2.3	3.6	3.2
NK	3.8	2.5	5.3	4.1
NPK	4.5	3.3	5.2	4.4
NPK + Zn	(2.9)[a]	(3.3)[a]	5.2	4.2

[a]Av of 3 trials only.

Table 9. Mean yield of 8 treatments by location and season in the Philippines. International long-term fertility trial in rice, INSFFER, 1977-82.

Treatment	Mean grain yield (t/ha)			
	Luisiana		Tanay	
	DS (7 trials)	WS (8 trials)	DS (5 trials)	WS (8 trials)
Check	3.4	2.5	3.1	2.9
N	5.0	3.7	4.8	4.2
P	3.6	2.7	3.5	3.4
K	3.5	2.6	2.9	3.0
NP	5.8	3.9	5.3	4.4
PK	3.9	2.8	3.3	3.3
NK	5.2	3.5	5.1	4.2
NPK	6.4	4.2	5.7	4.6

In 2 Philippine sites, yields responded to N alone after 5 continuous croppings in Luisiana and 13 in Tanay (Table 9). An NP combination increased response further especially in DS. Yield increase from NP was more than 0.8 t/ha over N alone in Luisiana and 0.5 t/ha over N alone in Tanay, showing that P deficiency is becoming limiting.

INSFFER TRAINING COURSE

Since 1979, 106 participants from 14 countries have completed the 4-mo INSFFER training course. Nineteen participants representing six countries (China, India, Indonesia, Philippines, Thailand, and Vietnam) attended the fifth course held 10 Jan to 29 Apr 1983.

The trainees conducted the following field fertilizer trials in IRRI using IR58 (105 d maturity):

- The fifth international trial on nitrogen fertilizer efficiency in irrigated lowland rice (irrigated). Yield differences were not significant among fertilizer forms and application methods under the same N rate. At 87 kg N/ha, 2/3 USG deep-point placed plus 1/3 PU topdressed 5-7 DBPI produced significantly higher yield (6.9 t/ha) than PU best split (2/3 basal plus 1/3 topdressed at 5-7 DBPI) which yielded 5.5 t/ha. The former treatment produced yield comparable to yields obtained at 174 kg N/ha with SCU, USG alone, and urea best split.
- Long-term fertility trial in irrigated lowland rice (third crop). N-treated plots yielded significantly higher than those without N. There was no response to N, P, K, Zn, S, azolla, or rice straw treatments. Details of the experiment results are presented in the section Soil and Crop Management (Management of Other Nutrients) of this report.
- Urea forms and their application methods in irrigated rice. At 58 kg N/ha, USG deep-point placed at transplanting yielded significantly higher (6.2 t/ha) compared to delayed application (28 DT) which yielded only 4.4 t/ha. Similar results were obtained at 116 kg N/ha, where USG applied 28 DT decreased yield by about 1.6 t/ha compared to application 7 and 14 DT.
- Azolla INSFFER trial. Incorporation of azolla (approximately equivalent to 30 kg N/ha) before transplanting plus 3-split applications of 30 kg N/ha as urea produced yield (6.3 t/ha) comparable to that with 90 kg N/ha as urea split applied (2/3 basal plus 1/3 topdressed at 5-7 DBPI). Azolla alone applied once before transplanting and 3 times after transplanting produced yields similar (5.6 t/ha) to those with 60 kg N/ha as urea, applied in 3 splits.

Soil and crop management

Rice crop cultural practices

Agronomy Department

MANAGEMENT OF NITROGEN FERTILIZER IN EARLY-MATURING RICE **310**
PLANT GROWTH REGULATORS TO INCREASE RICE GRAIN YIELD **311**
FACTORS INFLUENCING DEEPWATER RICE PRODUCTION ON THE CENTRAL PLAIN OF THAILAND **313**

MANAGEMENT OF NITROGEN FERTILIZER IN EARLY-MATURING RICE

Research to evaluate productivity, brown-rice protein content, and lodging resistance of IR varieties and promising early-maturing breeding lines, as affected by N rates and application methods, continued during 1983.

Results indicated that most very early-maturing lines have higher productivity (kg rough rice/ha per day) than IR36 and IR42 (Table 1, 2). Furthermore, several early-maturing rices (IR25588-7-3-1, IR25588-32-2, and IR28128-45-2) produced similar or higher yields than medium-maturing IR8 and IR42 while retaining comparable grain protein content in DS (Table 1).

Table 1. Field duration, productivity, and brown-rice protein content of 14 early-maturing IR rices as affected by N rates and application methods. IRRI, 1983 DS.

Entry	Field duration (d)	Grain yield[a] (t/ha)					Av yield		Brown-rice protein (%)
		Without fertilizer N	87 kg N/ha			150 kg N/ha	t/ha	kg/ha per day[b]	
			Urea split	SCU	USG	Urea split			
IR8	108	5.5 abcd	6.5 abc	6.9 ab	6.9 a	6.5 a	6.5	60	8.1
IR36[c]	89	4.6 de	4.7 d	4.5 de	4.7 de	5.3 cd	4.8	54	9.3
IR42	109	5.2 bcde	6.4 abc	6.8 ab	6.3 ab	6.5 a	6.2	57	8.4
IR50[c]	86	5.1 bcde	4.5 d	4.2 e	4.4 e	3.1 e	4.2	49	9.6
IR60	84	5.5 abcd	6.2 abc	6.5 b	6.1 abc	6.3 ab	6.1	73	9.7
IR9729-67-3	84	4.9 cde	5.9 bc	6.1 bc	5.8 bc	5.3 cd	5.6	66	8.8
IR18350-175-2-3	92	5.2 bcde	6.9 a	6.2 bc	6.7 ab	6.5 a	6.3	68	9.1
IR21015-80-3-3-1-2	92	4.3 e	6.4 abc	6.3 b	6.2 abc	5.5 bcd	5.7	62	8.9
IR25588-7-3-1	91	6.2 a	7.1 a	7.0 ab	6.5 ab	6.9 a	6.7	74	8.9
IR25588-32-2	91	6.0 ab	6.8 ab	6.8 ab	6.4 ab	6.6 a	6.5	72	9.1
IR25898-69-2-2	87	5.7 abc	6.4 abc	6.7 ab	6.1 abc	6.3 ab	6.3	72	8.8
IR25924-51-2-3[c]	87	5.4 abcd	5.7 c	5.3 cd	5.3 cd	4.9 d	5.3	61	9.0
IR28128-45-2	89	5.9 ab	6.7 ab	7.6 a	6.5 ab	6.2 abc	6.6	74	9.1
IR28210-96-4-3-3	88	4.9 cde	6.5 abc	6.1 bc	5.8 bc	6.1 abc	5.9	67	9.7

[a]Urea split, 2/3 basal and incorporated and 1/3 topdressed 5-7 DBPI; forestry grade SCU, B&I; and USG hand point-placed at 10-15 cm deep. [b]Does not include 18 d in the seedbed. [c]Affected by BI.

Table 2. Field duration and productivity of 13 early-maturing IR rices as affected by N rates and application methods.[a] IRRI, 1983 WS.

Entry	Field duration (d)	Grain yield (t/ha)					Av yield	
		Without fertilizer N	58 kg N/ha			90 kg N/ha	t/ha	kg/ha per day[b]
			Urea split	SCU	USG	Urea split		
IR36	93	3.7 abc	4.4 abc	4.0 abc	4.0 abc	3.9 bcd	4.0	37
IR42	111	3.3 c	3.9 cdef	4.5 a	3.9 bc	4.0 bc	3.9	31
IR58	86	3.8 abc	4.2 abcd	4.2 ab	4.1 abc	4.2 abc	4.1	40
IR60	87	3.6 bc	3.6 def	3.7 bc	3.8 bc	3.7 cdef	3.7	36
IR25588-7-3-1	87	4.3 a	4.4 abc	4.1 ab	4.0 abc	3.8 cdef	4.1	40
IR25621-135-1-1	89	3.8 abc	4.1 bcde	4.2 ab	4.0 abc	3.9 bcd	4.0	38
IR29692-86-2-3-3	90	3.6 bc	3.7 def	3.7 bc	3.8 bc	3.3 defg	3.6	34
IR29692-94-2-1-3	87	4.1 ab	4.6 ab	4.5 a	4.6 a	4.5 ab	4.5	42
IR29692-99-3-2-1	87	4.0 ab	4.8 a	4.4 a	4.2 ab	4.3 abc	4.3	42
IR29708-41-2-2-3	86	4.0 ab	4.4 abc	4.5 a	4.2 ab	4.7 a	4.4	43
IR29725-3-1-3-2	89	3.7 abc	3.5 ef	3.4 c	3.6 bc	2.8 g	3.4	32
IR29725-22-3-3-3	89	3.3 c	3.4 f	3.6 bc	3.5 c	3.0 g	3.4	32
IR29725-109-1-2-1	89	3.7 abc	3.6 def	3.6 bc	3.8 bc	3.9 bcd	3.7	35

[a]IR8 was severely affected by RTV and was harvested at PI. [b]Does not include 16 d in the seedbed.

Lodging resistance of IR8 in DS, based on lodging resistance factor (cLr) value, was significantly higher than that of IR42 (Table 3). Both varieties had significantly higher cLr values than the other early-maturing rices tested. N application and increased level of split-applied N further aggravated lodging susceptibility (Table 4).

In both seasons, the single basal incorporation of slow-release SCU and hand point-placed USG produced grain yields (mean of 5.1 and 5.0 t/ha) comparable to those with split urea application (5.2 t/ha). For the fourth time, however, single basal incorporation of slow-release SCU increased the average percentage of brown-rice protein by 0.9%; and hand deep point-placed USG increased it by 0.7% over the split application of PU in DS (Table 5).

Table 3. cLr value of 14 early-maturing rices. IRRI, 1983 DS.

Entry	cLr value[a]
IR8	0.285 a
IR36[b]	0.090 de
IR42	0.141 b
IR50[b]	0.096 d
IR60	0.080 e
IR9729-67-3	0.102 d
IR18350-175-2-3	0.102 d
IR21015-80-3-3-1-2	0.095 d
IR25588-7-3-1	0.093 d
IR25588-32-1	0.099 d
IR25898-69-2-2	0.079 e
IR25924-51-2-3[b]	0.095 d
IR28128-45-2	0.058 f
IR28210-96-4-3-3	0.116 c

[a]Av of 5 N treatments and 4 replications.

$$cLr = \frac{\text{total weight of freely suspended brass chain links + hook (g)}}{\text{culm length (cm)}}$$

[b]Affected by BI.

Table 4. cLr value as affected by N rates and application methods, IRRI, 1983 DS.

Urea source	Application method	cLr value[a]
Without fertilizer N	–	0.126 a
87 kg N/ha		
PU	Split	0.109 b
SCU	B&I	0.107 b
USG	Deep point placement	0.107 b
150 kg N/ha		
PU	Split	0.098 c

[a]Av of 14 rice entries and 4 replications.

Table 5. Effect of urea sources, application methods, and application rates on brown-rice protein of 14 rice entries, IRRI, 1983 DS.

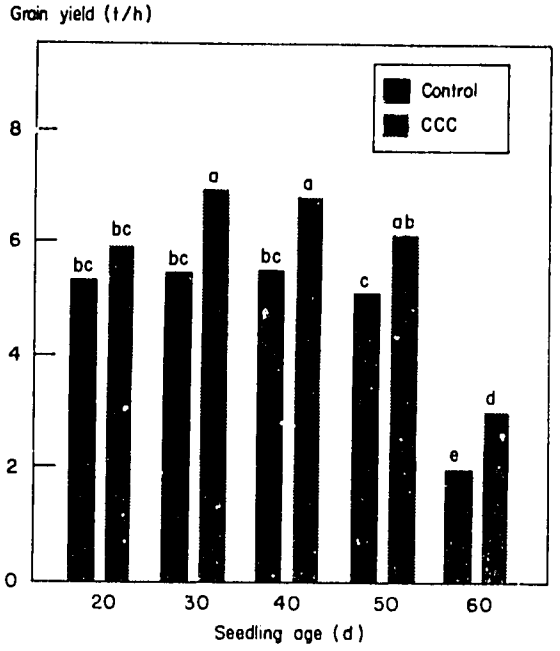
Entry	Brown-rice protein (%)				
	Without fertilizer N	87 kg N/ha			150 kg N/ha as urea split
		Urea split	SCU	USG	
IR8	7.3 b	8.1 a	8.6 a	8.2 a	8.6 a
IR36[a]	7.6 c	9.0 b	9.8 a	10.0 a	10.1 a
IR42	7.3 c	8.1 b	9.0 a	8.5 ab	9.0 a
IR50[a]	7.7 d	9.4 c	10.1 b	9.8 bc	11.0 a
IR60	8.2 d	9.5 c	10.4 ab	10.0 bc	10.6 a
IR9729-67-3	7.2 c	8.3 b	9.5 a	9.5 a	9.5 a
IR18350-175-2-3	7.6 c	8.6 b	9.8 a	9.8 a	9.9 a
IR21015-80-3-3-1-2	7.5 d	8.7 c	9.3 b	9.1 bc	9.9 a
IR25588-7-3-1	7.7 c	8.4 b	9.2 a	9.4 a	9.7 a
IR25588-32-2	7.5 d	8.7 c	9.5 b	9.6 ab	10.1 a
IR25898-69-2-2	7.3 c	8.6 b	9.5 a	9.3 a	9.5 a
IR25924-51-2-3[a]	7.5 c	8.5 b	10.0 a	9.5 a	9.7 a
IR28128-45-2	8.0 c	8.5 c	9.8 ab	9.3 b	10.2 a
IR28210-96-4-3-3	8.2 c	9.3 b	10.5 a	10.3 a	10.2 a
F-means	7.6	8.7	9.6	9.4	9.8

[a]Affected by BI.

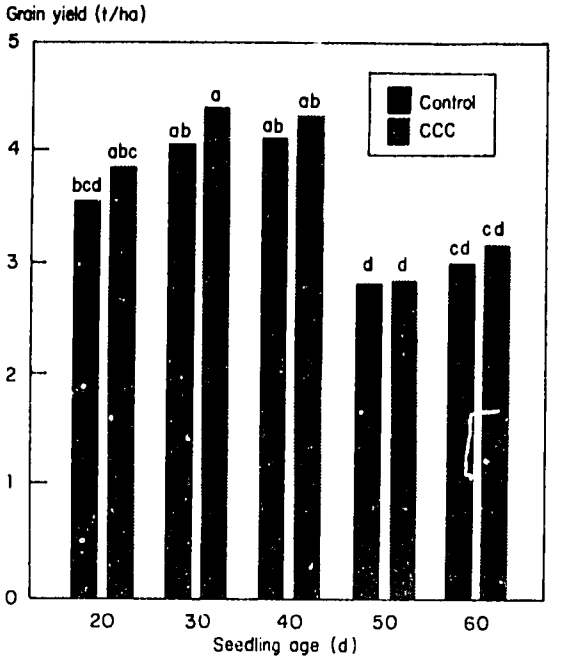
PLANT GROWTH REGULATORS TO INCREASE RICE GRAIN YIELD

Two field experiments were conducted in 1983 to study the effects of growth regulators on seedlings of different ages. Test varieties were intermediate-maturing IR42 and early-maturing IR58.

In DS, the plant growth retardant CCC (5,000 ppm solution at 100 ml/m^2 of seedbed area) was applied at 2- to 3-leaf stage in seedbeds with 20-, 30-, 40-, 50-, and 60-d-old seedlings. They were then transplanted in the main field and grown to maturity. Except in the normally used 20-d-old seedlings, CCC application resulted in significantly higher IR42 yields compared to the control (Fig. 1). The highest yields were obtained with CCC-treated 30- and 40-d-old IR42 seedlings. Those seedlings yielded 1.3 t/ha more than the untreated control and significantly more than all other treatments except CCC-treated 50-d-old seedlings. The IR42 grain yield increase with CCC treatment



1. IR42 grain yield as affected by seedlings treated with CCC (growth retardant) at 2- to 3-leaf stage and transplanted at different ages. IRRI, 1983 DS.



2. IR58 grain yield as influenced by seedlings treated with CCC (growth retardant) at 2- to 3-leaf stage and transplanted at different ages. IRRI, 1983 DS.

was caused by a lower percentage of unfilled spikelets, higher 100-grain weight, and delayed leaf senescence. These factors increased the ripening period by 3-4 d compared with the untreated control.

With IR58, no treatment increased yield significantly over the untreated control (Fig. 2). The distinct way in which varieties respond to growth regulators appears more important and needs further testing.

Table 6. Environmental factors, yield, and yield components of deepwater rice on the central plain of Thailand, 1983.[a]

Site	Adverse factors	Max water depth (cm)	Mean yield (t/ha)	Dry weight (g/m²)	Harvest index	Panicles (no./m²)	Panicle weight (g/panicle)	Variety
1	–	35	2.91	761	0.29	132	1.92	Khao Ma Na
2	Early drought	75	2.38	879	0.26	138	1.87	Khao Puang Glahng
3	Early drought, poor stand	120	2.37	696	0.26	84	2.54	Khao Ma Na
4	Early drought, poor stand, weeds	220	2.25	843	0.18	52	3.41	PG56
5	Early drought	90	1.86	1027	0.20	120	1.96	Sang Kaset
6	Poor stand, weeds	55	1.80	426	0.37	24	7.93	Khao Saat
7	Deep early flood	150	1.41	664	0.18	97	1.53	LMN III
8	Early drought	120	1.35	586	0.20	75	1.87	LMN III
9	Early drought, rat damage	50	1.25	904	0.14	113	1.27	Mali Luay
10	Early and mid-season drought	80	1.05	507	0.19	103	1.21	Khao Ma Kok
11	Severe early and midseason drought	100	0.34	477	0.13	37	2.11	Jam Pah Pay

[a]Yield was from 25-m² samples; yield components were from 1-m² samples.

FACTORS INFLUENCING DEEPWATER RICE PRODUCTION ON THE CENTRAL PLAIN OF THAILAND

Thirteen simple N, P, and herbicide experiments were established in farmers' fields to assess yield-limiting factors. Surface soil (0-10 cm) was analyzed for pH and chemical properties, and all sites were monitored for pests and diseases. Before flooding, a leaf-eating complex of gryllids, hispa, flea beetle, grasshoppers, RWM, LF, thrips, and leaf miner caused only minor foliage damage. GM damaged a few plants. At site 3 (Prachinburi), 4.4% deadhearts were recorded in July, but the preflood average was 0.8%. Root-knot nematodes were found in several fields.

During flooding, rats cut stems in patches of several fields. RSV infected 38% of the fields, but less than in 1981. It was severe (5%) at only one site, Ongkharak. YSB infestation increased rapidly during late elongation and heading in October, and reached an average of 41% damaged stems and 4.1% whiteheads at harvest.

Environmental factors and crop establishment (Table 6) strongly influenced early growth, and there was little response to fertilizer. N significantly increased dry weight (44%) and yield (11%) at site 3. N decreased yield at site 9 where rat damage was greater in fertilized plots. Herbicide application increased rice dry weight at sites 3 and 4. Yields were not correlated with soil N or P, but HI (weight of grain/grain + straw) was positively correlated with yield.

Soil and crop management

Tillage and management of soil physical conditions

Agronomy, Agricultural Engineering, Multiple Cropping, and Soil Chemistry/Physics Departments

SIGNIFICANCE OF PERCOLATION LOSSES IN LOWLAND RICE **316**
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RESTRUCTURING OF PUDDLED SOIL FOR RAINFED MAIZE **321**

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SIGNIFICANCE OF PERCOLATION LOSSES IN LOWLAND RICE

Agronomy Department

Field and greenhouse experiments studied the significance of percolation rates in lowland rice production. The greenhouse experiment used three soils: sandy loam, loam, and clay loam. Some of their chemical properties are listed in Table 1. Percolation rates (0, 5, 10, 15, 20, 40, and 80 mm/d), regulated with a hose cock clamp and hypodermic needle, did not affect redox potential (Fig. 1) or soil temperature (Fig. 2). Grain yields were similar at all percolation rates (Table 2). Percolation rate alone may not affect yield significantly in soils without toxins in high, constant temperatures in the Asian tropics.

The field study was conducted at two IRRI farm sites — blocks M17a and UE2. Percolation rate was modified by puddling. Effects on soil physical properties and yield and its components were monitored.

Bulk density and soil strength. Bulk density of puddled soil in the top 10 cm was about 30% lower than that of nonpuddled soil (Table 3). The effect of puddling on bulk density was limited to 20-cm depth and decreased with time.

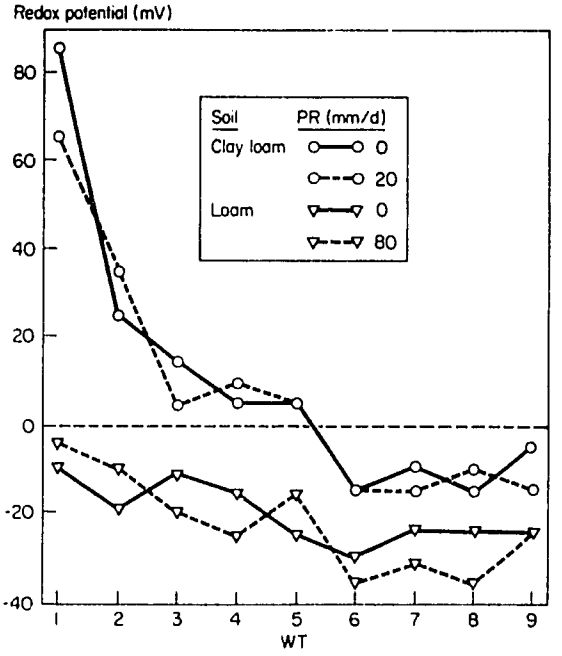
Soil strength in M17a at 7 and 60 DT was almost the same in puddled and nonpuddled conditions (Fig. 3). But in UE2, soil strength up to 15-cm depth was higher in nonpuddled soil.

Percolation rate and saturated hydraulic conductivity (K_s). Puddling decreased percolation rate and K_s in UE2 by about 70 to 80% (Table 4), but had negligible effect in M17a. Depth to water table was less in M17a than in UE2 throughout the growing period.

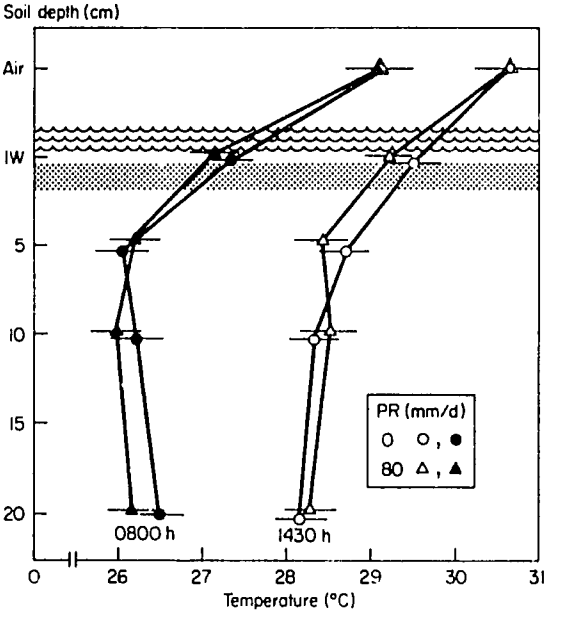
Oxidation-reduction potential. Puddling decreased soil redox potential at both locations (Fig. 4). The effect of puddling on Eh value at 10-cm soil

Table 1. Some chemical properties of soils used to study percolation rates in lowland rice production, 1983.

Soil property	Sandy loam	Loam	Clay loam
pH (1:1, wt/vol H_2O)	7.0	5.6	6.2
EC (mmho) (1:1, wt/vol H_2O)	0.20	0.26	0.94
CEC (meq/100 g soil)	17	24	27
OM (%)	1.0	3.4	1.3
Total N (%)	0.05	0.26	0.11
Olsen's P (ppm)	3	13	22
Exchangeable K (meq/100 g soil)	0.1	1.2	1.2
Available Zn (ppm)	0.8	1.0	1.4
Total Fe (%)	3.5	6.4	6.3
Total Mn (%)	0.6	0.4	1.2



1. Effect of percolation rate (PR) on the redox potential of soils at 10-cm depth. IRRI greenhouse experiment, 1983.



2. Effect of percolation rate (PR) on maximum and minimum temperature profiles in a loam soil. IRRI greenhouse experiment, 1983. IW = irrigation water.

Table 2. Effect of percolation rates (PR) on grain yield and yield components of rice. 1983.

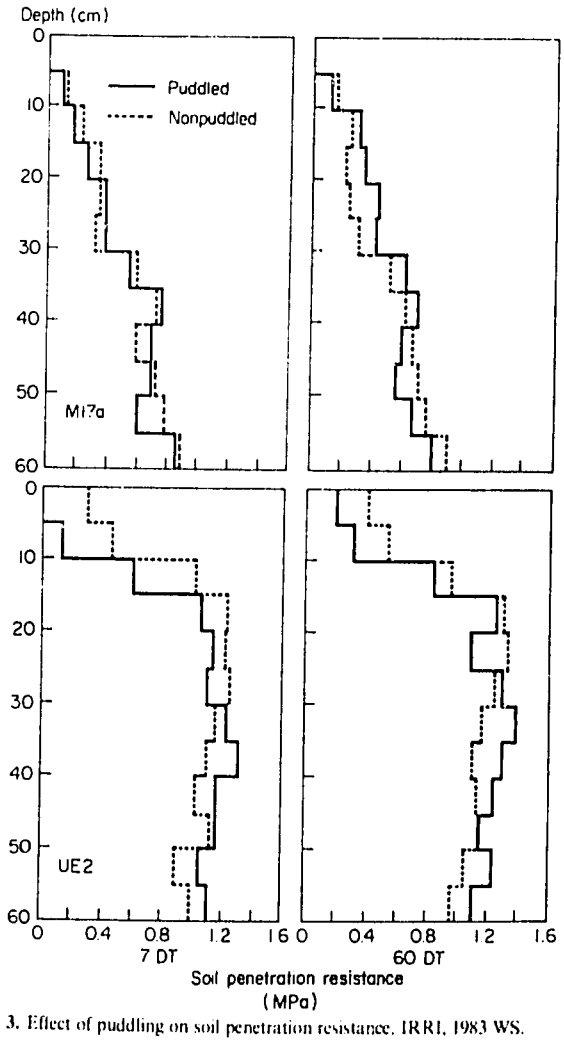
PR (mm/d)	Yield/ (g/pot)	Plant ht (cm)	Panicles (no./plant)	Panicle length (cm)	Grain (no./ panicle)	Panicle mass (g)	100-grain mass (g)	Unfilled spikelets (%)	Grain-straw ratio
					Clay loam				
0	92	99	22	24	108	2.2	2.4	14	1.20
5	70	95	18	23	103	2.0	2.4	16	1.10
10	81	95	20	24	110	2.5	2.4	13	1.20
15	73	97	18	24	104	2.2	2.4	13	1.00
20	77	102	18	25	107	2.3	2.5	15	1.10
	ns	ns	ns	ns	ns	ns	ns	ns	ns
					Sandy loam				
0	42	90	11	23	87	2.1	2.5	15	1.20
5	44	87	10	23	76	2.2	2.5	17	1.30
20	50	90	12	22	81	2.1	2.5	12	1.41
15	43	88	11	22	78	2.0	2.4	14	1.30
10	38	88	9	23	84	2.1	2.5	14	1.10
	ns	ns	ns	ns	ns	ns	ns	ns	ns
					Loam				
0	54	84	16	22	76	1.8	2.5	11	1.00
20	65	87	19	23	94	2.0	2.4	12	1.00
40	73	87	20	22	88	1.9	2.4	14	1.10
80	62	89	16	23	92	2.1	2.4	13	1.10
	ns	ns	ns	ns	ns	ns	ns	ns	ns

depth was greater at UE2 than at M17a. Eh values at 10-cm depth were similar (varying between 0 and -20 mV) in puddled soils at both locations.

Soil-temperature profiles. In block M17a, the minimum (at 0800 h) and maximum (at 1430 h) soil temperatures were hardly affected by puddling at any soil depth (Fig. 5), though puddling did decrease the diurnal temperature amplitudes, as it did at UE2. In block UE2, temperatures of irrigation water and soil were higher in nonpuddled soil. The maximum average temperature of nonpuddled soil down to 30-cm depth was about 1.4° C higher than that of puddled soil. At UE2, differences between maximum and minimum temperature in the top 10 cm was 2.4° C in puddled and 3.4° C in nonpuddled soil. At M17a the differences were 2.0° C for puddled and 2.6° C for nonpuddled soil. The diurnal fluctuations at both locations did not penetrate below 30-cm soil depth.

Table 3. Changes in bulk density of puddled (P) and nonpuddled (NP) soils. IRRI, 1983.

Depth (cm)	Bulk density (g/cc)							
	M17a				UE2			
	1 DT		60 DT		1 DT		60 DT	
	P	NP	P	NP	P	NP	P	NP
0-10	0.53	0.83	0.67	0.89	0.81	1.16	1.18	1.21
10-20	0.68	0.91	0.99	1.02	1.09	1.23	1.34	1.39
20-30	1.02	1.00	1.04	1.04	1.27	1.29	1.33	1.38



3. Effect of puddling on soil penetration resistance. IRRI, 1983 WS.

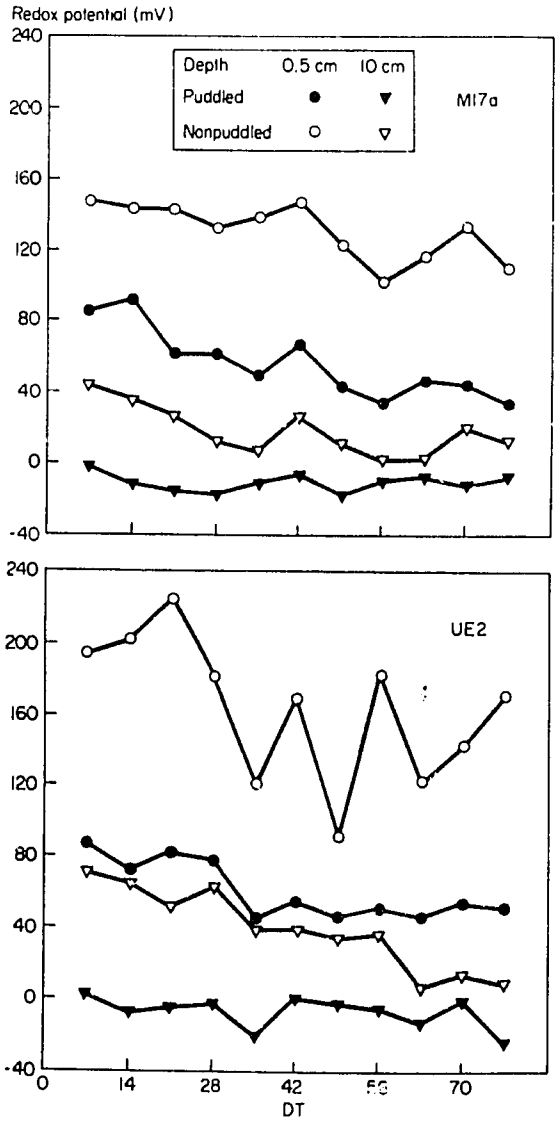
Table 4. Mean (±SD) values of percolation rate, saturated hydraulic conductivity (K_s), and water-table depth in M17a and UE2.[a] IRRI, 1983.

Location	Percolation rate (mm/d)		K_s (mm/d)		Water-table depth (cm)
	P	NP	P	NP	
M17a	1.8 ± 0.5	2.2 ± 0.5	2.0 ± 0.9	2.4 ± 1.9	22.7 ± 1.2
UE2	2.2 ± 0.7	8.5 ± 1.9	3.2 ± 0.9	15.3 ± 3.1	44.2 ± 2.8

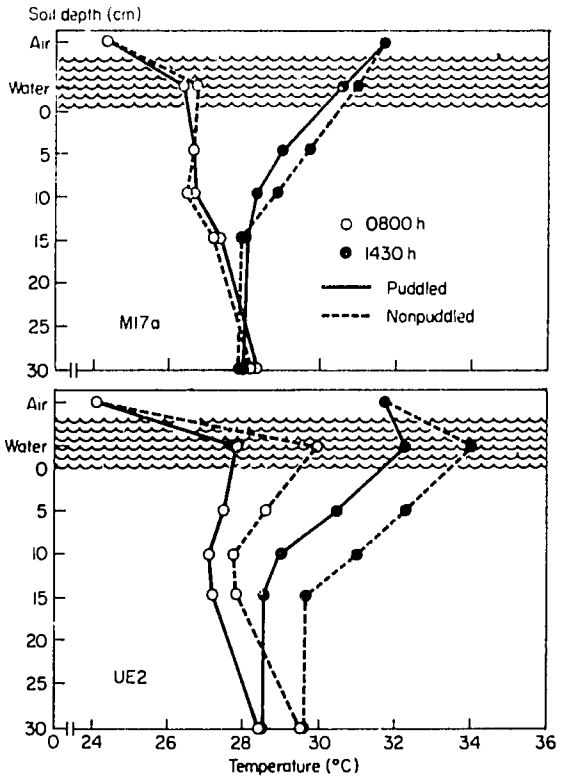
[a]P = puddled, NP = nonpuddled.

Nutrient losses from leaching. Irrespective of puddling treatment, soil solution concentrations of NO_3^-, NH_4^+, K, and Zn at 30-cm depth decreased with time; those of Mn and Fe increased; and P remained almost the same (Fig. 6). Solution concentrations of Mn and Fe were always higher in puddled soils, and those of NO_3^- always lower in puddled than in nonpuddled soils. Concentrations in puddled soils of NH_4^+, P, and Zn were either higher than or comparable to those in nonpuddled soils.

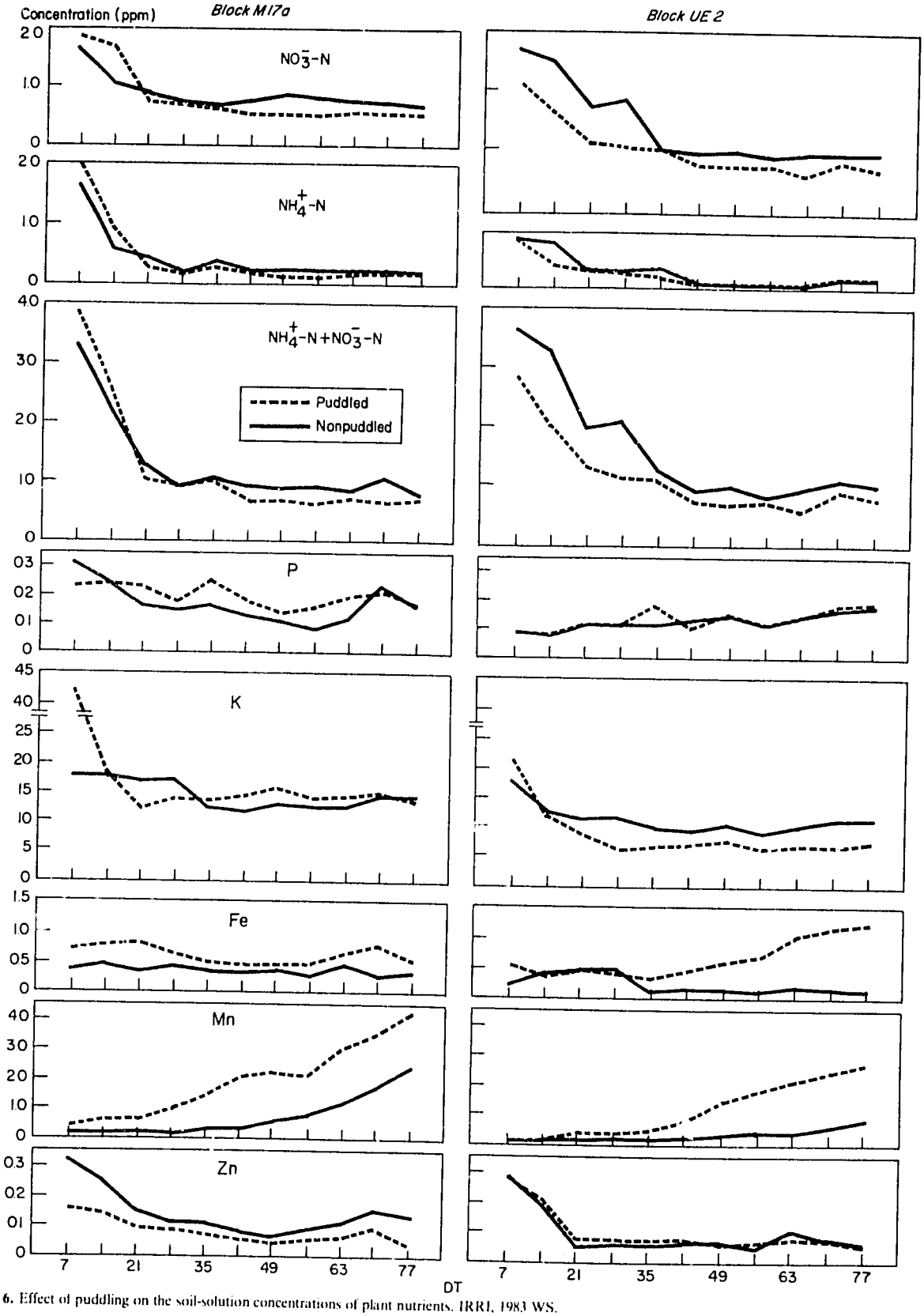
Nutrient uptake by plants. Puddling significantly increased nutrient uptake (Table 5) largely because of higher total DM production in puddled soil. For some elements (especially Mn and Zn) higher nutrient uptake in puddled soil was associated with increased nutrient concentration in grain and straw (Table 6, 7).



4. Effect of puddling on soil redox potential. IRRI, 1983 WS.



5. Maximum and minimum temperature profiles as affected by puddling. IRRI, 1983 WS.



6. Effect of puddling on the soil-solution concentrations of plant nutrients. IRRI, 1983 WS.

Table 5. Effect of puddling on the nutrient uptake of rice. IRRI, 1983.

Treatment	Total nutrient uptake (kg/ha)					
	N	P	K	Fe	Mn	Zn
			M17a			
Puddled	130	27	186	10	4.8	0.6
Nonpuddled	114	22	157	8	4.0	0.4
LSD	15**	3**	25*	ns	0.6*	0.1**
			UE2			
Puddled	110	25	209	7	5.1	0.4
Nonpuddled	74	15	138	5	2.3	0.2
LSD	20**	6**	36**	ns	1.5**	0.1**

Yield and yield components. The crop stand in nonpuddled soil of UE2 was poor because of higher soil bulk density and higher soil strength at transplanting time. This reduced plant height and yield.

Yield was significantly higher in puddled than in nonpuddled soil (Table 8), because of more grain per panicle and higher panicle mass.

Soil physical properties in the maximum-yield experiment sites (blocks N13 and UB2). Diurnal

Table 6. Nutrient uptake by rice grains as affected by puddling. IRRI, 1983.

Treatment	Nutrient uptake by grain											
	N		P		K		Fe		Mn		Zn	
	%	kg/ha	%	kg/ha	%	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha
						M17a						
Puddled	1.4	80	0.32	18.6	0.3	16.0	184	1.1	91	0.5	30	0.18
Nonpuddled	1.3	62	0.33	16.0	0.3	14.4	180	0.9	68	0.3	32	0.16
LSD	ns	9**	ns	2.2**	ns	ns	ns	ns	12**	0.1**	ns	ns
						UE2						
Puddled	1.2	66	0.34	18.6	0.3	17.2	207	1.2	79	0.4	31.4	0.17
Nonpuddled	1.2	42	0.31	11.1	0.3	11.2	218	0.8	52	0.2	29.6	0.11
LSD	ns	14**	ns	4.8**	ns	4.1**	ns	0.3**	24**	0.1**	1.7*	0.03**

Table 7. Nutrient uptake by rice straw as affected by puddling. IRRI, 1983.

Treatment	Nutrient uptake by straw											
	N		P		K		Fe		Mn		Zn	
	%	kg/ha	%	kg/ha	%	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha
						M17a						
Puddled	0.8	51	0.12	8.0	2.6	170	1291	8.8	649	4.3	56	0.4
Nonpuddled	0.9	52	0.09	5.6	2.5	142	1234	7.2	634	3.7	42	0.2
LSD	ns	ns	0.02*	1.6**	ns	25*	ns	ns	ns	ns	11**	0.1**
						UE2						
Puddled	0.6	44	0.09	6.3	2.7	192	782	5.6	654	4.6	34	0.24
Nonpuddled	0.6	32	0.08	4.0	2.3	126	678	3.9	369	2.1	21	0.12
LSD	ns	10*	ns	1.8**	0.3*	34**	ns	ns	68**	1.4**	6**	0.05**

Table 8. Effect of puddling on grain yield and yield components of IR36[a]. IRRI, 1983.

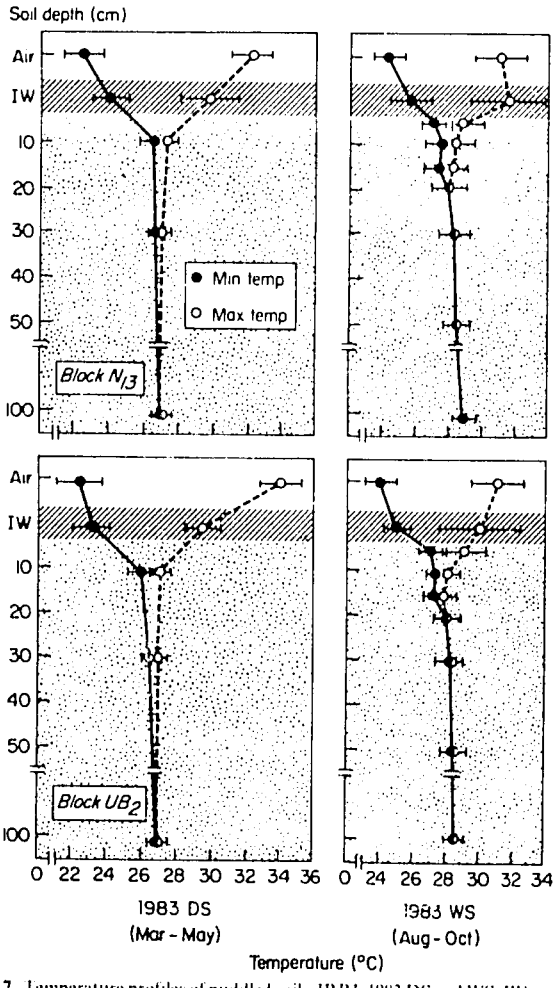
Treatment	PR (mm/d)	Grain yield (t/ha)	Plant ht (cm)	Panicles (no./m²)	Panicle length (cm)	Panicle mass (g)	Grains (no./panicle)	Unfilled spikelets (%)	100-grain mass (g)
					M17a				
P	1.8	5.9	94	431	20	2.7	105	8	2.4
NP	2.2	4.9	90	392	20	2.0	90	8	2.4
LSD	–	0.6**	ns	ns	ns	0.5*	13*	ns	ns
					UE2				
P	2.2	5.5	79	436	20	2.6	104	9	2.4
NP	8.5	3.6	68	456	20	1.9	85	11	2.3
LSD	–	0.8**	7**	ns	ns	0.6*	16**	ns	ns

[a]PR = percolation rate, P = puddled, NP = nonpuddled.

temperature fluctuations in puddled soils of blocks N13 and UB2 did not penetrate below 20 cm (Fig. 7). Minimum and maximum temperatures of irrigation water and soil were slightly higher in WS than in DS but never exceeded 35° C, which is a critical upper limit of soil temperature for rice growth.

Data on soil bulk density and soil strength 1 mo after transplanting are reported in Table 9. Soil strength of the 10-30 cm layer in UB2 was about 2.5 times higher than that of N13. A hardpan at this shallow depth might influence yield.

Percolation rates were about 1 mm/d in N13 and 3 mm/d in UB2. Saturated hydraulic conductivity profiles, measured *in situ* using piezometric soil water pressures and vertical percolation rates are shown in Figure 8.



7. Temperature profiles of puddled soils. IRRI, 1983 DS and WS. IW = irrigation water.

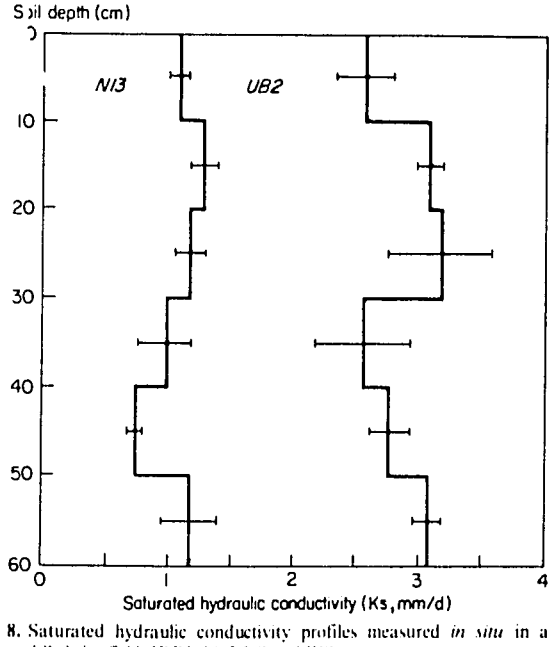
Table 9. Bulk density (Db), maximum soil strength (SS), and volumetric moisture content (v) of puddled soils. 1983.

Depth (cm)	N13			UB2		
	Db (g/cc)	SS (MPa)	v (%)	Db (g/cc)	SS (MPa)	v (%)
0-10	0.51	negligible	63	0.53	negligible	69
10-20	0.63	0.2	62	0.81	5	64
20-30	1.09	0.7	59	1.15	17	56
30-40	0.99	1.3	59	1.19	23	55
40-50	0.93	2.3	60	1.10	28	57
50-60	0.92	3.1	63	1.07	31	58

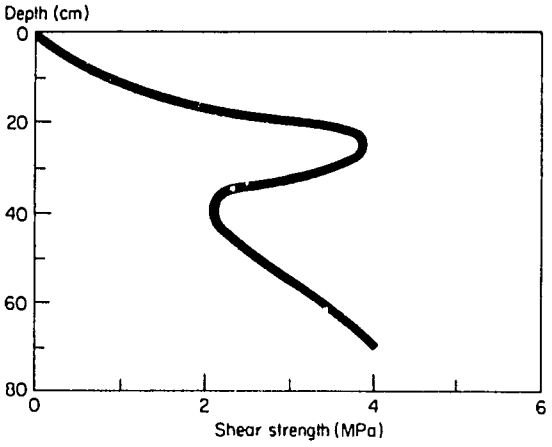
RESTRUCTURING OF PUDDLED SOIL FOR RAINFED MAIZE

Agricultural Engineering, Multiple Cropping, and Soil Chemistry/Physics Departments

Physical changes caused by puddling may also affect an upland crop that follows rice in a rainfed lowland cropping sequence. The upland crop takes its water from soil moisture remaining after rice harvest supplemented by DS rainfall. But the puddled soil may have an amorphous structure, with few large pores, and may also have a compacted layer at 25- to 40-cm depth. As the soil dries, its shear strength, measured by a cone penetrometer, can exceed 2 MPa (Fig. 9). At this strength,



8. Saturated hydraulic conductivity profiles measured *in situ* in a puddled rice field. IRRI, 1983 DS and WS.



9. Resistance (shear strength) to cone penetrometer at different depths in plot F12 at IRRI, June 1983.

root elongation of maize and other crops is impeded. Moreover, the soil below the compacted layer may be depleted of O_2. In such soil structures, roots have difficulty in penetrating deeply and in absorbing water.

Strip tillage is one way of restructuring these puddled soils. A single subsoiler tine breaks into the compacted zone and disturbs the soil to 35 or 40 cm depth along parallel strips 40 or 50 cm apart. The strips are then planted with maize seeds or some other crop for which individual plants are sufficiently large to provide a closed canopy when grown at these row spacings. This method, using appropriate technology, would require low power (draft) and energy, could achieve a rapid turnaround at high soil moisture, and would not waste water needed for repuddling for the next rice crop during the oncoming WS.

During 1983 DS at IRRI, the strip tillage method was evaluated by comparing soil physical and plant variables among plots with strip tillage, no tillage, and conventional tillage (moldboard plowing fb two harrowings). The soil — Typic Tropaquept — had a uniform texture to 50-cm depth (Table 10), although there was a slight variation in dry bulk density. Preliminary trials of strip tillage machinery showed that a specially-designed tine pulled by a 4 kW (6 hp) hand tractor could achieve acceptable soil disturbance to 30-cm depth. Traction was barely adequate at the high soil moisture immediately after rice harvest. For the experiment, a 27 kW (37 hp) tractor pulled a single subsoiler tine for strip tillage. Using this system, turnaround time (the interval between simulated draining of the puddled field and planting of the succeeding crop) was 4 d, compared to 1 d for untilled plots. During this time, the soil dried slightly at seed depth (Table 11). Strip tillage restructured the soil to 35-cm depth, substantially increased total porosity of the 0-30 cm layer, but created a very cloddy tilth. The clods were much larger than the maize seeds (variety IPB1) that were dibbled into the strip-tilled soil, and the moldboard-plowed and the untilled plots.

Because of the cloddy tilth and slight drying of the surface soil, germination and emergence rates were less on the strip-tilled plots than on the zero-tilled or conventionally tilled plots (Table 11). However, two seeds were planted in each hill, and sufficient plants emerged in each plot to permit meaningful evaluation of the crop responses to tillage. Moreover, a supplementary experiment showed that if the cloddy tilth was mildly compacted, germination and emergence were equal to those on the untilled plots. The major plant response to tillage (Fig. 10) was deeper and more prolific rooting on the strip-tilled plots, reflecting increased porosity of the 0-30 cm layer. Roots at depth in the strip-tilled plots extended more widely

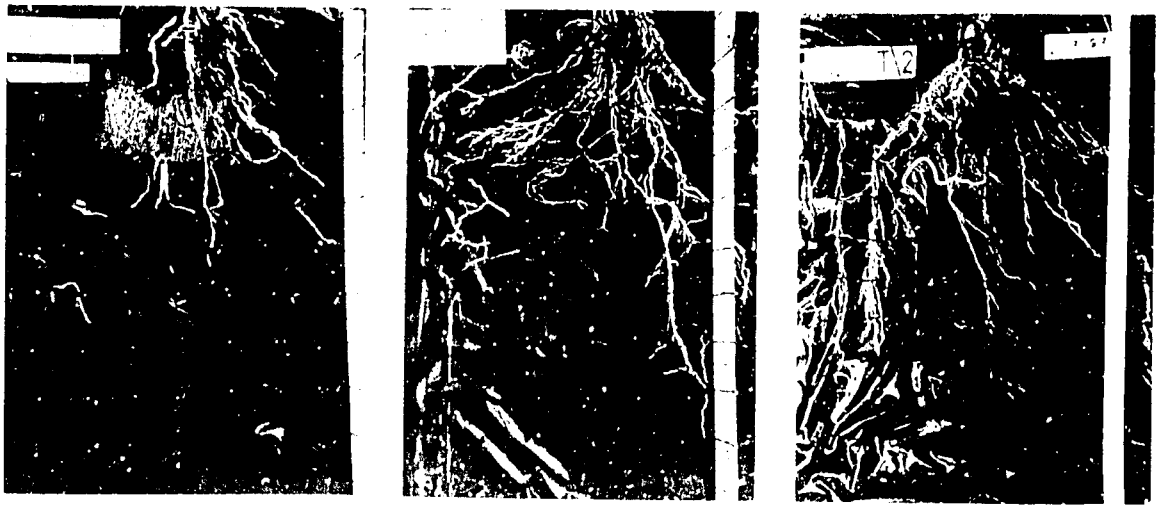
Table 10. Soil physical properties on plot F12 at IRRI, 1983.

Depth (cm)	Organic C (%)	Bulk density (t/m^3)	Clay (%)	Silt (%)	Sand (%)	Texture
0-10	1.4	0.96	41	40	19	Silty clay
10-20	1.1	1.05	36	39	25	Clay loam
20-30	1.0	1.06	40	39	21	Clay loam
30-40	0.9	1.00	39	38	23	Clay loam
40-50	0.7	0.98	41	34	25	Clay

Table 11. Effect of tillage treatment on turnaround time, volumetric soil-water content (0-10 cm) at planting, and germination and emergence of maize plants. Plot F12, IRRI, 1983 DS.

Tillage	Turn-around time (d)	Volumetric water content (%)	Germi-nation[a] (%)	Emer-gence[a] (%)
None	1	53 ± 2	84 ± 2	79 ± 2
Conventional	2½	54 ± 3	66 ± 7	62 ± 7
Strip	4	51 ± 2	52 ± 8	49 ± 8

[a]For seeds sown at 6-cm depth.



10. Maize roots on an untilled plot (T_0), a moldboard-plowed plot (T_1), and a strip-tilled plot (T_2). IRRI, 1983.

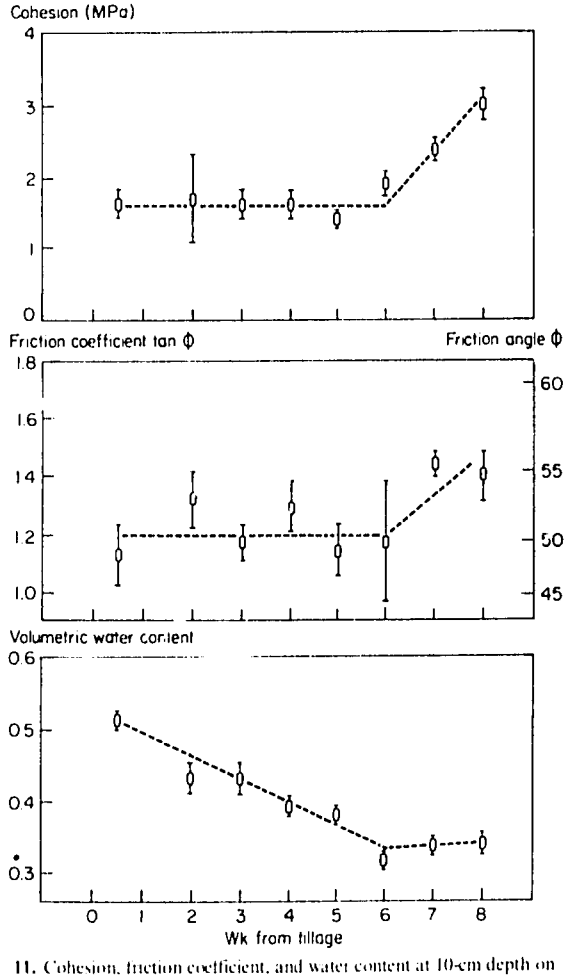
along the tillage line than *across* the line. This further demonstrated the effectiveness of strip tillage in promoting root growth below the compacted layer. Aboveground plant growth showed no significant response to tillage treatment (Table 12). Tillage did not affect nutrient uptake. Strip-tilled plots had shorter plants because of the 2-3 d longer turnaround time for those plots; their plants were 2-3 d younger at the time of height measurement. Plant height did not respond to deeper rooting on the strip-tilled plots because the water table was shallow. The experimental site was next to a flooded field, and despite 1.0-m-deep interception ditches, the water table was within 0.6 m of the soil surface in many places. Therefore, plants on strip-tilled plots did not need the deeper rooting promoted by tillage.

Physical measurements showed that, for the 10-30 cm soil layer, soil shear strength as measured by a cone penetrometer was much less in tilled strips than in untilled or conventionally tilled soil. At the existing soil bulk densities, penetrometer shear

Table 12. Effect of tillage treatment on mean height of maize plants on 1 May 1983. Plot F12, IRRI farm.

Tillage	Days from sowing	Plant ht[a] (cm)
None	26	44.8 ± 0.9
Conventional	24½	46.4 ± 2.4
Strip	23	42.7 ± 1.3

[a]Av of plantings at 2½ and 6-cm depth.



11. Cohesion, friction coefficient, and water content at 10-cm depth on plot F12, IRRI farm, as related to weeks since tillage. Av over 3 tillage treatments, and for normal stresses of 0-2.5 MPa. 1983.

strength was greater than 2 MPa (the limiting strength for maize root penetration) at volumetric water contents less than about 0.45. Shear strength was measured also by shear vane; both penetrometer and vane measures of strength relate to the ability of a root or a tillage implement to displace soil particles. Values for confined shear strength, when fitted to a simplified Mohr-Coulomb model, estimated cohesion C and friction angle ϕ, plotted in Figure 11 against wk since tillage. At 10-cm soil depth, averaged over all tillage treatments, C and ϕ were affected more by soil water content than by tillage. The values for ϕ exceed 45°. This suggests that even for a soil that has been puddled for many years, the soil geometry is too complex for a valid Mohr-Coulomb analysis.

After the maize crop, the soil needed repuddling for a succeeding WS rice crop. The water infiltration rate was measured to determine whether deliberate disruption by strip tillage of the compacted layer would allow land preparation water to percolate wastefully. Percolation rate was no more rapid on the strip-tilled than on the other plots (Table 13). Because of the deep cracking from the very dry April and May of 1983, all plots had rates as high as 20 mm/h. Nonetheless, all plots allowed repuddling and supported satisfactory rice crops in the ensuing WS.

Table 13. Effect of tillage treatment on end-of-season percolation of impounded water. Plot F12, IRRI, 1983 DS.

Tillage	Percolation rate[a] (cm/h)
None	2.2 ± 0.4
Conventional	1.8 ± 0.4
Strip	2.2 ± 0.4

[a]After allowing for 0.1 cm/h evaporation.

Climatic environment and rice

Plant Physiology and Multiple Cropping Departments

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RICE-WEATHER STUDIES

Multiple Cropping Department

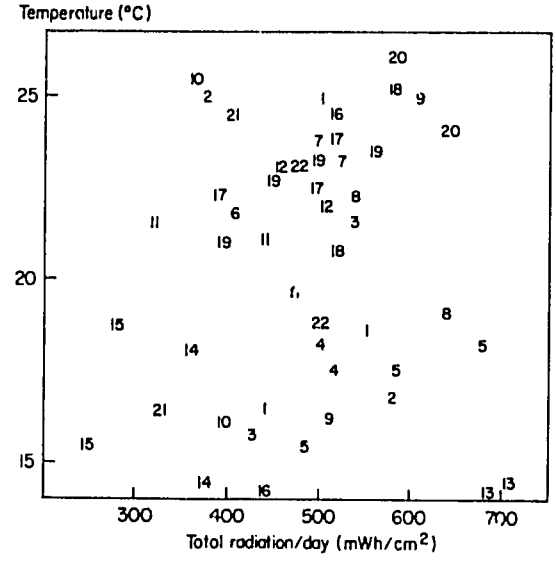
The geographical distribution of rice growing areas shows rice is cultivated in diverse climatic conditions. Under full irrigation when water is not a constraint and with minimal biological stresses, rice yield depends primarily on atmospheric factors such as air temperature and total solar radiation. The full impact of different radiation and temperature regimes on rice yields is not completely understood because detailed rice-weather studies have been confined to a few locations. These areas represent a narrow range of weather variability and actual measurements of weather variables, particularly total radiation, are limited.

Rice-weather studies are a special IRTIP project conducted in close cooperation with the World Meteorological Organization. IRTIP irrigated nurseries promote a better understanding of varietal behavior in response to climatic differences. Climatic records from a large number of IRTIP sites were used in selecting 22 locations in 16 rice growing countries. The sites were chosen because of their specific radiation and temperature combinations during the particularly sensitive 30-d period after flowering. For the selected locations, Figure 1 shows the various temperature and radiation regimes after flowering when nurseries are transplanted according to predetermined dates.

Initially, the project compared several instruments for monitoring total incident solar radiation:

- RIMCO electronic integrating pyranometer, model R/EIP,
- Medos pyranometer 81/EP07 with digital integrator 62/MDI-100,
- Multipurpose pyranometer-integrator set 616B (Science Associates),
- Kipp Solarimeter with Cimel integrator CE261,
- Gunn-Bellani solar radiation integrator, and
- Li-200 SB pyranometer with Li-510 B integrator.

After 3 mo at the lowland agrometeorological station at IRRI, the self-contained RIMCO pyranometer was chosen as the standard monitoring instrument. It is weather-proof under humid tropical conditions, does not need frequent calibration, does not need a reliable source of electricity or frequent change of batteries, and uses very simple recording operations. The Gunn-Bellani solar radiation integrator was chosen as a backup instrument. It is also self-contained, is relatively inexpensive, and needs no mechanical or electronic parts to drive the system.



1. Minimum temperature and total radiation regimes expected during 30 d after flowering at the following IRTIP nursery locations. 1. Joydebpur, Bangladesh; 2. Yezin, Burma; 3. Nanjing, China; 4. Palmira, Colombia; 5. Sakha, Egypt; 6. Hyderabad, India; 7. Pattambi, India; 8. Coimbatore, India; 9. Kapurthala, India; 10. Cuttack, India; 11. Bogor, Indonesia; 12. Sukamandi, Indonesia; 13. Ahero, Kenya; 14. Suweon, Korea; 15. Milyang, Korea; 16. Parwanipur, Nepal; 17. Ibadan, Nigeria; 18. Dokri, Pakistan; 19. Los Baños, Philippines; 20. Parantha, Sri Lanka; 21. Pingtung, Taiwan, China; 22. Sanpatong, Thailand.

All sites received these two radiation monitoring devices. In addition, maximum and minimum thermometers, and dry and wet bulb thermometers were replaced at some locations where needed.

At a number of locations, new standard agrometeorological stations were constructed and meteorological observers were trained on the spot. By mid-1983, most agrometeorological stations were operational. The first International Rice Weather Yield Nurseries (IRWYN) were transplanted in July. All 22 sites received seed material from 9 of the best IRWYN entries from the Philippines (IRRI), Sri Lanka, and Taiwan (China). National program coordinators include one of their best local selections as the tenth entry.

In 1983, 26 IRWYN trials were completed and another 52 are planned for 1984.

HEADING SYNCHRONIZATION IN IR50, IR36, AND IR42

Plant Physiology Department

The heading pattern in 100 hills of IR50, IR36, and IR42 was evaluated in 1983 DS and WS. The plants received 150 kg N/ha and were 20 × 20 cm apart.

Dry season. IR50 and IR36 were seeded on the same date and then transplanted when both had developed five leaves. Heading date was noted when 50% of the panicles in a hill were exserted. IR50 and IR36 reached maximum heading 7 to 8 d from initial panicle appearance and headed completely in 13 to 14 d. High rates of panicle exsertion were 2 to 3 d before or after maximum heading period.

Wet season. IR50, IR36, and IR42 were seeded at different times but transplanted after development of the fifth leaf. IR36 was seeded twice: 2 and 3 d earlier than IR50. IR42 was sown 25 d ahead of IR50 and also on the same date as IR50.

Season hardly affected duration, peak period, and spread of high heading percentage (Table 1).

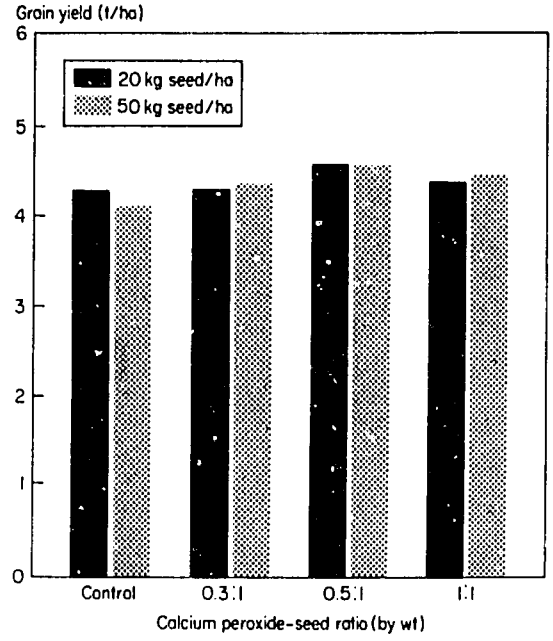
CALCIUM PEROXIDE AS OXYGEN SUPPLIER

Plant Physiology Department

Calcium peroxide-seed ratio and seeding rate. Field experiments in 1982 showed that at 50 kg seeds/ha, reducing the CaO_2-seed ratio from the recommended rate of 1:1 (by weight) to 0.3:1 did not affect grain yield. A field test in 1983 compared performance of broadcast 50 kg seeds/ha and 20 kg seeds/ha with various CaO_2-seed ratios. Differences in seedling stand with various CaO_2-seed ratios were insignificant.

Table 1. Heading pattern of IR36, IR50, and IR42 seeded at different dates. IRRI, 1983.

Variety	Seeding date	Duration of heading (d)	Peak period (d)	Spread of high heading percentage (d)
IR50	22 Dec	13	7	5
	12 Jul	13	8	4
IR36	22 Dec	14	8	6
	9 Jul	16	7	4
	10 Jul	16	8	4
IR42	17 Jun	16	11	5
	12 Jul	13	6	4
	Mean	14.4	7.8	4.6



2. Effect of various thicknesses of CaO_2 coating on grain yield. IRRI, 1983 DS. Control was uncoated pregerminated seeds.

Yields of CaO_2-coated seeds broadcast in shallow water were comparable to traditional broadcast pregerminated seeds in a drained field (Fig. 2). Yields were highest in 0.5:1 plots but yield differences between CaO_2-seed ratios and between seeding rates were insignificant. With broadcast seeding at 20 kg/ha in flooded fields, the CaO_2-seed ratio can be reduced to 0.3:1. Yield is expected to compare favorably with yield of plants receiving the recommended ratio of 1:1.

Seeding method, seeding rate, and nitrogen. Traditional direct-seeded crops of 80 to 120 kg seeds/ha lodge early if applied N is high. A 2-row manual seeder places CaO_2-coated seeds 10 mm into the mud, deeper than by broadcasting them on puddled soil.

Row seeding and broadcasting of CaO_2-coated seeds were compared at 30 and 50 kg seeds/ha and 0 to 150 kg N/ha during 1983 DS. With a 2-row paddy seeder, seeds were more uniformly distributed at 30 kg seeds/ha and the plants did not lodge. Row-seeded and broadcast crops with high

N completely lodged 4 d before harvest. Differences in yield between seeding rates at the same N were insignificant. Increase in yield with N was slightly higher at lower seeding rate. Compared to the traditional seeding rate of 80 to 120 kg seeds/ha, 30 kg seeds/ha is low but yield was still adequate. With uniform seed distribution (by paddy seeder) at low seeding rate, yield may be improved further in direct-sown and transplanted rice by increasing N application. High percentage of seedling emergence from submerged soil with CaO_2-coated seeds makes that possible. Suppression of early weed growth by field submergence and the convenience in weeding straight-row planting are an added advantage.

Constraints on rice yields

Agricultural Economics and Agronomy Departments

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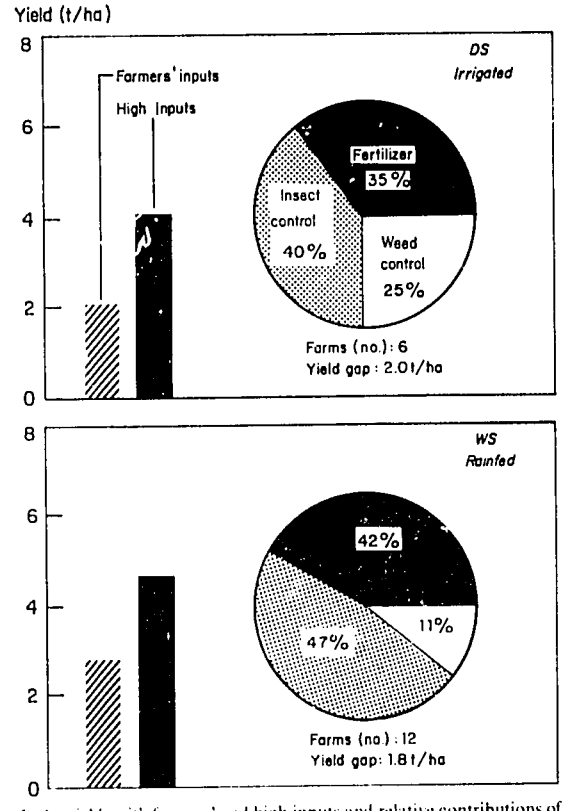
RICE YIELD CONSTRAINTS

Agricultural Economics and Agronomy Departments

National average rice yields in the tropics are below practical and potential levels. IRRI research aims to identify factors which prevent higher on-farm yields and determine whether such constraints can be economically removed. IRRI collaborates with national programs conducting similar on-farm research in eastern India and Pakistan.

Past constraints research at IRRI focused on irrigated environments. More recently, emphasis has shifted to rainfed, specifically shallow rainfed environments, which account for about one-quarter of the world's rice lands. Two Philippine rainfed sites were studied: in Tarlac, Central Luzon, farmers grow one rice crop each year; and in Camarines Sur, Bicol, two rainfed rice crops are grown each year. Irrigated sites in Camarines Sur and Tarlac were used mainly for DS experiments and for comparison with rainfed sites.



1. Av yields with farmers' and high inputs and relative contributions of fertilizer, weed control, and insect control toward improvement of rice yields on irrigated and rainfed farms in Tarlac, Philippines, 1983 DS and WS.

MANAGEMENT CONSTRAINTS

Agronomy Department

Rice yield constraints on rainfed and irrigated farms. *Tarlac irrigated sites.* DS experiments on six

Table 1. Input levels in yield-constraints experiments on irrigated farms in 3 areas in the Philippines, 1983.

Water regime	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P_2O_5	K_2O	M	C	F	G
			Tarlac, 1983 DS						
Irrigated	Farmers'	6	49	0	0	0	0.3	1.8	0
Irrigated	High	6	87	30	30	1.0	1.0	3.0	2.0
			Camarines Sur (Libmanan site), 1983 DS						
Old irrigated area	Farmers'	10	26	9	6	0.3	0.5	1.5	0
Old irrigated area	High	10	84	30	30	1.0	1.0	3.1	2.0
New irrigated area	Farmers'	8	39	6	0	0.1	0.8	1.8	0
New irrigated area	High	8	87	30	30	1.0	1.0	3.8	2.0
Flood-prone area	Farmers'	8	20	2	0	0.1	0.6	1.9	0
Flood-prone area	High	8	87	30	30	1.0	1.0	3.9	2.0
			Camarines Sur (San Fernando site), 1983 DS						
Poorly irrigated	Farmers'	9	38	8	2	0.4	1.3	2.0	0
Poorly irrigated	High	9	77	30	30	1.0	1.0	3.2	1.7
Adequately irrigated	Farmers'	4	22	4	4	0.5	1.0	2.3	0
Adequately irrigated	High	4	87	30	30	1.0	1.0	3.3	2.0
			Camarines Sur (Libmanan site), 1983 WS						
Old irrigated area	Farmers'	9	23	8	5	0.1	0.6	1.8	0
Old irrigated area	High	9	60	30	30	1.0	1.0	3.3	2.0
New irrigated area	Farmers'	9	15	5	2	0.1	0.7	1.7	0
New irrigated area	High	9	60	30	30	1.0	1.0	3.1	2.0
Flood-prone area	Farmers'	2	0	0	0	0.5	1.0	0.5	0
Flood-prone area	High	2	60	30	30	1.0	1.0	3.0	2.0

[a] Av no. of mechanical (M) weeding, either by HW or by rotary weeder, and chemical (C) herbicide applications. [b] Av no. of foliar (F) sprays (azodrin, gusathion, etc.) or of granular (G) applications (furadan, diazinon, etc.) to paddy water.

Table 2. Yields at farmers' and increasing N levels from experiments on irrigated farms in 3 areas in the Philippines, 1983 DS.

Province	Sites (no.)	Yield[a] (t/ha)				
		Farmers' level	Zero N	58 kg N/ha	87 kg N/ha	116 kg N/ha
Tarlac	6	2.1 b	2.7 b	3.8 a	4.1 a	4.1 a
Camarines Sur						
Libmanan (old area)	10	3.2 c	3.5 c	4.4 b	4.9 ab	5.0 a
Libmanan (new area)	8	3.5 c	4.1 b	4.8 a	5.0 a	5.0 a
Libmanan (flood-prone)	8	4.0 d	4.7 c	5.0 bc	5.5 ab	5.6 a
San Fernando (adequately irrigated)	4	4.7 b	4.2 b	5.9 a	5.9 a	6.2 a
San Fernando (poorly irrigated)	9	2.7 ab	2.4 b	3.0 a	3.0 a	2.9 a

[a]Separation of means in a row by Duncan's multiple range test at the 5% level.

farmers' fields determined the yield gap between farmers' inputs and high inputs; the relative contributions of fertilizer, weed control, and insect control to the yield gap; and evaluated the yield response to applied P and K and increasing N levels. Farmers' N applications averaged 49 kg/ha (Table 1). Insect control consisted of two foliar sprays but weed control was negligible. High fertilizer application accounted for 35% of the 2.0 t/ha yield gap in DS (Fig. 1). Improved insect control contributed 40% and weed control accounted for 25%. Grain yields with researchers' split-applied PU at 58, 87, and 116 kg N/ha were similar and were significantly higher than the yields without applied N (Table 2). Plots without added N and farmers' N level produced similar yields, suggesting an inefficient method and timing of N application by farmers.

Application of NPK at the rate of 87-30-30 kg/ha produced yields significantly higher than the yields without N. Yields without P or K were reduced but the differences were not significant (Table 3).

Tarlac rainfed sites. WS experiments were conducted on 12 rainfed farms — 6 each in high and low elevation areas. Farmers in high-elevation

Table 3. Yield response to N, P, and K applications on rainfed and irrigated farms in 3 areas in the Philippines, 1983.

Province	Water regime	Sites (no.)	Yield[a] (t/ha)			
			NPK	PK	NK	NP
		DS				
Tarlac	Irrigated	6	4.1 a	3.0 b	3.7 ab	3.8 ab
Camarines Sur						
Libmanan	Old irrigated area	10	4.9 a	3.5 c	4.0 b	4.6 a
Libmanan	New irrigated area	8	5.0 a	4.1 b	4.8 a	4.6 a
Libmanan	Flood-prone irrigated area	8	5.5 a	4.7 b	5.2 ab	5.3 a
San Fernando	Poorly irrigated	9	3.0 a	2.4 b	2.9 ab	2.9 ab
San Fernando	Adequately irrigated	4	5.9 a	4.2 b	6.1 a	6.2 a
		WS				
Tarlac	Low elevation, rainfed	5	3.7 a	3.0 b	3.4 ab	3.6 ab
Tarlac	High elevation, rainfed	5	4.7 a	4.2 a	4.5 a	4.7 a
Camarines Sur						
Libmanan	Low elevation, rainfed	3	3.5 a	3.3 a	3.0 a	3.5 a
Libmanan	Old irrigated area	5	4.9 a	4.3 c	4.4 bc	4.7 ab
Libmanan	New irrigated area	6	4.6 a	4.1 b	4.0 b	4.4 a
Libmanan	Flood-prone irrigated area	2	3.6 a	3.1 b	3.3 b	3.2 b
San Fernando	Low elevation, rainfed	6	4.4 a	5.1 a	4.4 a	4.6 a
San Fernando	Intermediate, rainfed	8	4.7 a	4.8 a	4.6 a	4.6 a
San Fernando	High elevation, rainfed	6	4.4 a	4.2 ab	4.5 a	4.5 a

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. Fertilizer levels: DS – 87 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha; WS – 60 kg N/ha, 30 kg P_2O_5/ha and 30 kg K_2O/ha.

Table 4. Input levels in yield-constraints experiments on rainfed farms in 3 areas in the Philippines, 1983 WS.

Landscape position	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P_2O_5	K_2O	M	C	F	G
			Tarlac						
Low elevation	Farmers'	11	20	6	5	0	0.4	2.1	0.1
Low elevation	High	11	60	30	30	1.0	1.0	3.0	2.0
High elevation	Farmers'	11	19	12	4	0	0.4	1.8	0.1
High elevation	High	11	60	30	30	1.0	1.0	3.0	2.0
			Camarines Sur (Libmanan site)						
Low elevation	Farmers'	4	0	0	0	0.5	0.2	3.0	0
Low elevation	High	4	60	30	30	0.8	1.2	3.5	2.0
High elevation	Farmers'	1	21	21	21	0	0	3.0	0
High elevation	High	1	60	30	30	1.0	1.0	3.0	2.0
			Camarines Sur (San Fernando site)						
Low elevation	Farmers'	7	16	2	2	1.7	1.5	2.6	0
Low elevation	High	7	47	30	30	0.4	1.0	3.7	2.0
Intermediate	Farmers'	11	20	1	1	0.8	1.4	1.9	0
Intermediate	High	11	60	30	30	0.3	1.1	3.6	2.0
High elevation	Farmers'	13	1	0	0	0.8	0.9	2.6	0
High elevation	High	13	60	30	30	0.7	1.1	3.5	1.9

[a]Av no. of mechanical (M) weeding, either by HW or by rotary weeder, and chemical (C) herbicide applications. [b]Av no. of foliar (F) sprays (azodrin, gusathion, etc.) or of granular (G) applications (furadan, diazinon, etc.) to paddy water.

areas applied 19 kg N/ha (Table 4). Their insecticide applications averaged two foliar sprays, and weed control was negligible. Low-elevation farmers used similar amounts of inputs.

In high-elevation areas, yields from farmers' inputs averaged 2.8 t/ha and those from high inputs averaged 4.5 t/ha, producing a yield gap of 1.7 t/ha. In low-elevation areas, high inputs increased grain yields by 1.9 t/ha over farmers' inputs. On both high and low elevation farms, high levels of fertilizer and insect control contributed significantly to the yield gap. Across all farms, improved insect control accounted for 47% of the 1.8 t/ha yield gap and high fertilizer levels, 42%. Improved weed control contributed 11% (Fig. 1).

Farmers' variety (mostly IR56) and test variety IR58 produced similar yields irrespective of landscape position or input level (Table 5). Zn ($ZnSO_4$) application did not increase grain yield in either landscape position (Table 6).

In a separate experiment, no P and no K treatments produced yields similar to those in the NPK treatments in both low and high elevation areas (Table 3). The absence of fertilizer N reduced grain yield significantly in low-elevation farms but not in high-elevation farms.

Camarines Sur (Libmanan) irrigated sites. DS experiments were conducted on 26 irrigated farms: 10 in the old area and 8 each in the new and flood-prone areas. Farmers' fertilizer levels were low (Table 1) and insect control consisted of two applications of foliar sprays. Farmers controlled weeds primarily with postemergence herbicides.

Across all sites, high input yields averaged 5.1 t/ha, significantly higher by 1.6 t/ha than the average yield with farmers' inputs. High fertilizer levels accounted for 70% of this gap; insect control contributed 18%; and weed control, 12% (Fig. 2). Yields responded significantly to 58 kg N/ha as researchers' split-applied PU in the old and new irrigated areas, but not in the flood-prone area (Table 2). Applying 87 kg N/ha gave no further yield response at both old and new irrigated areas. Farmers' yields in the three irrigated areas were similar to or significantly lower than those from plots without applied N, suggesting poor N use efficiency.

Application of complete fertilizer at the rate of 87 kg N, 30 kg P_2O_5, and 30 kg K_2O/ha in all areas produced significantly higher yields than the yields with no applied N. Plots without added P had lower yields, but the reduction was significant only

Table 5. Yield performance of farmers' varieties[a] compared to test variety IR58 at farmers' and high levels of inputs on rainfed and irrigated farms in 3 areas in the Philippines, 1983 WS.

Province	Landscape position	Sites (no.)	Input level	Grain yield (t/ha)		
				Farmers' variety	Test variety	Difference
			Rainfed			
Tarlac	Low elevation	6	Farmers'	2.8	2.4	-0.4^{ns}
Tarlac	Low elevation	6	High	4.7	4.5	-0.2^{ns}
Tarlac	High elevation	6	Farmers'	2.8	2.5	-0.3^{ns}
Tarlac	High elevation	6	High	4.5	4.2	-0.3^{ns}
Camarines Sur						
Libmanan	Low elevation	2	Farmers'	3.4	2.8	-0.6*
Libmanan	Low elevation	2	High	4.3	3.1	-1.1*
San Fernando	Low elevation	4	Farmers'	5.1	4.8	-0.3^{ns}
San Fernando	Low elevation	4	High	5.2	5.6	0.4^{ns}
San Fernando	Intermediate	6	Farmers'	4.7	3.4	-1.3*
San Fernando	Intermediate	6	High	4.4	4.3	-0.1^{ns}
San Fernando	High elevation	8	Farmers'	4.4	3.3	-1.1*
San Fernando	High elevation	8	High	5.0	4.9	-0.1^{ns}
			Irrigated			
Camarines Sur						
Libmanan	Old area	4	Farmers'	3.2	3.1	-0.1^{ns}
Libmanan	Old area	4	High	4.3	4.3	0^{ns}
Libmanan	New area	3	Farmers'	2.7	2.9	0.2^{ns}
Libmanan	New area	3	High	4.3	4.3	0^{ns}

[a]Dominant farmers' varieties: Tarlac – IR56 for both elevations; Libmanan – IR56 for rainfed sites, IR36 for old irrigated area, and IR50 for new irrigated area; San Fernando – IR52, IR36, and IR56 for low, intermediate, and high elevations.

in the old irrigated area (Table 3). Only two of eight sites in the new irrigated area and one of eight sites in the flood-prone showed significant response to added P. K application was unnecessary in the test sites.

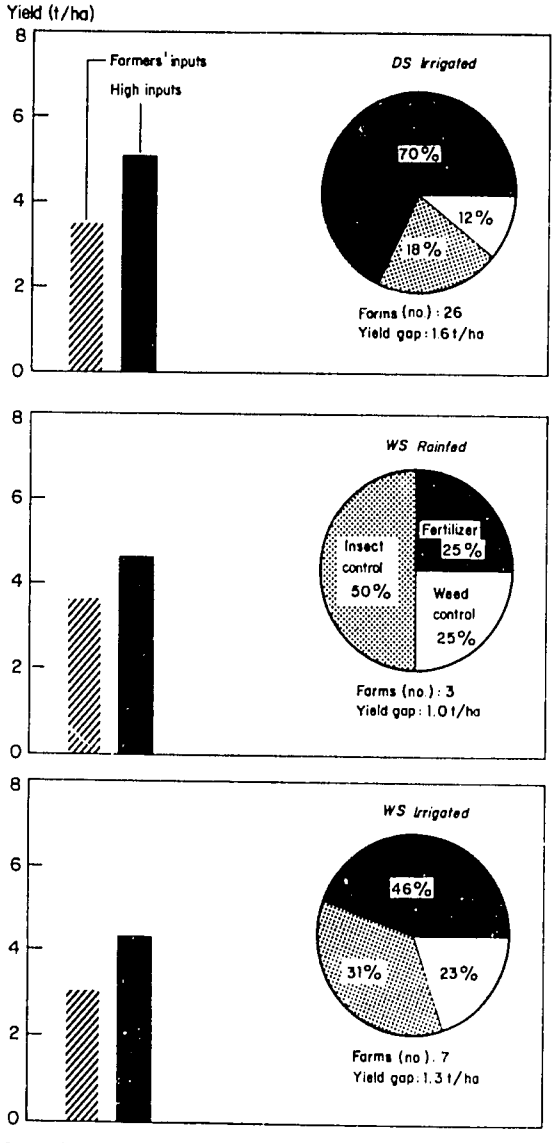
Camarines Sur (Libmanan) rainfed sites. During WS, the yield gap in rainfed and irrigated areas was determined. In the rainfed area, 12 trials — 7 at low elevation and 5 at high elevation — were conducted. One trial at high elevation was lost because of severe water shortage.

Farmers at the lower landscape did not apply fertilizer but controlled weeds by hand weeding or herbicide application. One farmer at the upper

Table 6. Yields with and without Zn applications on rainfed and irrigated farms in 3 areas in the Philippines, 1983 WS.

Province	Landscape position	Sites (no.)	Without Zn	With Zn[a]	Difference
			Yield (t/ha)		
		Rainfed			
Tarlac	Low elevation	11	4.2	4.1	-0.1^{ns}
Tarlac	High elevation	11	4.6	4.4	-0.2^{ns}
Camarines Sur					
Libmanan	Low elevation	5	3.7	3.8	0.1^{ns}
Libmanan	High elevation	1	5.3	5.3	0^{ns}
San Fernando	Low elevation	7	4.8	4.7	-0.1
San Fernando	Intermediate elevation	11	4.7	5.0	0.2
San Fernando	High elevation	13	4.7	4.8	0.1
		Irrigated			
Camarines Sur					
Libmanan	Old area	9	4.7	4.6	-0.1^{ns}
Libmanan	New area	9	4.5	4.5	0^{ns}
Libmanan	Flood-prone area	2	3.6	3.7	0.1^{ns}

[a]As $ZnSO_4$ at 10-30 kg/ha, basal B&I.



2. Av yields with farmers' and high inputs and relative contributions of fertilizer, weed control, and insect control toward improvement of rice yields on irrigated and rainfed farms in Libmanan, Camarines Sur, Philippines, 1983 DS and WS.

landscape applied 21 kg each of N, P_2O_5, and K_2O/ha but did not control weeds. Insecticide applications averaged three foliar sprays in both areas (Table 4).

Farmers' inputs at the lower landscape averaged 3.4 t/ha and high inputs, 4.3 t/ha. At high elevation, high input yields increased significantly by 1.3 t/ha over farmers' inputs. The average yield gap in rainfed areas was 1.0 t/ha with improved insect control accounting for 50% and fertilizer and weed control each contributing 25% (Fig. 2).

In two low elevation trials, the test variety (IR58) produced significantly lower yields than the farmers' variety (IR56) at both farmers' and high input levels (Table 5) mainly because of rat damage. Application of 20 kg $ZnSO_4$/ha did not significantly increase grain yield (Table 6) even though the test soils were deficient in Zn.

In a separate experiment, yields from NPK at 60 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha were similar to those from PK, NK, and NF combinations (Table 3). Low yields and absence of treatment differences were mostly caused by drought stress.

Camarines Sur (Libmanan) irrigated sites. In the irrigated sites, nine trials each were conducted in the old and new irrigated and flood-prone areas in WS. In the flood-prone area, seven trials were lost because of flooding caused by two strong typhoons. Farmers' levels of fertilizer, weed control, and insect control, particularly in flood-prone areas, were low compared to researchers' levels (Table 1).

Farmers' yields (1.9 to 5.2 t/ha) averaged 3.2 t/ha. High input yields varied from 2.3 to 6.0 t/ha, averaging 4.4. The yield gap from 20 irrigated farms was 1.2 t/ha. Contributions of fertilizer and weed and insect control to the yield gap were determined only from four farms in the old irrigated area and three in the new. Yields averaged 3.2 t/ha in the old area and 2.8 t/ha in the new. The average yield with high inputs in either landscape was 4.3 t/ha. Yields with both farmers' and high inputs were low because three trials (two at flowering stage and one at ripening stage) were severely damaged by a typhoon. Across all farms, the average yield gap was 1.3 t/ha. High fertilizer levels accounted for 46% of the gap; improved insect control, 31%; and weed control, 23% (Fig. 2).

Dominant farmer varieties were IR36 (old irrigated area) and IR50 (new irrigated area). Both produced yields similar to those of IR58 (test variety) (Table 5). Application of Zn as $ZnSO_4$ (20-30 kg/ha) gave no positive yield response in the test areas (Table 6) even though available Zn contents of test soils were below the 1.0 ppm critical level.

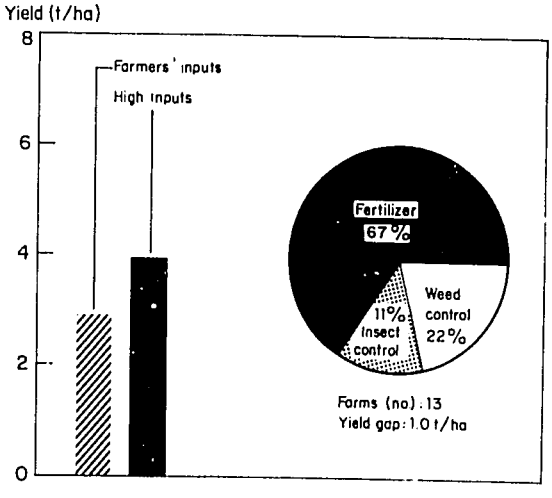
In a separate experiment, results from 11 trials in the old and new irrigated areas showed that yield response to complete fertilizer application (60-30-30) was comparable to those from the NP treat-

ments (Table 3). In both areas, plots that did not receive N and P had significantly reduced yields. In the flood-prone areas, a typhoon damaged both trials at ripening stage, resulting in substantial yield losses at various fertilizer combinations.

Camarines Sur (San Fernando) irrigated sites. DS experiments were conducted on 13 irrigated farms, 9 of which had severe water shortage. Farmers applied relatively low N levels: 22 kg/ha in adequately irrigated sites and 38 kg/ha in poorly irrigated sites (Table 1). P and K applications in both areas were minimal. Farmers' levels of weed and insect control with foliar insecticides were similar to those at high level.

Yields from farmers' inputs averaged 2.2 t/ha in poorly irrigated sites and 4.5 t/ha in adequately irrigated sites. In poorly irrigated sites, improved weed control contributed 46% of the 0.8 t/ha yield gap; high fertilization, 36%; and insect control, 18%. In adequately irrigated sites, fertilizer application accounted for 1.2 t/ha of the 1.4 t/ha gap while improved insect and weed control had negative effects. Across all sites, high inputs increased the yield by 1.0 t/ha over farmers'inputs. Of this gap, high fertilization accounted for 67%; improved weed control, 22%; and insect control, 11% (Fig. 3).

In both areas, yields responded significantly to 58 kg N/ha. However, increasing the rate to either 87 or 116 kg N/ha did not increase yields further



3. Av yields with farmers' and high inputs and relative contributions of fertilizer, weed control, and insect control toward improvement of rice yields on irrigated farms in San Fernando, Camarines Sur, Philippines, 1983 DS.

(Table 2). Plots without fertilizer N produced yields similar to those with farmers' N rate, suggesting poor effficiency with farmers' method and timing of application. Yield responses to different fertilizer combinations are shown in Table 3. Application of P and K without added N decreased yields significantly by 0.6 t/ha in poorly irrigated sites and by 1.7 t/ha in adequately irrigated sites. Removal of either P or K did not reduce the yields significantly.

Camarines Sur (San Fernando) rainfed sites. During WS, the magnitude of the yield gap was determined from 31 rainfed trials — 7 at low elevation, 11 at intermediate elevation, and 13 at high elevation (Table 4). Yields from farmers' inputs averaged 4.7 t/ha at low elevation, 0.1 t/ha lower than those from high inputs; 4.5 t/ha at intermediate elevation with 0.3 t/ha yield gap; and 4.0 t/ha at high elevation with a 0.7 t/ha yield gap. The yield gap at high elevation was large because most farmers did not apply fertilizer. The contributions of fertilizer, and insect and weed control were determined from four trials at low elevation, six at intermediate, and eight at high. At the low and intermediate positions, yields with farmers' inputs and high inputs were comparable. Lodging was the main problem in plots that received high rates of fertilizer, causing substantial yield losses at high inputs. At high elevation, high inputs increased yield by 0.6 t/ha over farmers' inputs. Of this yield gap, high fertilization accounted for 0.3 t/ha while improved insect and weed control contributed nothing.

Farmers in two landscape positions grew mostly early-maturing IR36 at intermediate elevation and IR56 at high elevation. At low elevation, the dominant variety was IR52. Compared to test variety IR58, farmers' varieties at the intermediate and high elevations produced significantly higher yields but only under farmers' level of inputs. At low elevation, farmers' and test varieties produced comparable yields (Table 5). Basal incorporation of 10 kg $ZnSO_4$/ha did not increase grain yields in all test areas (Table 6).

Response to fertilizer combinations was evaluated in a separate experiment. Table 3 shows no significant increase from complete fertilizer (60 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha) over PK, NK, and NP combinations irrespective of landscape position.

SOCIOECONOMIC CONSTRAINTS

Agricultural Economics Department

The economics contribution to IRRI's constraints program provides an economic evaluation of on-farm trials and analyzes farming systems used in constraints research.

Profitability of researchers' technology. Constraints experiments described in the previous section showed that on-farm yields could be raised by 1-2 t/ha by following researchers' input levels and management practices. Economic analysis investigated the same data from Tarlac and Bicol to see whether researchers' technology would be profitable, given farmer-effective prices prevailing in the areas.

Incremental benefits and costs of the proposed technology are given in Table 7. Researchers' practices were not profitable in rainfed Camarines Sur. And in irrigated areas, profit remained unchanged with increased output barely compensating for additional expenditures. In contrast, researchers' technology was profitable in both irrigated and rainfed Tarlac sites, with incremental profits ranging from $56 to $129/ha.

Table 7. Economic performance of anticipated high level combinations of 3 inputs and farmers' level of those inputs in constraints experiments in farmers' fields, Philippines, 1983.

Location, water regime	Sites (no.)	Increase or decrease[a] ($/ha) over farmers' level from high inputs		
		Output value	Input cost	Profit
DS				
Libmanan, Camarines Sur				
Irrigated (new)[b]	8	134	129	5
Irrigated (old)	10	155	134	21
Irrigated (flood-prone)	9	135	138	-3
San Fernando, Camarines Sur				
Irrigated[c]	13	91	135	-44
Tarlac, Tarlac				
Irrigated	6	198	142	56
WS				
Libmanan, Camarines Sur				
Irrigated (new)	3	170	146	24
Irrigated (old)	4	112	127	-15
Rainfed (plain)	3	88	115	-27
San Fernando, Camarines Sur				
Rainfed (plateau)	8	61	130	-69
Rainfed (plain)	6	-30	115	-145
Rainfed (bottomland)[d]	4	8	128	-120
Tarlac, Tarlac				
Rainfed (plateau)	6	231	125	106
Rainfed (plain)	6	254	125	129

[a]At ₱14 to $1. [b]One site had zero yield due to rat damage. [c]Two sites had zero yield due to drought. [d]Two sites had zero yield due to floods.

Profitability of different inputs comprising the technology package is presented in Table 8. The incremental benefit-cost ratios (B:C) of all three practices (fertilizer, insect, and weed control) exceeded 1 at Tarlac. In Camarines Sur, B:Cs were greater than 1 only for fertilizer in DS and for weed control in irrigated areas in WS. A frequently applied general rule is that B:C should exceed 2 to make technology change attractive to low-resource farmers. This would imply that high input levels proposed by researchers would not be sufficiently profitable for farmers in Camarines Sur. The only exception would be fertilizer in DS in nonflood-prone areas of irrigated Camarines Sur. Similar results were obtained in irrigated areas of Tarlac. In rainfed Tarlac, B:Cs for both fertilizer and weed control exceeded 2 in WS.

Researchers were able to raise farmers' yields by 1-2 t/ha. Economic analysis, however, showed that, with the exception of rainfed Tarlac, the proposed technology was not sufficiently profitable to induce adoption by low-resource farmers.

Technical efficiency. Technical efficiency is a measure of a farm's ability to produce maximum output for a given set of inputs and production technology. If the causes of farm technical efficiency are understood, research and extension can focus on improving technology of less efficient farmers. Farm-specific estimates of technical efficiency of some of the same Bicol rainfed rice farmers were derived through a stochastic translog frontier production functions model.

Production frontier model. The empirically estimated production frontier was

$$\ln Y = a_0 + \sum_{i=1}^{4} b_i \ln X_i + \sum_{i=1}^{4}\sum_{j=1}^{4} b_{ij} \ln X_i \ln X_j + u + v \quad (1)$$

where Y is yield per farm; X_1 is d of preharvest labor; X_2 is pesticide cost; X_3 is d of land preparation; X_4 is the rice area in ha; v is a

Table 8. Economic performance of anticipated high levels of 3 inputs and farmers' current practices in yield-constraints experiments in farmers' fields, Philippines, 1983 DS and WS.

Location, water regime	Sites (no.)	Increase or decrease over farmers' level										
		Fertilizer[a]					Insect control[b]			Weed control[c]		
		Farmers (kg/ha)		Profit[d] ($/ha)		B:C	Farmers ($/ha)	Profit[d] ($/ha)	B:C	Farmers ($/ha)	Profit[d] ($/ha)	B:C
					DS							
Libmanan, Camarines Sur												
Irrigated (new)	8	52	24	0	40	1.8	9	-39	0.3	3.4	2	1.1
Irrigated (old)	10	29	17	20	69	2.2	6	-40	0.4	3.2	-5	0.7
Irrigated (flood-prone)	9	32	20	0	39	1.6	7	-43	0.3	3.0	-5	0.7
San Fernando, Camarines Sur												
Irrigated	13	49	19	14	15	1.2	3	-50	0.2	1.5	-4	0.8
Tarlac, Tarlac												
Irrigated	6	58	0	0	37	1.7	3	2	1.0	0.5	8	1.4
					WS							
Libmanan, Camarines Sur												
Irrigated (new)	3	0	0	0	41	1.3	5	-20	0.7	2	5	1.2
Irrigated (old)	4	27		0	-11	0.8	7	-19	0.7	6	8	1.4
Irrigated (flood-prone)	3	7	0	0	-14	0.7	14	-29	0.6	9	9	1.6
San Fernando, Camarines Sur												
Rainfed (plateau)	8	2	0	0	7	1.1	10	-40	neg	3	-18	neg
Rainfed (plain)	6	20	0	0	-42	neg	6	-48	0.2	5	-38	neg
Rainfed (bottomlands)	4	3	0	0	-70	neg	7	-35	0.4	2	-23	neg
Tarlac, Tarlac												
Rainfed (plateau)	6	12	8	0	59	2.5	4	28	1.4	0	22	2.8
Rainfed (plain)	6	10	7	6	53	2.4	4	16	1.2	0	42	4.4

[a]Researchers' fertilizer at 87-30-30 kg in DS and 60-30-30 kg in WS; farmers' level in N + P_2O_5 + K_2O. [b]Researchers' insect control costs $62/ha in Camarines Sur, $78/ha in Tarlac. [c]Researchers' weed control costs $17/ha in Camarines Sur, $13/ha in Tarlac. [d]At rough rice price of $107/t in Camarines Sur and $156/t in Tarlac.

normally distributed error term N(0,1), and u is a farm-specific error term which follows a half normal distribution.

Table 9 shows the maximum likelihood estimate (MLE) of equation 1 for the Bicol rainfed rice farms. The variance ratio parameter (γ) is comparatively large, given that it lies in the interval (0,1) and differs significantly from zero. This implies that about 82% of the difference between observed output and maximum technological production frontier output is attributed to differences in farmers' levels of technical efficiency and not to unintentional random variability.

Farm-specific technical efficiency. The technical efficiency of the ith farm relative to the stochastic production frontier is derived as the ratio of observed to expected Y, that is,

$$e^{u_i} = Y_i / f(X_i) e^{v_i} \tag{2}$$

while the mean and variance of technical efficiency are

$$E(u_i) = \sigma_u (2/\pi)^{\frac{1}{2}} \tag{3}$$

and

$$v(u_i) = \sigma_u^2 (\pi-2)/\pi \tag{4}$$

The mean level of technical efficiency of sampled farmers was 50% with a variance of 14%.

Farm-specific technical efficiencies across all sampled farms ranged from 0.4 to 0.9 (Table 10). Less than 20% of the samples obtained output within 20% of maximum technological output estimated by the frontier.

Factors related to technical efficiency. Farm-specific factors were examined to identify those associated with between-farm differences in tech-

Table 9. MLE and OLS estimates of stochastic translog production frontier for sample farmers.[a] IRRI, 1983.

Parameter	Estimates	
	Maximum likelihood estimate	Ordinary least squares
α_0	4.4438	3.5621
	(1.0213)	(1.2100)
α_1	0.2601	0.2552
	(0.0803)	(0.8560)
α_2	0.1203	0.1163
	(0.0401)	(0.0523)
α_3	0.3931	0.4025
	(0.1233)	(0.1425)
α_4	-0.4362	-0.4402
	(0.2018)	(0.2201)
β_{11}	0.1565	0.1472
	(0.0702)	(0.0811)
β_{12}	-0.1223	-0.1303
	(0.0562)	(0.0621)
β_{13}	0.0935	0.1026
	(0.0622)	(0.0693)
β_{14}	-0.4201	-0.4021
	(0.1983)	(0.2006)
β_{22}	-0.0030	-0.0039
	(0.0121)	(0.0158)
β_{23}	0.0876	0.0821
	(0.0321)	(0.0363)
β_{24}	0.1235	0.1189
	(0.0337)	(0.0421)
β_{33}	-0.0086	-0.0093
	(0.0041)	(0.0053)
β_{34}	0.0582	0.0602
	(0.0339)	(0.0382)
β_{44}	0.0682	0.0713
	(0.0248)	(0.0318)
Log likelihood function	-21.8316	-78.2103
σ^2	0.4818	0.2512
σ_u^2	0.3927	
γ	0.8151	
	(0.1825)	

[a]Figures in parentheses are asymptotic standard errors.

Table 10. Frequency distribution of farm-specific technical efficiency for sample farmers. IRRI, 1983.

Efficiency levels	Farms (no.)	Percentage
0.35 – 0.40	8	10
0.41 – 0.45	12	15
0.46 – 0.50	18	23
0.51 – 0.55	5	6
0.56 – 0.60	3	4
0.61 – 0.65	5	6
0.66 – 0.70	6	8
0.71 – 0.75	5	6
0.76 – 0.80	3	4
0.81 – 0.85	8	10
0.86 – 0.91	6	8
Total	79	100

nical efficiency (Table 11). Method of crop establishment, fertilizer application, experience in farming, and extension contact were associated with higher levels of technical efficiency. Farmers' age and years of formal schooling were not.

Risk and fertilizer use. Crop response to N varies yearly because of random changes in weather, pests, and diseases. It is widely believed that this variability in yields makes farmers unwilling to apply input levels which would maximize expected profit. This issue is particularly pertinent in rainfed Bicol since 82% of sample farmers do not fertilize their rice crops. Researchers examined whether risk seemed to be an important determinant of fertilizer use by these farmers.

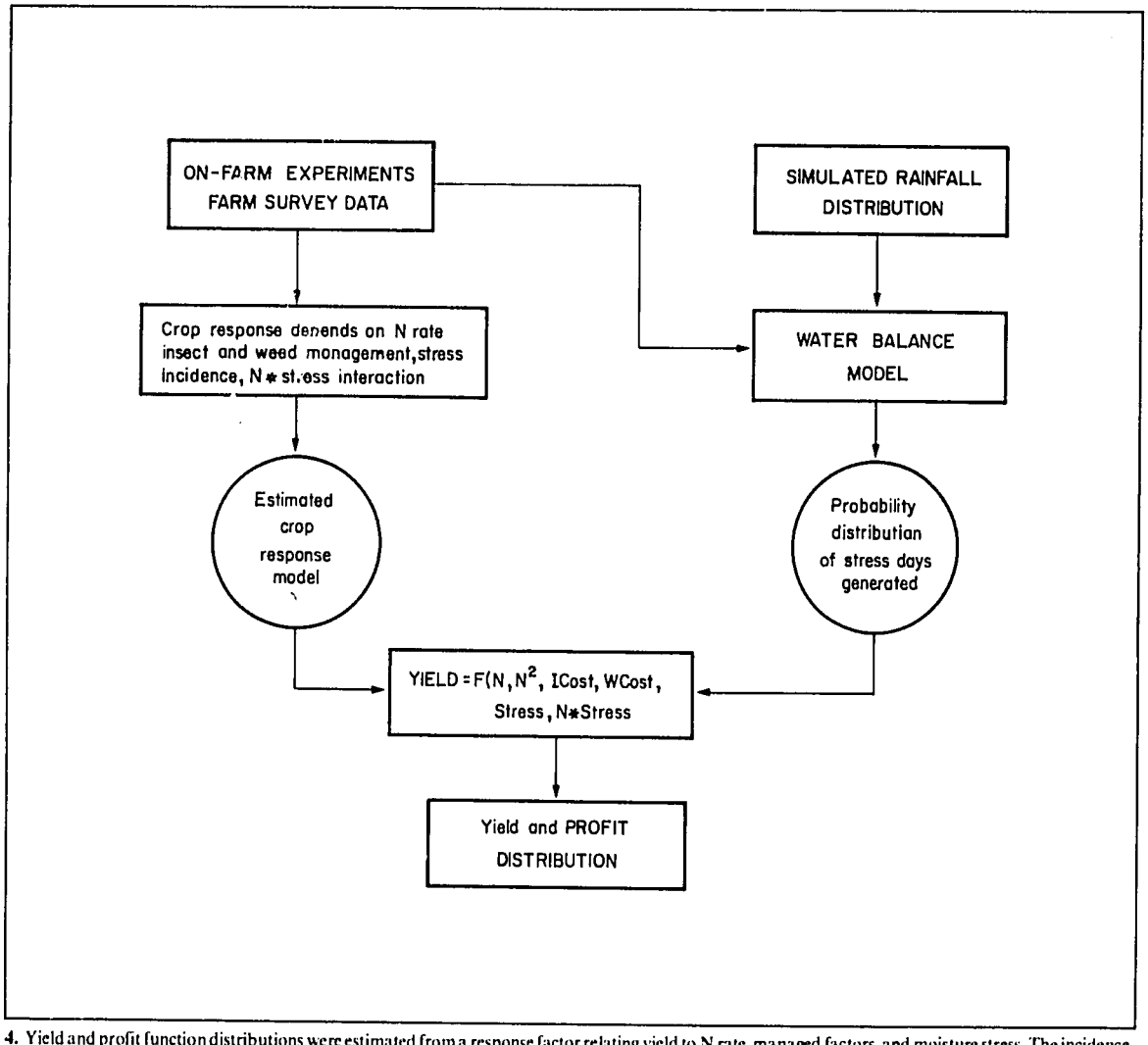
Modeling production risk. A crop production model was developed for the Bicol site (Fig. 4). One component was a stochastic production function model estimated from on-farm constraints trials (Table 12) and another was a rainfall and water balance simulation model. Combined, these provided means and yield distribution for each N rate.

The risk neutral optimal N rate was 51 kg N/ha in the first season and 44 kg N/ha in the second. Results of this analysis demonstrated that as N rates increased, the variance of profit increased at an increasing rate. This trend was greater in the second season when the incidence of moisture stress was higher (Fig. 5).

Table 11. Ordinary least squares estimates of the determinants of variation in technical efficiency across sample farms. IRRI, 1983.

Variable	Units	Estimates[a]	Marginal R^2
Intercept		0.3282	
		(0.1346)	
Crop establishment (transplanting = 1, direct seeding = 0)	Dummy 0, 1	0.2023	0.15
		(0.0562)	
Fertilizer application (applied = 1, not applied = 0)	Dummy 0, 1	0.1031	0.12
		(0.0318)	
Age	Yr	0.0004	0.02
		(0.0013)	
Education	Yr of schooling	0.0056	0.01
		(0.0135)	
Experience	Yr of farming	0.0037	0.07
		(0.0013)	
Extension contact	No. of visits	0.0245	0.13
		(0.0138)	
R^{-2} = 0.4582			

[a]Figures in parentheses are standard errors of estimates.



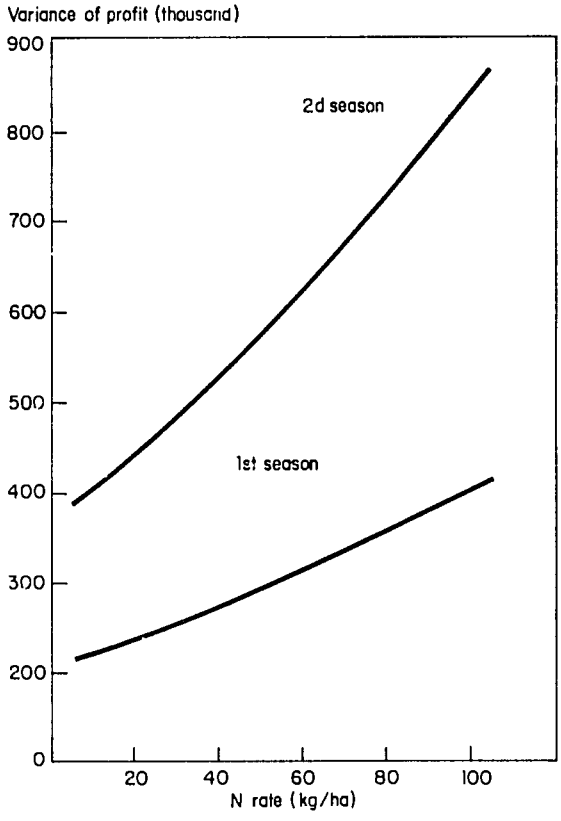
4. Yield and profit function distributions were estimated from a response factor relating yield to N rate, managed factors, and moisture stress. The incidence of moisture stress over time was estimated through a water balance simulation model. IRRI, 1983.

Risk attitudes and N rates. A constant partial risk averse utility function was used to approximate the farmer's utility function and optimal N rates applied by moderately risk-averse farmers. The model predicted that risk-averse farmers (partial risk aversion coefficient of 0.8) would apply 49 kg N/ha in the first season and 41 kg/ha in the second. This is 4% and 7% less and implies a 20 and 35 kg/ha decrease in yields from the risk neutral N rate. These results, consistent with others in the Philippines, imply that risk aversion may not be a predominant factor in the low level of fertilizer use in the nonflood-prone sites of Bicol.

Bicol farmers are poor and seek to maximize returns from scarce household capital using all

Table 12. Generalized least squares estimates of quadratic production function: 668 observations, Camarines Sur, Bicol, Philippines, 1980-81, 1981-82.

Variable	Coefficient estimate	Standard error	Significance level
INTERCEPT	2230.76	158.36	0.01
NITRO	31.08	5.17	0.01
N^2	-0.12	0.08	0.14
ICOST	0.54	0.16	0.01
WCOST	1.53	0.43	0.01
CEC	26.31	3.78	0.01
SS	-28.64	4.43	0.01
NSS	-0.33	0.12	0.01
DV1	-669.69	91.38	0.01



5. As N rates increase, the variance of profit increases at an increasing rate. This occurred more in the second season when the probability of drought stress at the Bicol rainfed site was higher. IRRI, 1983.

capital investments open to them. Studies are continuing to examine the impact of internal and external capital rationing, at the household level, on the allocation of household funds in rice production and between agricultural and non-agricultural enterprises.

Technology adoption. Adoption of MVs is virtually complete in irrigated parts of Asia but is minimal in deepwater and upland areas where short-duration varieties are poorly adapted. In other areas, as in vast tracts of the Gangetic Plains in India, adoption of MV rices is partial. Factors associated with the adoption of MV rices and fertilizer use in a Tarai site of Eastern Nepal in 1979 were examined.

Multivariate model for variety adoption. Based on the established procedures for multivariate probit analysis, equations for examining the factors influencing adoption are

$$I = a + bX_1 + cX_2 + dX_3 \ldots + nX_n \qquad (5)$$

and

$$Y = g(I) \qquad (6)$$

where I is an index reflecting the combined effect of the X factors which prevent or promote adoption. $Y = 1$ (adoption) if I exceeds a threshold value; $Y = 0$ (non-adoption) if I falls below the threshold value.

Factors included in the variety adoption model are listed in Table 13. The first five variables are interval scale while the last two are dummy variables. The model correctly predicted 85% of adopters and nonadopters of MVs. Tenure status, extension contact, credit, and the percentage of rice area irrigated were significantly associated with the adoption of MVs, but farm size and the operator's education were not.

The predicted probabilities of MV adoption for farms with selected characteristics are listed in Table 14. The probability of MV adoption is 85% for an owner-cultivator with access to credit. However, without irrigation, the farmer is unlikely (probability drops to 13%) to adopt MVs. The probability of adoption of an average owner-operator with irrigation but without credit is 69%. But the adoption probability falls to 5% for an owner without irrigation or credit. There is a reasonable likelihood (50%) that tenants with irrigation and credit would grow MVs. However, tenants without irrigation — which tends to be the case in practice — are unlikely (2%) to grow MVs.

Table 13. Probit regression coefficients for determinants of MV adoption in eastern Tarai, Nepal, 1979.

Variable	Coefficient	Standard error	Asymptotic t-values
Constant	-3.0336	0.5712	-5.3113
Farm size	-0.0248	0.0277	0.8958
Education	0.0073	0.0388	0.1876
Extension contact	0.0256	0.0143	1.7912
% rice area irrigated	0.0215	0.0039	5.5214
Adult family labor	0.0893	0.0197	0.9743
Tenure status	0.9785	0.4973	1.9676
Credit	0.5260	0.2763	1.9038
-2 times log likelihood ratio	1.11.1***		
χ^2 distribution degrees of freedom	7		
% of cases predicted correctly	85.3%		

Table 14. Predicted probability of MV adoption for an average farmer, eastern Tarai, Nepal, 1979.

	Predicted probability			
	Owner		Tenant	
	With credit	Without credit	With credit	Without credit
Irrigated	0.85	0.69	0.52	0.31
Nonirrigated	0.13	0.05	0.02	0.00

Table 15. Tobit regression coefficients for determinants of adoption and quantity of fertilizer use on rice, eastern Tarai, Nepal, 1979.

Variable	Coefficient	Standard error	Asymptotic *t*-values
Constant	-562.1116	127.4116	4.4117
Education	5.1965	6.5165	1.2578
Extension contact	6.6440	1.4900	4.4590
Fertilizer transportation cost	-52.9731	31.2243	1.6965
Credit	145.2624	49.0145	2.9636
Rice area	5.4160	9.7821	0.5536
% rice area irrigated	0.7385	1.0365	0.7125
Variety	265.9312	77.7802	3.4190
Adult family labor	16.2985	14.5696	1.1186
Sigma (σ)	174.5531	2.6446	66.0025
-2 times log of likelihood	133***		
χ^2 distribution degrees of freedom	8		
% of cases predicted correctly	89.8%		

Adoption and use of fertilizer. The coefficients for the Tobit model used to investigate factors associated with the adoption and quantity of fertilizer use in rice production are reported in Table 15. The model, significant at the 1% level, correctly predicted 90% of adopters and non-adopters.

Extension contact, fertilizer transportation cost, access to credit, and adoption of MVs were significantly associated with fertilizer adoption and quantity used. The probability of an owner-operator growing MVs on an irrigated parcel, with access to credit and with zero fertilizer transportation cost, is 65%. The expected quantity of inorganic fertilizer applied (mainly AS) is 58 kg/ha (Table 16). The probability of applying fertilizer drops to 34% and use rate declines to 20 kg/ha (less than half a bag) for a farmer without access to credit. There is less than a 50% chance that farmers will grow MVs in rainfed conditions, and less than a 10% chance that growers of local varieties would apply fertilizer.

INSTITUTIONAL AND POLICY-RELATED CONSTRAINTS

Agricultural Economics Department

IRRI collaborates with the International Food Policy Research Institute (IFPRI) and the International Fertilizer Development Center (IFDC) to study institutional and policy-related constraints to increased rice supplies in Asia. A collaborative project between these centers and ASEAN member

Table 16. Predicted probabilities of adoption and expected amount of fertilizer use by rice growers, eastern Tarai, Nepal, 1979.[a]

	MV				Local varieties			
	With credit		Without credit		With credit		Without credit	
	Prob	kg/ha	Prob	kg/ha	Prob	kg/ha	Prob	kg/ha
Irrigated[b]								
Near fertilizer source	.66	58	.34	20	.14	3	.03	–[c]
Far fertilizer source	.47	33	.18	9	.05	–[c]	.01	–[c]
Nonirrigated[b]								
Near fertilizer source	.49	36	.20	10	.06	–[c]	.01	–[c]
Far fertilizer source	.31	18	.09	–[c]	.02	–[c]	[d]	–[c]

[a]Prob = probability. [b]Farm located close (no fertilizer transport cost) and far from fertilizer source (Rs 1.87/50-kg bag). [c]Calculated fertilizer use rate near zero. [d]Probability of less than .01%.

countries Indonesia, Malaysia, the Philippines, and Thailand has been established. Major research areas of the Rice Policies in Southeast Asia Project are irrigation, trade and reserve stocks, fertilizer consumption, and an integrative model. The research is conducted by collaborators in each country. Staffs of the three centers provide technical assistance and coordination.

A second IRRI-IFPRI research project is the Asian Development Bank (ADB)-funded project Assessment of Food Demand/Supply Prospects and Related Strategies for Developing Member Countries of the ADB. This study analyzes food demand and supply prospects of 21 ADB developing member countries between the years 1990 and 2000. A major component of this project is the assessment of rice production and irrigation development strategies for the Philippines. The project is expected to be completed by the third quarter of 1984.

Consequences of new technology

Agricultural Economics Department

IMPACT OF PRODUCTIVITY GROWTH IN ASIA **344**
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Trends at aggregate level **345**
Changes in input use and income at farm level **346**
Government policies, economic incentives, and social profitability **350**

The impact of new rice technology on rice production, income, income distribution, employment, and social welfare is analyzed so that biochemical and mechanical technology can be designed to meet the needs of the rice sector. Studies are at macro and micro levels. They consider the impact of economic policies, sociopolitical institutions, distribution of control of resources, and the physical environment on the consequences of any new technology.

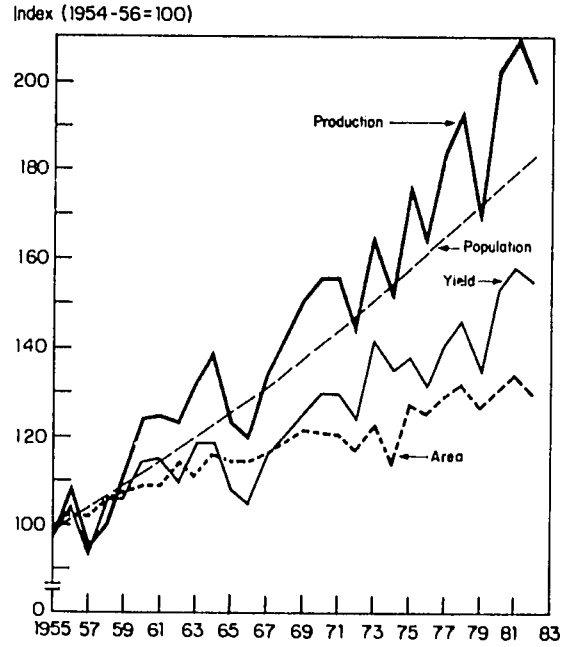
IMPACT OF PRODUCTIVITY GROWTH IN ASIA

Growth rate of rice production in South and Southeast Asia rose moderately from 2.4% to 3% after the introduction of MVs in 1966. Technological changes in rice production through the adoption of MVs, greater fertilizer use, and expanded irrigation

- increased the growth rate of rice production above the population rate on relatively less land,
- helped achieve self-sufficiency in many rice importing countries, and
- reduced real price of rice.

Source of output growth. Rice production and population grew at about the same rate in the 1950s and 1960s, but after 1966, rice production increased more rapidly (Fig. 1). Yield increases also outpaced area expansion by the end of the 1960s. Expanding crop area was responsible for about 60% of growth before 1965 (Table 1). Between 1965 and 1980, 68% of the increase in rice production was caused by yield improvements and only 32% by expansion of crop area. MVs and fertilizer each accounted for about 22% while irrigation accounted for 25% of increased production.

By 1980, 40% of the rice area had been planted to MVs while fertilizer use per ha rose fourfold. Irrigated area increased at a lesser rate, but irrigation raised the productivity of MVs and fertilizer. The contribution of MVs tends to be understated since greater fertilizer use and increasing irrigation investments were induced partly because they could produce more when used with MVs. And as MVs with shorter growth duration began to be bred in the late 1970s, part of the area effect may be caused by the increased possibility of planting a second crop in rainfed conditions.



1. Trends in population, rice production, area, and yield in South and Southeast Asia, 1955-82.

Table 1. Contribution of area and yield increasing factors to rice production growth in selected countries of Asia, 1954-81.

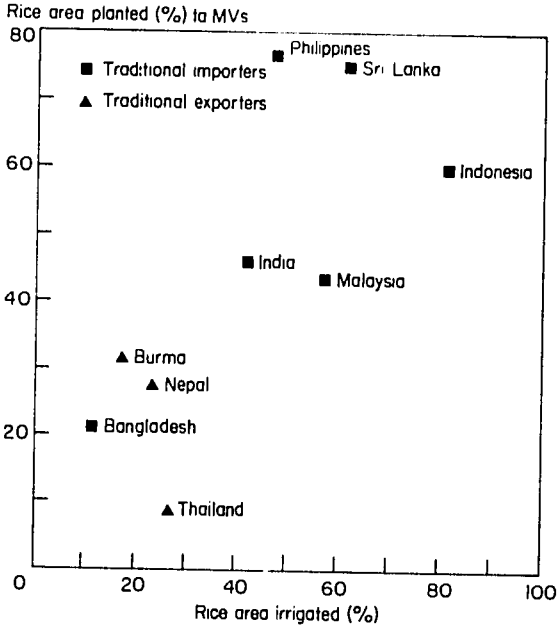
	Contribution (%) of factors					
	1954-66 to 1964-68		1964-66 to 1979-81			
			Area	Yield		
	Area	Yield		MV	Fertilizer	Irrigation
Burma	63	37	9	35	19	37
Bangladesh	39	61	50	7	23	20
India	81	19	14	23	31	32
Indonesia	34	66	37	23	20	20
Philippines	68	32	19	26	31	24
Sri Lanka	56	44	31	23	21	25
Thailand	68	32	63	13	10	14
Av of above	58	42	32	21	22	25

REGIONAL COMPARATIVE ADVANTAGE AND SELF-SUFFICIENCY

In Thailand and Bangladesh, area expansion continued to be the major source of output growth. Adoption rates of MVs are lower in traditional

exporting countries — Thailand, Burma, Nepal — and in Bangladesh where a low percentage of the rice area is irrigated (Fig. 2). In those countries, rice is cultivated in large deltaic areas where the cost of developing effective water control systems is high. Traditional importing countries — India, Indonesia, Malaysia, Philippines, and Sri Lanka — where irrigation costs are relatively cheaper have had a higher adoption rate of MVs. Because early MVs were more suited to irrigation and because of the strong national drive for self-sufficiency in importing countries, MVs have lessened the advantage that traditional rice exporters have had over importers.

Malaysia, Sri Lanka, and the Philippines were able to substantially improve their self-sufficiency ratios by late 1970s (Table 2). Export surpluses of Burma and Nepal declined but those of Thailand increased. Self-sufficiency ratios of Bangladesh, India, and Indonesia did not change significantly, although that of Indonesia has improved significantly since 1981. Comparisons of this measure of self-sufficiency, however, should not be made without reference to government policies and to price. Since this crude measure is partially defined by government policy on trade and prices, it is important to ask "self-sufficiency at what price?"



2. Rice area irrigated and planted to MVs, 1980.

Table 2. Adoption of MVs, extent of irrigation, and trends in self-sufficiency ratio among traditional Asian importers and exporters.

	% of area (in 1980) with		Self-sufficiency ratio[a]	
	MVs	Irrigation	1964-66	1979-81
Traditional importers				
Bangladesh	21	12	97	98
India	46	42	98	101
Indonesia	60	81[c]	95	93
Malaysia	44	58[c]	66	86
Philippines	77	47	89	103
Sri Lanka	75	62	49	88
Traditional exporters				
Burma	31	18	126	110
Nepal	27	23[c]	122	102
Thailand	9[b]	27	128	138

[a] $\frac{\text{Production}}{\text{Production + imports - exports}}$ [b] Relates to 1979.
[c] Relates to av of 1978-80.

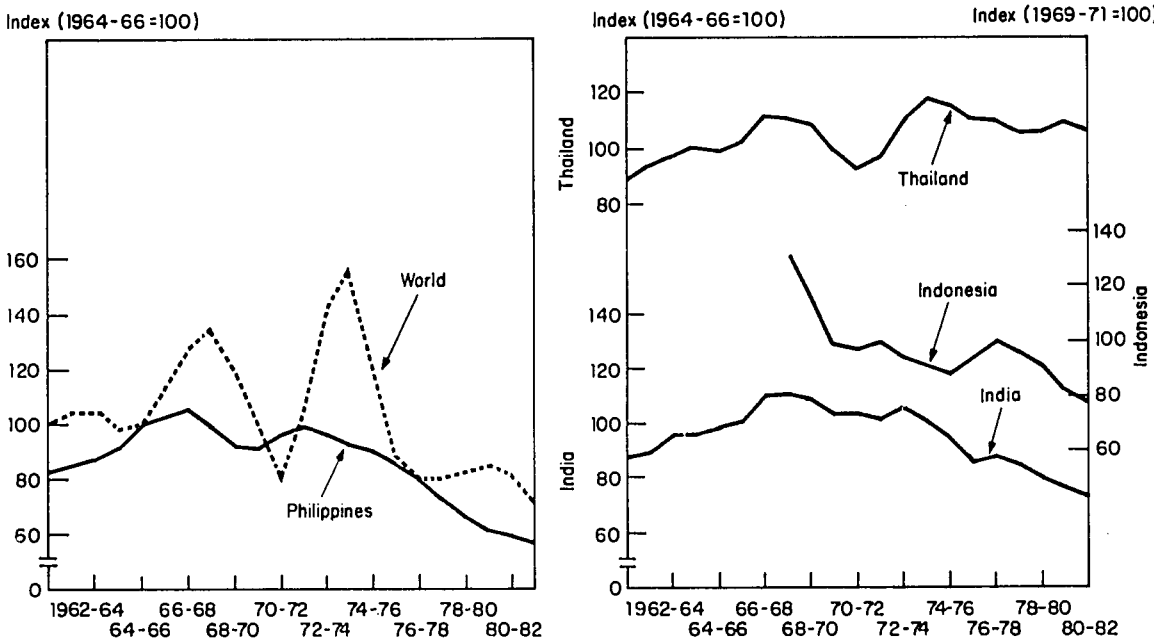
Trends in real price of rice. Benefits of technological change are ultimately reflected in trends in prices. The average world price of rice in real terms was 11% lower in the 1970s than in the 1960s (Fig. 3). If the unusually high world prices in 1973-75 were excluded, the decline in average real world price was as much as 27%.

As self-sufficiency was achieved in traditional importing countries such as the Philippines and India, the real price of rice decreased significantly. More liberal import policy in recent years accelerated the sharp decline in real price in Indonesia even though its self-sufficiency ratio remained about the same. In Thailand, where rice is a major export, changes in export duties prevented the domestic real price from closely following the decline in real world price. Substantial yield improvements, especially in traditional importing countries during the 1970s, is a major reason for these downward price trends.

While lower real price undoubtedly benefits consumers, it is not clear whether rice producers gain as much from technical change.

CHANGES IN PHILIPPINE RICE FARMING

Trends at aggregate level. Philippine rice production grew at an average rate of 4.5% between 1965 and 1980, doubling total production from 2.6 to 5.1



3. Trends in real price of rice in selected countries. Each point refers to 3-yr av.

million t of milled rice. The growth in supply reduced net imports, and small but growing amounts of rice have been exported since 1977. Domestic real price of rice has declined dramatically mostly because of supply shifts caused by the new seed-fertilizer technology, irrigation expansion, and government-restricted exports.

Yield increases have accounted for 83% of output growth in the past 15 yr. Yields rose by 75% while crop area expanded only by 12%. The larger crop area was actually increased second-crop area because cultivated land diminished by 8%. Yields from irrigated land increased and the proportion of irrigated area expanded from 35% to 47%. Yield increases from rainfed areas also contributed substantially to total production growth.

Only a small part of recent yield growth was caused by first-time adoption of MVs; 60% of total rice area was already planted to MVs in the early 1970s. About one-third of yield growth came from increased fertilizer use.

The combination of short-duration pest-resistant varieties, and others more tolerant to moisture stress and adverse soil conditions, has led to a 78% MV adoption in rainfed wetlands by 1980. Irrigated areas have 89% adoption. Upland areas also report increased MV adoption.

Changes in input use and income at farm level. To document the impact of new rice technology on farms, surveys were conducted from 1965 to 1982 in Central Luzon and Laguna. About 100 farmers in each location were interviewed during each survey. But since the sample farmers partially changed over time, only those who were included in all surveys were analyzed. Although these panel farms represent only the more progressive rice areas, they provide unique data for analyzing changes in the economic welfare of rice farmers and the social profitability of rice production over time. The spread of biochemical and mechanical technologies, acceleration of irrigation investments, and institution of land reform occurred during the period. Adoption rate of these technological innovations depended on availability of technology, relative factor prices, and output price. All these factors are influenced by market forces and also by government policies on public expenditure, credit, trade, price, and marketing.

Land reform implemented in 1972 converted many rice farmers from sharecroppers to leaseholders and a few to amortizing owners paying fixed rent or amortization. The proportion of share-tenants in the sample declined from 75% to 7% in Central Luzon and from 89% to 16% in

Laguna. The proportion of leaseholders correspondingly increased (Table 3). Only 1 of the 38 panel farms in Laguna was rainfed and irrigation improvements increased cropping intensity from 183% in 1965 to 191% in 1981. In Central Luzon, about 60% of farms were irrigated. The impact of irrigation investment is shown by the shift from one to two irrigated crops as the proportion of second-cropped area rose from 12% to 44%.

As expected, MV adoption on panel farms was more rapid than for the Philippine average (Table 4). Adoption was virtually complete by 1970 in Laguna and by 1979 in Central Luzon. No significant difference in adoption rate was found for different farm sizes and tenure classes. MVs were initially adopted at a higher rate on irrigated farms.

A substantial number of farmers were already applying fertilizer and insecticide in both locations and herbicides in Laguna by 1966 but at a very low level. By the early 1980s, close to 100% were using fertilizer at average rates 6 times greater than in 1966. Laguna farms typically applied higher rates of fertilizer except for a decrease in 1981, atypical of the rest of the province. Several panel farms gained external benefits from wastes from a nearby large poultry dressing plant. As these wastes mixed with the flowing irrigation water, farmers in the area were able to reduce the use of chemical fertilizers.

Starting at a lower level, the spread of insecticides and use of herbicides increased even faster than fertilizer use. Therefore, average application rates rose faster. After 1975, Central Luzon farmers

Table 3. Trends in farm size, tenure changes, and cropping intensity based on panel farms[a] in 2 areas of Luzon, Philippines, 1965-82 WS.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Farms (no.)	28	28	28	28	28	38	38	38	38	38
Av farm size (ha)	2.4	2.52	2.53	2.07	1.92	2.31	2.27	2.25	2.48	2.28
Tenure (% of farms)										
Share-tenants	75	50	22	3	7	89	74	35	8	16
Leaseholders	18	39	64	79	79	11	26	60	77	70
Owner-cultivator	7	11	14	7	11	–	–	–	4	8
Mixed	–	–	–	11	3	–	–	5	11	6
Rice cropping intensity (%)	112	114	132	140	144	183	196	197	192	191

[a]Panel farms are a subset of the sample used in the years covered by the survey.

Table 4. Trends in adoption of MVs and use of fertilizer and agricultural chemicals of panel farms in 2 areas of Luzon, Philippines, 1965-82 WS.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Area (%) planted to MV	0	62	76	97	98	0	90	99	97	100
Farms (%) with fertilizer	64	75	86	96	96	66	87	97	100	95
Fertilizer: (₱/ha)	27	66	229	318	444	25	73	359	330	374
(kg N/ha)	9	32	32	56	59	13	50	79	78	57
Farms (%) with insecticides	25	61	79	96	93	39	84	92	95	92
Insecticides expenditure (₱/ha)										
(in nominal terms)	2	7	38	85	141	1	12	63	79	69
(in 1972 prices[a])	3	8	19	26	33	2	15	31	24	18
Farms (%) with herbicides	11	46	50	46	71	87	89	92	89	95
Herbicide expenditure (₱/ha)										
(in nominal terms)	b	4	26	25	46	4	9	26	35	55
(in 1972 prices[a])	b	5	13	8	11	7	11	13	11	15

[a]Deflated by wholesale price index of agricultural chemicals (1972=100) published by the Central Bank of the Philippines.
[b]Less than a peso.

appear to be using higher rates of insecticides per ha. With more insect- and pest-resistant varieties available, Laguna farms have lowered insecticide use per ha. Relatively more farms in Laguna use herbicides, but average applications were similar in both locations.

Adoption of mechanical technology for land preparation and threshing in Central Luzon began before introduction of MVs (Table 5). Large four-wheel tractors and threshing machines are found in Central Luzon where farms are bigger and single rice cropping is more common. The use of large threshers facilitated landowners' control over division of the crop. As land reform progressed and irrigation increased the double-cropped area, threshing delays became more costly and transfer of big machines difficult. Central Luzon farmers began to thresh manually. Power tillers used by almost all Laguna farmers are also becoming popular in Central Luzon. Portable threshers introduced in the late 1970s found rapid acceptance in both locations.

Laguna farms are more labor-intensive (Table 6). Average labor use per ha is about 20% higher than in Central Luzon with the largest difference in weeding. Adoption of the new seed-fertilizer technology generally raises labor demand for weeding, applying insecticide and fertilizer, and harvesting and threshing. But herbicide use and mechanization of land preparation and threshing tend to offset these increases. Total labor used per ha increased between 1966 and 1974 and later declined in both locations. After 1979 the decrease in labor for crop establishment was caused by the adoption of wet seeding by almost 20% of farms in the Central Luzon sample.

The proportion of hired labor increased, particularly for land preparation and crop care. Mechanization of land preparation involved contracting services of machines as well as operators. The greater productivity of timely weeding and other crop care activities with MVs apparently increased labor requirements beyond the supply of family labor. Rising family income and declining

Table 5. Trends in mechanization rate based on panel farms in 2 areas of Luzon, Philippines, 1965-82 WS.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Farms (%) using power tillers	0	0	18	54	64	21	58	82	97	100
Farms (%) using 4-wheel tractor	7	29	32	21	11	0	0	8	3	8
Farms (%) using large threshers	79	75	43	25	11	0	0	0	0	0
Farms (%) using portable threshers	0	0	7	21	82	0	0	0	84	100

Table 6. Trends in labor use on panel farms in 2 areas of Luzon, Philippines, 1965-82 WS.

	Labor use[a] (labor d/ha)									
	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Land preparation	15	10	9	8	9	20	13	10	11	10
	(8)	(16)	(27)	(33)	(46)	(18)	(39)	(58)	(52)	(50)
Crop establishment	22	23	33	31	25	17	22	28	19	22
	(76)	(73)	(76)	(65)	(76)	(58)	(53)	(72)	(63)	(61)
Crop care	5	11	13	12	8	21	20	34	34	32
	(19)	(17)	(13)	(14)	(26)	(7)	(65)	(74)	(67)	(59)
Harvesting, threshing, and postharvest tasks	17	20	35	29	31	33	34	34	31	29
	(90)	(77)	(93)	(90)	(90)	(100)	(98)	(98)	(91)	(92)
Total	59	64	90	80	73	91	89	106	95	93
	(58)	(55)	(69)	(63)	(73)	(53)	(71)	(80)	(72)	(69)

[a]Figures in parentheses denote percent of hired labor.

real wages of unskilled labor may also have induced some substitution of hired for family labor.

Rice yields almost doubled in both Laguna and Central Luzon between 1965 and 1982 (Table 7) with Laguna farms having higher yields than Central Luzon. Income derived from rice farming by farm-operators, landowners, and landless workers depends on many other factors besides increased productivity. These are mainly changes in relative factor use, relative price of rice to inputs and all other consumer goods, land reform, and demand for labor and land in the nonrice sector.

The proportion of rice output going to non-agriculture rose as mechanization and use of nonfarm inputs increased. But income per ha in paddy equivalent received by farmers and hired labor from rice farming during WS rose over the whole period. Farmers' return per ha increased by 140% in Central Luzon and 100% in Laguna between 1965 and 1982. Returns to labor and land increased with higher yields. The cost of hired labor in paddy per ha expanded by about 180%, even higher than the increase in return to family farm operators in Central Luzon. Income received by landowners who do not cultivate their own land declined because of land reform. Distribution of income has changed from landowners to farm operators and hired labor over time.

Rice producers consume goods and services other than rice, and their welfare depends on what happens to prices of all commodities. The rapidly declining real rice price has significantly eroded the impressive gains in the paddy equivalent income of rice producers (Table 8). In 1982, paddy price, deflated by the consumer price index in rural areas, was only slightly more than half that of 1966. The deflated net value added per ha declined slightly by the beginning of the 1980s compared to the mid-1960s. The farm households real income per ha per season, however, increased at the expense of landowners because land reform transferred to the farm operators a substantial part of the returns to land. Because of declining farm size, Central Luzon farm income on a per-farm-per-season basis declined slightly. However, taking into account the increase in rice cropping intensity, average real farm income per year rose by 25% in Central Luzon and 30% in Laguna in the past 15 yr. Superior irrigation explains the higher annual farm income in the Laguna sample.

The data do not allow the estimation of the annual income of hired laborers or landless workers. The sample farms show increasing real wages if measured in terms of kg paddy per day both for the average of all tasks and for transplanting (Table 9). When nominal wage was deflated by the consumer price index, real wages remained constant or even declined in the 1980s. The Philippine average real wage consistently declined during the same time. The slight decline in wage is not caused by the new seed-fertilizer technology, which actually expands labor demand. The wage decline simply indicates that the labor supply has outpaced growth in labor demand in both the agriculture and nonagriculture sectors. Thus, despite greater paddy income, the real income of many rice producers in terms of purchas-

Table 7. Trends in yields, returns to factor earners based on panel farms in 2 areas of Luzon, Philippines, 1965 to 1982 WS.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Paddy yield (kg/ha)	1910	2559	2020	3921	4251	2326	3358	3738	3970	4362
Returns to factor earners (kg/ha)										
Current inputs	143	220	366	627	781	144	317	527	684	598
Fixed capital	149	196	162	487	531	180	176	190	445	637
Net value added										
Hired labor	305	441	423	854	844	473	780	772	992	914
Landowner	690	692	522	520	605	883	1119	885	814	826
Farm household	623	1010	547	1433	1490	646	966	1364	1035	1387
Family labor	199	338	255	369	295	356	275	227	309	392
Operator's residual	424	627	292	1064	1195	290	691	1137	726	955

Table 8. Trends in paddy price and real returns to various earners from rice production based on panel farms in 2 areas of Luzon, Philippines, 1965-82 WS.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Paddy price										
₱/kg in nominal terms	.42	.49	1.09	1.06	1.28	.41	47	1.09	1.07	1.40
₱*/kg in real terms[a]	.70	.65	.69	.42	.36	.72	.63	.65	.49	.42
Net value added (₱*/ha per season)										
Hired labor	214	288	294	359	304	339	489	503	489	384
Landowner	484	452	362	219	218	632	701	576	401	347
Farm household	437	660	380	603	537	462	605	889	510	582
Family labor	140	221	177	155	106	254	172	148	153	165
Operator's surplus	297	439	203	448	431	208	433	741	358	418
Farm household income										
₱*/farm per season	1049	1663	961	1248	1031	1067	1373	2000	1265	1327
₱*/farm per yr[b]	1175	1896	1269	1748	1485	1953	2691	3940	2428	2534

[a]₱* means price deflated by consumer price index outside Manila (1972 = 100). [b]Farm household income per farm per season multiplied by the rice cropping index.

Table 9. Trends in real wages in the Philippines, 1965-82.

	Central Luzon					Laguna				
	1966	1970	1974	1979	1982	1965	1970	1975	1978	1981
Panel farms, WS										
Av wage of hired labor										
kg/labor d	8.9	12.4	6.9	16.9	15.8	9.8	12.5	9.1	14.5	14.3
₱*/labor d	6.3	8.1	4.8	7.1	5.7	7.0	7.9	5.9	7.1	6.0
Wage of transplanting labor										
kg/labor d	5.0	6.5	4.8	9.2	9.6	7.4	10.9	7.9	10.8	11.6
₱*/labor d	3.5	4.2	3.6	3.9	3.5	5.3	6.8	[illegible]	5.3	4.7
Philippine annual average wage										
₱*/labor d[a]	5.2	4.3	4.1	4.1	n.a.	5.1	4.3	4.5	4.4	3.8

[a]Based on official data from the Bureau of Agricultural Economics.

ing power may have declined during the past 15 yr. This is particularly true for rainfed rice farmers and landless workers because the panel farms came from more progressive rice growing areas where productivity gains were greatest. Consumers clearly benefit from productivity gains in terms of falling real rice prices.

Government policies, economic incentives, and social profitability. Government policy has its greatest impact on producer incentives through the prices of rice, fertilizer, and irrigation. Rice prices in the Philippines have been about equal to world prices converted at official exchange rates. Between 1977 and 1981, the government was hesitant to export the domestic surplus and therefore domestic prices were 10% below world levels for those years.

The costs of fertilizers and agricultural chemicals have been above world prices. Price control, import licensing, and cash subsidies have effectively subsidized domestic manufacturers of fertilizer rather than farmers. Farmers' fertilizer prices were 32% higher than world fertilizer prices in 1979. But irrigation costs are almost completely subsidized by the government. Collected irrigation fees cover only 14% of the annualized investment and operating cost.

Except for subsidies on irrigation investment and operation, most government policies reduce economic incentives to produce rice. Effective protection rates indicate that sector specific policies reduce value added in rainfed rice production by 9% and increase value added in irrigated rice production by 9%. This raises the income on irrigated farms compared to rainfed farms (Table

Table 10. Incentives and social profitability in Central Luzon rice production, 1979.[a]

	Rainfed farms	Irrigated farms
Effective protection rate (%)[b]	-9	9
Domestic resource cost coefficient[c]	0.58	0.54

[a]Production data are from the IRRI Central Luzon loop survey. [b]This is the ratio of value added in domestic prices to value added in world prices. It measures the implicit tax on value added (returns to domestic factors). A positive value indicates a subsidy. [c]This is the ratio of the domestic resource cost (DRC) to the shadow exchange rate. The DRC is the ratio of the social cost of domestic factors to value added in world prices. A value less than 1.0 indicates that the activity is socially profitable.

10). Despite the unfavorable prices induced by government policy, yields and production have grown in all environments because of continuing improvements in rice technology and irrigation investments.

The most important government policy affecting incentives, however, is the overvaluation of the domestic currency caused by the industrial protection system. This reduces returns to all rice farmers by about 20%. Less consumer and industrial bias in government price intervention policies would raise private profitability in rice production and producers' real income.

When costs and returns are measured in social, rather than private prices, it is clear that rice production in Central Luzon is socially profitable. Domestic resource cost coefficients are less than 1.0, indicating that the cost of domestic resources used in rice production is less than the foreign exchange earned (Table 10). Results for irrigated production are highly sensitive to the cost of irrigation. The real capital cost of irrigating an additional hectare has risen 10% annually during the 1970s. Thus, continued growth in yields will be needed to maintain current social profitability as irrigation costs continue to rise.

Cropping systems program

Analysis of the physical and biological environment

Soil Chemistry/ Physics, Agronomy, Multiple Cropping, and Plant Pathology Departments

PHYSICAL ENVIRONMENT AND THE GROWTH AND YIELD OF RICE ON A TOPOSEQUENCE HILL SLOPE 354
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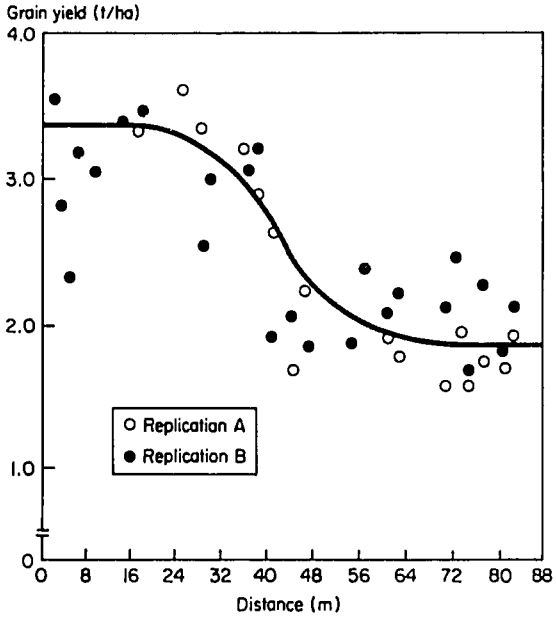
PHYSICAL ENVIRONMENT AND THE GROWTH AND YIELD OF RICE ON A TOPOSEQUENCE HILL SLOPE

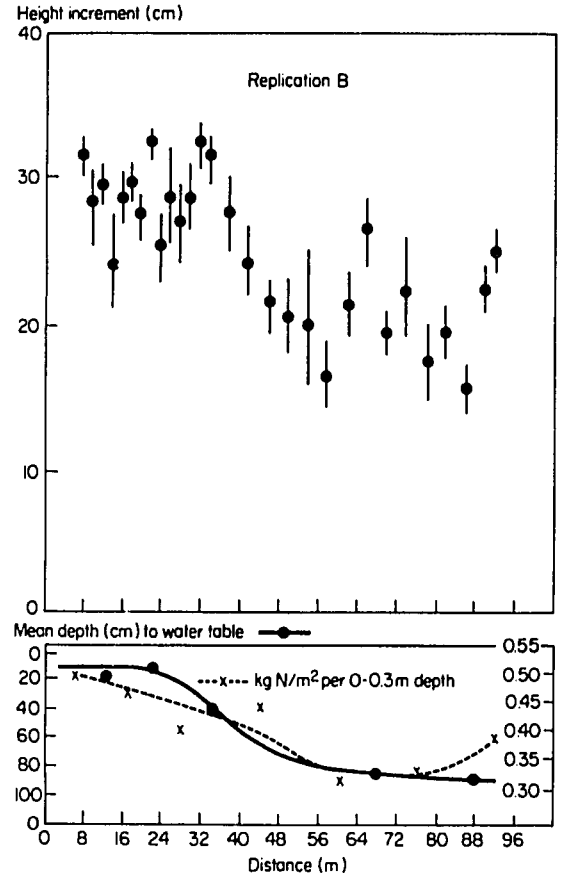
Soil Chemistry/ Physics, Agronomy, Multiple Cropping, and Plant Pathology Departments

For upland rice, plants grown at different positions on a hill slope may take up different amounts of groundwater and nutrients and therefore show differences in growth and yield. They may also experience differences in soil temperature that may affect their root and seed physiology and in aboveground physical microclimatic conditions that promote diseases.

During 1983 WS at IRRI, DSR IR36 was grown in 100-m-long rows, at 0.25 m row spacing, on a Tropudalf soil along the line of steepest incline on a gently sloping unterraced hillside. Crop height was measured weekly from emergence to harvest at every 2.0 m along the slope. At several positions, soil moisture content to 1.4-m depth was measured weekly, and soil bulk density and nutrient content to 0.3 m were determined monthly during the crop season. At specific toposequence positions, depth to water table, soil-water tension to 1.4 m, soil temperature to 0.3 m, and rice leaf wetness were observed daily or two or more times per day. Close to the sites where depth to water table and soil-water tension were measured, soil samples were taken at 0.1-m increments to 0.5-m depth. Their saturated hydraulic conductivities were determined in the laboratory.



1. Grain yield of IR36 at various distances up a toposequence slope. IRRI, 1983 WS.



2. Height increment during 20 Jul to 10 Aug 1983 of IR36 plants at various distances up a toposequence slope at IRRI. Also shown are mean depth to water table and soil N content during the same period.

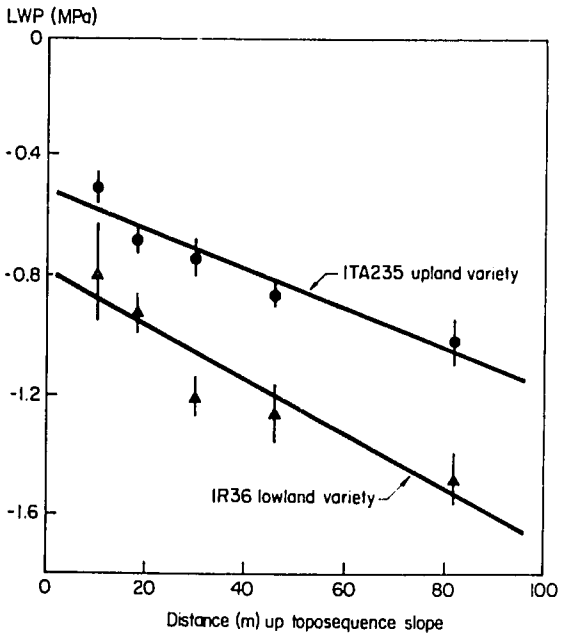
For 2 replicated toposequence strips, grain yield, measured every 2 m along the slope, showed a dependence on distance up the hill slope (Fig. 1) that corresponded to dependence of the seasonal average depth to water table. At successive 2- to 3-wk intervals during vegetative growth, plant height increments and corresponding mean depth to water table showed similar dependencies on hill-slope position. However, the relationship of crop growth to water table depth (and by inference to groundwater uptake and crop water use) cannot be considered causal for this toposequence. This is because along this *unterraced* slope, there is a complex pattern of nutrient concentrations (represented in Figure 2 by the N content of the 0-0.3 m

soil layer). High intensity rainfall formed this pattern by differential leaching and by transport downslope of soil particles and nutrients.

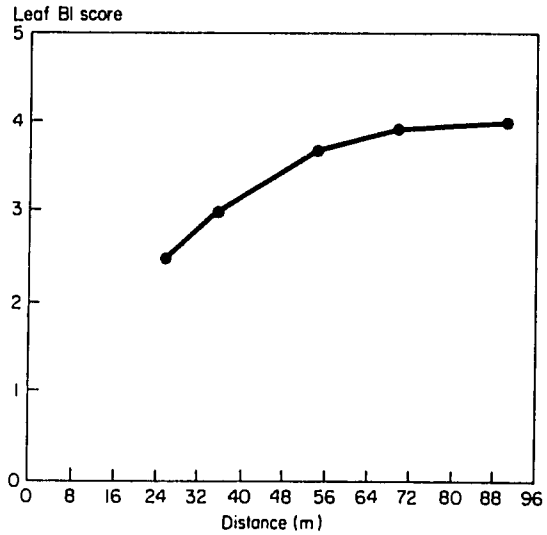
Nutrient contents of the harvested grain and straw showed little dependence on toposequence position. However, N content of grain and straw, and particularly Ca content of straw, were less at positions lower down the toposequence. This possibly indicates that those nutrients were leached more strongly at the lower positions where soils were submerged longer in late July during a rainy period following a major typhoon.

After rainfall, water table recession rates were measured at 10 toposequence positions. They ranged from 3 to 13 cm/d, sufficiently slow for groundwater uptake to contribute appreciably to crop growth and yield. Recession rate did not correlate with position on the toposequence or with the 0-1.25 m soil textural profile. For the same 10 toposequence positions, saturated hydraulic conductivity (k_{sat}) ranged between 3 and 300 cm/d. At all sites, k_{sat} in the least permeable layer *much* exceeded the corresponding recession rate. This suggests that downward flow rate was strongly impeded *below* the depths sampled.

Between rains and during a dry period preceding harvest, soil on the upper 30 m of the toposequence



3. Effect of position along a toposequence on midmorning LWP of 2 MVs. IRRI, Aug 1983.



4. Leaf Bl score (av of 28 varieties or lines) at various distances up a toposequence slope. IRRI, Aug 1983.

dried to a maximum extent of -0.1 MPa (-1 bar) in its 0-0.2 m layer. In the lower 50 m, drying did not proceed beyond -0.05 MPa. This dependence on toposequence position for *soil* water potential was reflected in the values for midmorning *leaf* water potential. Figure 3 shows the relationship of LWP (for lowland IR36 and upland ITA235 grown nearby along the same hill slope) to upslope distance for 1 d when water tables had receded below 1.0 m. The upland variety was able to maintain higher (less negative) potentials at all toposequence positions.

Bl incidence for IR36 and other varieties increased with distance up the slope (Fig. 4); however, fungicidal sprays minimized Bl effect on rice growth and yield. Supporting measurements of leaf wetness showed that most leaves were wet for a considerable part of nearly every day, regardless of whether it had rained that day or the night before. Some Bl-infective periods probably resulted from heavy dew rather than rain.

In 1983 WS, average soil temperature through the 5 to 30 cm layer increased by 0.05° C/10 m of upslope distance. Morning (0800 h) temperatures were between 25 and 27° C, and afternoon (1400 h) values were as high as 35° C at 5-cm depth. At depths shallower than 5 cm, temperatures would have been much higher and may have approached 40° C, at which temperature rice germination percentage is greatly reduced.

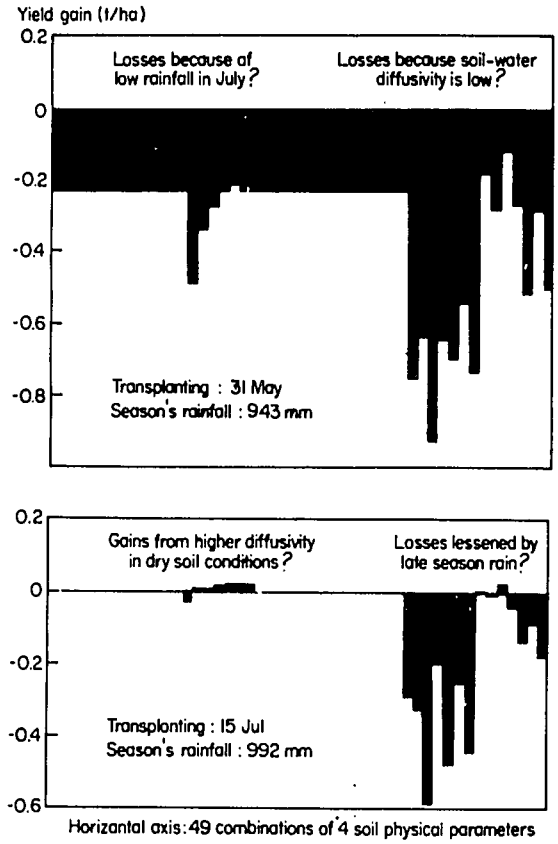
SIMULATION OF YIELD RESPONSE OF RAINFED RICE

Soil Chemistry/ Physics, Agronomy, and Multiple Cropping Departments

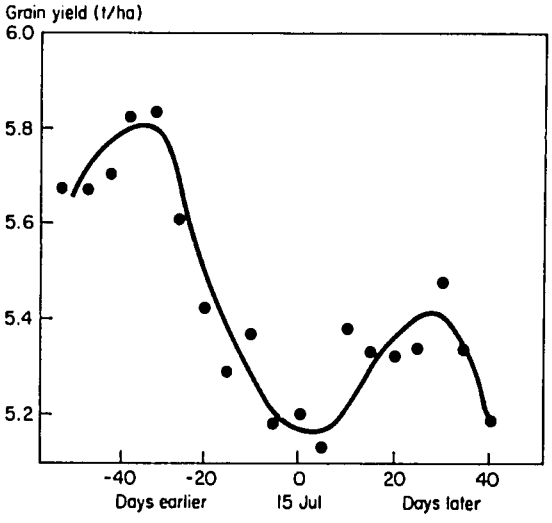
In a rainfed rice-based cropping sequence, the many rice management options include variety, type of soil cultivation, transplanting date, and seedling age and population density. The options are important for the rice yield and also for the timing and management of preceding or succeeding nonrice crops. Using an IRRI-developed model and Los Baños weather records, computer simulations were undertaken for IR36 to predict outcomes of some of the possible options.

With 1980 weather records, one set of simulations predicted that if IR36 had leaves that were slightly more erect, permitting more light penetration, it would have yielded slightly more grain that year. Its yield would also be insensitive, over a broad range, to the actual weight of seedlings transplanted per unit ground area.

Another set of simulations used weather records for 1959 to 1978 to explore the interaction of soil physical properties and crop water balance as they affect rainfed IR36 yield. Water balances were calculated for each year by a cumulative comparison of daily rainfall, potential evaporation, and seepage. These balances helped determine the earliest date that 100 mm of water would have accumulated within a bunded field, which would be the earliest time that a Los Baños farmer could transplant his WS rice. In wet years, such as 1960 and 1966, the date could be appreciably earlier than the conventional 15 Jul.



6. Computer simulations, based on 1960 WS Los Baños weather, of effects of soil physical properties on grain yield of rainfed IR36. The length of a vertical bar represents the departure from a standard yield of 5.54 t/ha. IRRI, 1983.



5. Computer simulations, based on 1966 WS Los Baños weather, of effects on rainfed IR36 grain yield of transplanting earlier or later than the conventional 15 Jul. IRRI, 1983.

The rice growth simulation was undertaken to predict how much yield the farmer would gain or lose by such an earlier transplanting. With 1966 weather data and a representative set of soil physical properties, predictions were made of yields that could result from transplanting up to 40 d earlier or later than 15 Jul (Fig. 5). For early transplanting, a predicted yield gain would result from very high rainfall in May 1966 followed by high irradiance in June. Predictions for July transplanting were lower because of low rainfall in that month. Higher yields might be expected from

later transplantings because of plentiful rainfall in Oct 1966 and high irradiance during early November.

The effects of changes in soil physical properties were simulated using each of the 20 yr of weather records. These properties influence the simulations through their determination of the soil's water-holding and water-transmitting characteristics, which are specified in the model by four independent soil parameters. By appropriate assignment of these parameters, it is possible to investigate the effects of inherent soil properties (such as texture) and of manipulable properties (such as structure) on rice growth. Ranges for these parameters for rice soils were established from published data. From within those ranges 49 realistic combinations of the 4 parameters were selected.

For each combination and assuming a 15 Jul transplanting, WS rainfed grain yield was predicted for 1959 to 1978. For 1960, yields were calculated for an early transplanting date of 31 May as well as for the conventional 15 Jul (Fig. 6). Predictions are shown as departures from the 5.54 t/ha yield predicted for the 15 Jul transplanting and for a representative (median) set of soil physical parameters. Yields predicted for 31 May transplanting were less than those for 15 Jul at *all* combinations of parameters despite the fact that the two seasons' rainfall totals were very similar. This probably reflects the influence of a July dry spell that occurred at a sensitive physiological stage. For 15 Jul transplanting, some of the simulated soil conditions led to predictions for slight yield *increases* caused by higher soil-water diffusivity at low soil-water content. For either transplanting date, changes of soil physical parameters are more likely to reduce than to increase yield. These reductions may arise because of simulations of low hydraulic conductivity and low soil-water diffusivity at low soil-water content. For any particular combination of parameters, yield declines are predicted to be lower for 15 Jul transplanting than for 31 May. One interpretation is that late-season rain interacted with the low conductivities and diffusivities to allow a larger soil-water uptake and crop growth.

Cropping systems program

Analysis of the social and economic environment

Agricultural Economics Department

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RELATIONSHIP BETWEEN ENVIRONMENT AND FARMERS' CROPPING SYSTEMS

Farmers use available technology to develop cropping systems based on the physical, biological, and socioeconomic conditions they face. An understanding of the quantitative relationships between environment and present cropping systems is needed for technology design.

Present cropping systems need to be compared in many different environments to quantify cause-and-effect relationships. Environmental measures may be treated as causative, "independent" or "determinant" variables. Measures of the cropping systems followed by farmers may be treated as the effect, "dependent" or "descriptor" variables.

Measuring descriptors of cropping systems. Descriptors are diverse with respect to principles expected to govern their behavior. For example, yield as a descriptor of a cropping system is responsive to measurable inputs on a plot of land, while crop area reflects allocative decisions of a farmer. Total crop production, yield times area, is even more complex.

Land-indexed descriptors are commonly used, for example, production per ha, labor h per ha, N per ha, percentage of land in upland crops vs lowland crops, etc.

The multiple cropping index (MCI) tells how many sequential crops are produced on the land resource yearly. But it provides no information about the amount of crop output or about use of resources other than land. In many situations, land-indexed descriptors may be less appropriate than labor or capital-indexed descriptors.

One way of organizing measures of cropping systems for technology design is to distinguish output-output, output-input, and input-input descriptors. Input-related measures can be subdivided into those related to land, labor, capital, or management inputs. This scheme was used in a 1979 study of the environmental effect on cropping systems identified at 14 Philippine sites (Annual report for 1979).

However, while multiple indices capture details of cropping systems, they are unwieldy for design. Identifying and designing for individual input-output traits of a system is tedious and hinders development of a general strategy for technical intervention. Also information use is inefficient because relationships among descriptors are not considered. For example, correlation among several descriptors would suggest that few descriptors might be used as indicators of a wide range of characteristics. Succinct methods are needed to describe agricultural systems in a manner that reflects their operating characteristics.

Combining information about dissimilar products and processes is one of the less tractable problems in developing descriptive schemes. The MCI which measures the number of crops grown per year is affected by the length of crop duration: a sequence of short-season crops leads to higher indexes than that of long season crops. Hence, the measure's implication for resource use intensity is ambiguous. The measure gives land allocation but no indication of the volume or importance of output that would help in cross-sectional or intertemporal comparisons and analysis.

Economic valuation of crops and then summing is an easy way of homogenizing products for aggregate output measures. It is usually expressed in per farm or per hectare units. The measure is not very satisfactory when both interregional and local comparisons are of interest because the prices appropriate for valuation at one level of aggregation or location may not be appropriate at another. Also prices change and make continual updating of valuations necessary. There is also the problem of choosing an appropriate set of prices; choices often depend on the purpose of comparisons. Finally, there is the theoretical inconvenience that prices are an aspect of the environment according to which farmers make choices of production processes and output kind and amount. It is inconvenient for a factor to enter both sides of the conceptual model, that is, as both descriptor and determinant.

Resource equivalency ratios. Three related measures of cropping systems were devised in 1983 to provide a succinct but comprehensive measure of the system, and solve the problem of output heterogeneity. The measures, called resource equivalency ratios (RER), require little data and possess intrinsic meaning. They show the total output of a farm per unit of resource and therefore measure efficiency. Their computation is similar to that of the land equivalent ratio (LER), but on a whole farm basis rather than by plot, and for labor and capital as well as for land.

The RER of a farm is the number of units of a resource at a standard productivity required to equal the farm's production per unit of the resource. RER measures a production unit's output of various goods and services as the ratio of the quantity of a resource needed to produce those goods and services at a standard productivity rate, to the amount of the resource available to the production unit. The production unit may be a subunit of a farm, a farm, village, region, or other geopolitical unit, or farming system or subsystem. The goods and services are the various crops produced by the farm.

The ratio may be computed for several cropping system resources, usually land, labor, and capital. The RER are the land equivalency ratio (LER), labor equivalency ratio (PER), and capital equivalency ratio (KER). Quantities of resources "needed" and "available" may be measured as stock variables compared to flow variables.

Available land measured as a "stock" would reflect farm size. Measured as the "flow" of land services, it would reflect the total planted area which might exceed farm size if more than one crop is grown per year. When the stock measure is taken, the resulting LER is influenced by intensity of land use (land idleness and multiple cropping), natural land qualities (fertility, drainage, etc), and the use of other inputs. When the flow measure is chosen, land use intensity does not directly affect LER and is more purely a productivity measure.

Standard resource productivities used in an RER calculation may represent a population mean, technical maximum, temporal benchmark, or other meaningful value. RER values can then be interpreted as an output-to-input ratio indexed to that standard. It is useful if standards are chosen at a high level of aggregation, i.e. for a country or several countries. If standard land productivities across crops are computed as mean productivities from a national farm population, a 0.5 LER for a specific farm means the farm's total crop output per ha is half that of an average farm. If the absolute level of productivity standards are arbitrarily chosen (they should approximate the relative productivities of the resource across crops), RER values have no intrinsic meaning.

To compute an RER for a farm or other production unit once standard resource productivities are chosen, one needs the amount of each output produced and the amount available to the unit resource for which the analysis is conducted. If output of a farm i of each product j is denoted as y_{ij} and the amount of resource k available to farm i is x_{ik}, then the RER for that farm in resource k (RER_{ik}) is given as

$$\frac{\sum_{j=1}^{n} \frac{Y_{ij}}{Y_{jk}}}{x_{ik}}$$

where Y_{jk} is the standard yield of output j per unit of resource k.

The summation term in the numerator of the expression is the amount of resource k required at standard productivity rates to produce the various farm output quantities. The denominator is the amount of resource k available to the farm. Slightly rearranged, the expression is as follows:

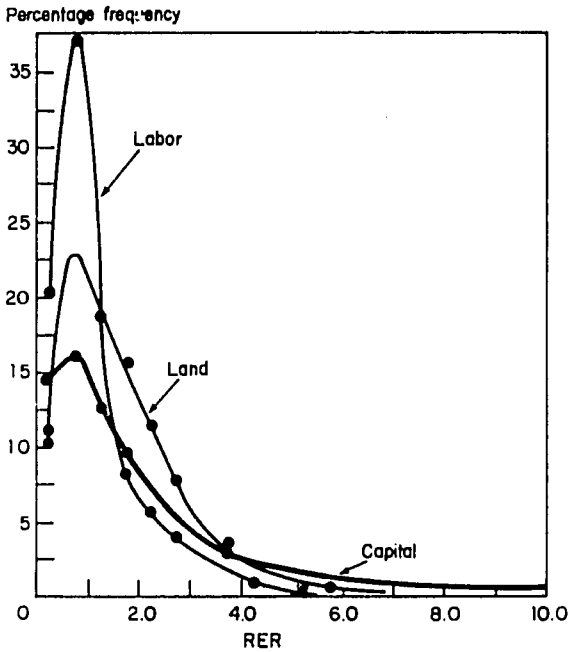
$$\frac{\sum_{j=1}^{n} Y_{ij} \frac{1}{Y_{jk}}}{x_{ij}}$$

explained as the sum of the weighted outputs of a farm per unit of resource. The weight of each output is the inverse of the standard productivity of resource k in each respective output j.

The above expression is similar to that which would express the monetary value of output per unit resource (eg, gross farm income per ha farmland) except that respective output prices are replaced by the inverse of standard resource productivities. The measures become more similar as correlation increases between chosen inverse productivities and output prices. One might expect a high inverse correlation between per ha yield and price at the national level, across crop species.

Distribution of resource equivalency ratios on rainfed farms. To examine the RER measures of cropping systems, ratios were computed for 847 Philippine rainfed rice-based farms. Villages and then farms were randomly chosen within a widespread climatic regime where monthly rainfall averages more than 200 mm in 5-6 mo/yr and less than 100 mm in 2-3 mo/yr. The stock measures of land, labor, and capital were used in computation.

Distributions of each RER were negatively skewed (Fig. 1), with a lower bound of zero



1. Frequency distribution of RER. IRRI, 1983.

approached as farm output approached zero (with a non-zero amount of inputs used), and an upper bound of infinity approached as the amount of a resource employed in production approached zero (with non-zero output). The PER varied least across farms, with 90% of values falling below 2.5, and 40% of observations falling in a range 0.75 to 1.25. The LER fell below 3.2 on 90% of farms and between 0.75 and 1.25 on 30% of farms. On 10% of farms the KER was higher than 2.1% and only 16% of the values fell between 0.75 and 1.25.

The frequency of combinations of RER values on farms was influenced by the substitution among resources in production, the Law of Diminishing Marginal Returns, and the quality of resources. The use of a large amount of one resource while holding other resources at low levels will reduce the RER for the intensively employed resource and raise the RER for the less-used resources. The quality of the physical environment, soil fertility or water-holding capacity, pest and disease incidence, rainfall stability, and other factors may depress or raise the RER for all resources uniformly. The frequencies of RER were examined across farms.

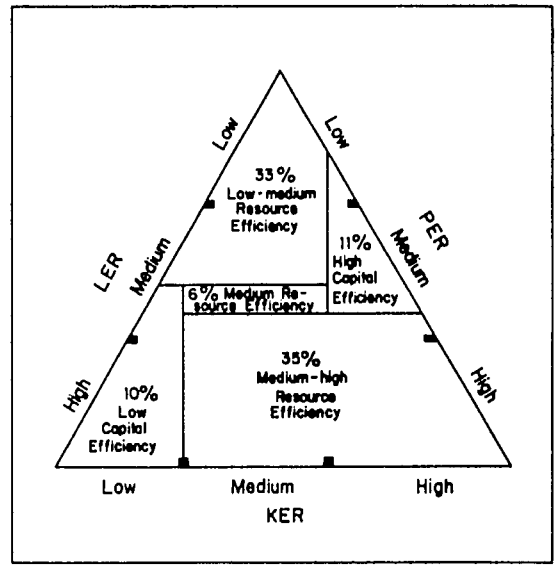
RERs were classed as low, medium, or high depending on whether the value fell into the lower, middle, or upper one-third of all RER values for each resource. Figure 2 shows the distribution of combinations of RER values for 847 farms. On 47 farms (5%), the PER and LER fell in opposite one-thirds of the distribution and cannot be depicted on the triangular chart.

RER represents a farm classification scheme that can be employed for purposes of technology design and policy purposes. To use the typology in this manner, it is necessary to understand the environmental factors that influence farmers' choices in resources that result in a farm's classification. Analysis of the relationship between farm classes (descriptors) and environmental factors (determinants) is continuing in 1984.

MULTIPLE CROPPING AND EMPLOYMENT

Between 1975 and 1980, Iloilo farmers replaced local rices with early-maturing high-yielding varieties and switched from transplanting to direct seeding. Since more work was needed to harvest their higher yields, modern rices increased labor use by about 7% in rainfed areas and 15% with irrigation. Direct seeding lowered labor needs by 20% so that average total employment per ha per crop fell by 18%. The new techniques also set in motion other changes that affected bigger shifts in the labor force.

Direct seeding of early-maturing varieties made it possible to increase the number of crops grown



2. Distribution of 847 Philippine rainfed farms by efficiency of resource use. IRRI, 1983.

Table 1. Percentage of land planted to various cropping patterns on 45 farms in Iloilo, Philippines, crop years 1974-75 to 1980-81.

Cropping pattern[a]	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
R – R	5	20	38	49	45	38	37
R – U	11	28	30	17	31	39	42
U – U	2	5	12	6	8	5	4
R	82	47	20	27	14	17	11
U	0	0	0	1	2	1	6
Cropping intensity	1.2	1.5	1.8	1.7	1.8	1.8	1.8

[a]R = rice, U = upland crop, – = followed by.

Table 2. Labor use for rice production on 45 Iloilo farms, 1975-76 to 1979-80.

Crop yr	Labor h/farm			Labor h/ha		
	Direct seeded	Trans-planted	All rice	Direct seeded	Trans-planted	All rice
1975-76	415	1182	1597	513	798	691
1976-77	815	900	1715	536	708	613
1977-78	881	425	1306	430	715	493
1978-79	1012	171	1183	407	590	426
1979-80	740	88	828	336	505	388

Table 3. Wage rates imputed from hiring transactions on 45 Iloilo farms from crop years 1975-76 to 1979-80.

	Wage rate ($/labor d)				
	1975-76	1976-77	1977-78	1978-79	1979-80
Nominal wage rates					
Land preparation	1.24	1.17	1.21	2.21	2.05
Transplanting	1.25	1.10	0.97	0.85	0.77
Weeding	0.59	1.10	0.80	0.71	0.69
Harvesting	1.27	1.89	1.94	1.99	2.13
Consumer price index	100	106	115	123	146
Real wage rates					
Land preparation	1.24	1.10	1.05	1.80	1.40
Transplanting	1.25	1.04	0.84	0.69	0.53
Weeding	0.59	1.04	0.70	0.58	0.47
Harvesting	1.27	1.78	1.69	1.62	1.49

per year from 1.2 in 1974 to 1.8 in 1980 (Table 1). Higher cropping intensity raised labor demand. Eight percent more labor h were used in 1976 than in 1975 and about 21% more hired labor (Table 2). Wages also increased (Table 3) so farmers looked for ways in addition to direct seeding to cut labor

Table 4. Average time of rice land preparation by hand tractor and water buffalo on 45 Iloilo farms, crop years 1975-76 to 1979-80.

Yr	Av time (h/ha)					
	Hand tractor			Water buffalo		
	Rainfed	Irrigated	All rice	Rainfed	Irrigated	All rice
1975-76	0	0	0	167	130	153
1976-77	0	2.1	1.2	160	103	137
1977-78	0.1	0	0.1	128	80	104
1978-79	5.5	2.6	4.2	124	82	105
1979-80	7.4	7.7	7.5	99	95	97

costs. Adoption of machine threshing started in 1977, and by 1980, no rice crops were threshed by hand. Farmers also began using hand tractors (Table 4). By 1980, labor use dropped to half the 1975 level (Table 2). Average production of rough rice per labor h rose sharply, from 2.6 kg/h to 8.0 kg/h (Table 5).

Wages for the disappearing job of transplanting fell during the technical changeover but rose for land preparation, harvesting, and threshing which had to be done quickly for multiple cropping. The real agricultural wage, for all tasks combined, increased at first then declined to a level just above that in 1975. Higher wages were not the only component of increased labor costs. With labor-saving techniques, jobs were completed more quickly so that the amount of work performed per hiring transaction fell from 61 h to 11 h (Table 6). Hence, the transaction's cost per hour of hired labor increased.

Composition of the labor force shifted only slightly. The proportion of work hired rose initially then dropped back to the level before the technical change. In contrast, the proportion of work done by farm household heads fell from 32% in 1975 to 28% in 1976, then rose gradually back to 36% in 1980. Rice work done on the family farm by women and children declined steadily from 8% to 3% (Table 7). Children now stay in school longer; parents consider this an investment in children who will support them in old age.

Although MVs and irrigation increase labor use, when early-maturing varieties and direct seeding were used in Iloilo, multiple cropping increased, and conditions that ultimately reduced total

Table 5. Rice production per labor h on 45 Iloilo farms, 1975-76 to 1979-80.

Period	Rice production (kg/labor h)			
	Planting method		Variety	
	Direct seeded	Trans-planted	Modern	Local
1975-76	2.6	2.5	3.1	2.2
1976-77	4.1	2.9	4.1	2.6
1977-78	6.0	2.5	5.7	2.8
1978-79	7.6	3.7	8.0	2.9
1979-80	8.0	1.3	8.1	1.2

Table 6. Hired-labor hours and plot operations for which labor was hired. Iloilo, Philippines, 1975-76 to 1979-80.

Period	Total time (h)	Plot operations (no.)	Time/plot operation (h)
1975-76	41,775	689	60.6
1976-77	50,626	1,487	34.0
1977-78	40,173	1,839	21.8
1978-79	32,232	1,640	19.7
1979-80	21,222	1,860	11.4

employment in rice production developed. Higher labor productivity and greater labor requirements increased wage rates that in turn made mechanization profitable. Higher incomes from improved yields and multiple cropping supported investment in machinery and higher education for children as they moved out of the work force. Wages of workers remaining in the work force are maintained at what it costs to do the work by machine, a real wage level that is higher than wages were before technological change.

COST OF LOWLAND-UPLAND MODE SHIFT

Converting land from upland to lowland and back between seasons costs more in land preparation than leaving land in the same system year-round. Without thorough puddling for lowland rice following an upland crop, yields may be affected. Similarly, upland yields may be adversely affected if the seedbed does not have a loose, friable texture the season after lowland rice. Whether a farmer experiences higher costs for thorough land preparation, or lower yield because land preparation was not thorough, the result is reflected in the profit from a cropping pattern.

This feature of upland-lowland cropping systems explains differences in the profitability of farms with different land resources. Some farms have land that can be left as lowland all year by using irrigation during DS. Other land is sufficiently well drained for growing upland crops during WS. Still others are a combination of both. They all are significantly more profitable than a farm which has land that can only grow lowland rice in WS and a dryland crop during the less rainy times of the year (Annual report for 1978).

A collaborative research project with the National Food and Agriculture Research Council of the Philippines studied this problem across a range of cropping systems and physical environments. The economic performance of 63 farmers and experimental cropping patterns reported by Regional Integrated Agricultural Research System technicians were analyzed by regression. The total per-ha value of crops produced in an annual cropping pattern was related to the number of upland-lowland shifts, the number of crops grown without shifting model, the per-ha cost of labor and materials, and the sites from which data were taken.

The estimated coefficients (Table 8) all had the expected signs, and those of most interest were significantly different from zero. Shifting the mode of production from upland to lowland or vice versa

Table 7. Distribution of rice labor by source on 45 Iloilo farms, 1975-80.

Period	Total h/ha	Labor (%) by family member			Hired labor (%)	Exchange labor (%)
		Adult male	Adult female	Children		
1975-76	641	32	5	3	58	2
1976-77	572	28	2	3	65	2
1977-78	366	25	2	1	68	3
1978-79	427	32	3	1	61	4
1979-80	322	36	3	1	57	4

Table 8. Relationship of the value of crop production ($/ha) to shifts between lowland and upland modes of production.

Independent variable	Coefficient	*t*-statistic
No. of mode shifts	−186	2.13*
Lowland crops per shift to lowland	178	1.29
Upland crops per shift to upland	230	2.10*
Labor and power cost/ha	2.2	7.08***
Materials cost/ha	2.1	13.36***
Dummy for experiment	−35	0.34
Constant	−344	
Adjusted R^2	94.0	
F statistic	70.6	

costs a farmer about $184/ha in lower production compared to the patterns without mode shifts. For each crop grown per shift to upland mode, farmers earned an additional $230. The $178 estimated earnings for each lowland crop grown per shift to lowland mode was not significant.

Apart from gains from staying in a given production mode, farmers across the several locations earn about a 2:1 return on the value of both labor and materials that they invest in crop production, a rate quite widely realized in Philippine agriculture (Research highlights for 1979). Whether a cropping pattern was grown by a farmer or a researcher did not significantly affect returns. The quality of resources at certain sites did affect returns, reflected in significant coefficients of site dummy variables.

Cropping systems program

Pest control in rice-based cropping systems

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INSECTS

Entomology Department

Insect abundance and rice cropping intensity. Irrigation, early-maturing varieties, and direct seeding methods have fostered double rice cropping in upland and lowland environments within the past 20 yr. The area devoted to rice has also expanded but not as much as double cropping. This intensification of rice production in Asia has been associated with frequent insect pest epidemics.

Rice intensification factors were analyzed to see their influence on insect abundance. Total number of rice crops per yr in upland (Batangas), rainfed lowland (Pangasinan, Iloilo, Cagayan), and irrigated lowland (Nueva Ecija) environments ranged from 1.0 to 1.9. The total rice area ranged from 46 to 94% within a 1-km radius of each kerosene light trap, which is the effective dispersal distance of insect pests.

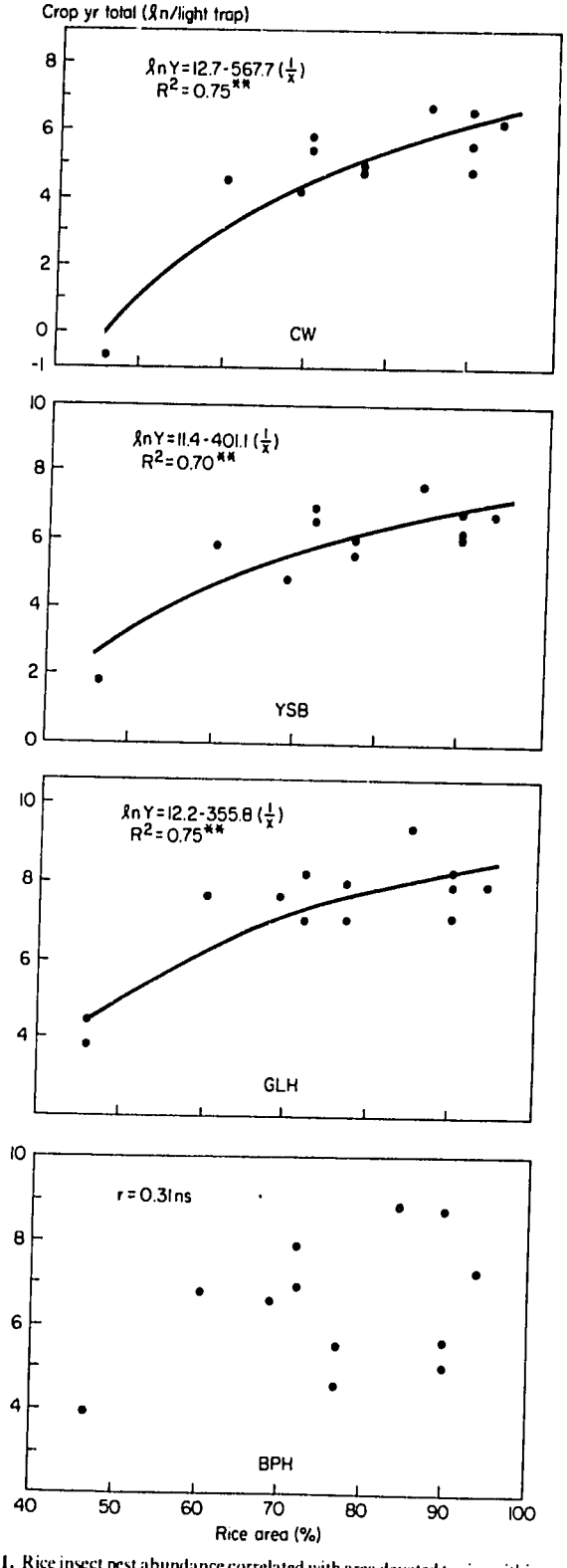
Multiple regression analysis showed that the number of rice crops per yr and rice area were the greatest factors influencing observed insect abundance. Variety, crop maturation period, and agrochemical usage did not improve the correlation for any insect species.

CW, GLH, and YSB showed a stronger correlation with area planted to rice than did BPH (Fig. 1). As the rice area increased beyond 50%, the curves flattened to show a levelling of the response at the more fully planted sites. The lack of BPH correlation may be caused by the insect's greater dispersal behavior beyond the 1-km limit.

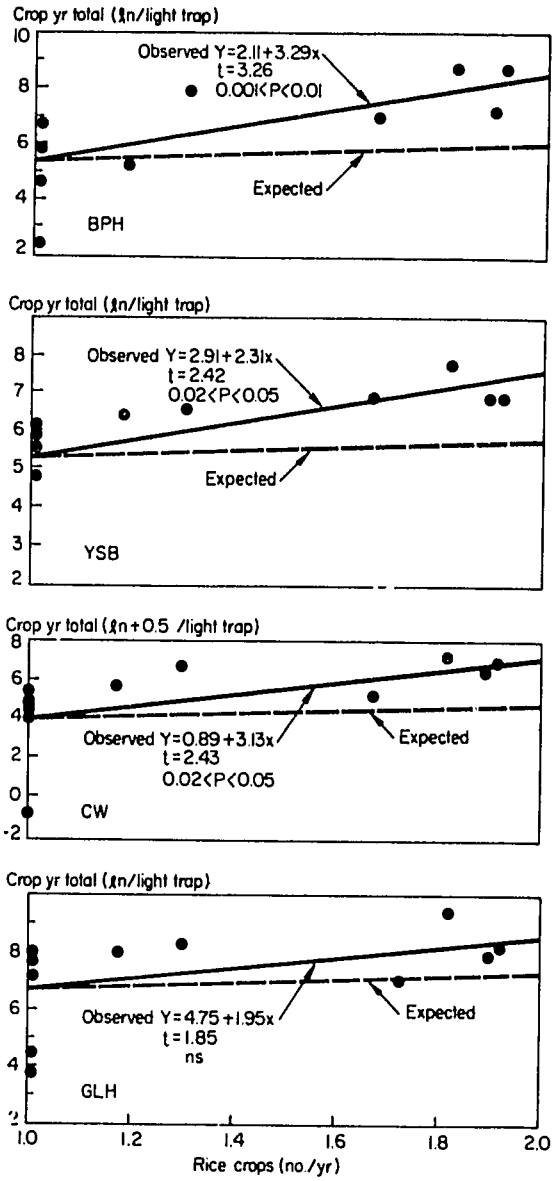
BPH showed the highest correlation with number of rice crops per yr (Fig. 2). Moving from 1 to 2 crops/yr increased BPH populations 568%/crop. Less responsive were CW (88%) and YSB (47%). The higher populations of BPH and CW may be explained by their shorter generation times. GLH correlation was not quite significant, but clearly showed a similar trend.

To minimize insect pest epidemics, it is better to increase rice area than the number of crops per year. This is especially true for areas which already have 50% planted to rice.

Effect of rainfed lowland environment on rice insect abundance. Light trap catches indicate general insect activity for an area. A propane-powered light trap was operated in 1980-83 in the rice fields of Bauan village, Solana, Cagayan.



1. Rice insect pest abundance correlated with area devoted to rice within a 1-km radius of each light trap. Each data point in the graphs is the annual kerosene light trap catch from a location in the Philippines, 1983.



2. Comparison of the observed exponential (insect numbers are natural logarithms) and an expected doubling (arithmetic increase) of rice insect pest populations as rice cropping intensity increases from 1 to 2 crops/yr. Each data point is the annual kerosene light trap catch from a location in the Philippines, 1983.

Solana farmers grow insect-susceptible, traditional Wag-wag varieties which tolerate the weather extremes in that rainfed drought- and flood-prone environment. Available rainfall, field moisture status, and planting time data presented an opportunity to relate insect abundance to weather and cropping conditions. Field moisture status was determined daily by the Multiple Cropping Department. The rice area planted was calculated for the field, not the seedbed. Farmers plant their dry seedbeds in June or July in a "normal" year.

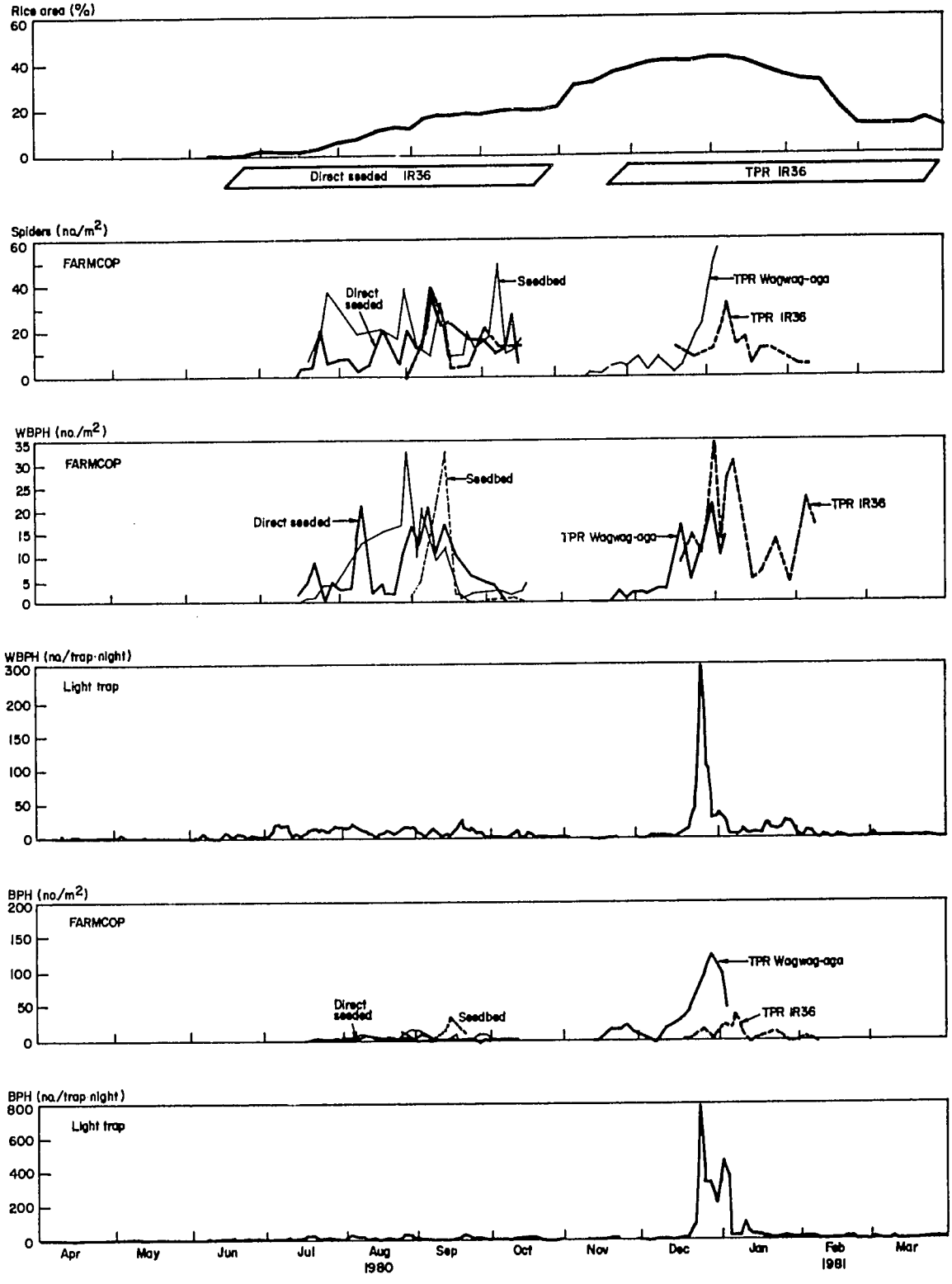
Greater insect monitoring took place in the 1980-81 crop year when the FARMCOP suction insect sampler was used on the DSR and TPR crops and seedbeds (Fig. 3). GLH and WBPH were more abundant on the direct seeded crop and the seedbeds. The prolonged crop establishment period was caused by drought in June; some seedbeds were started in May; others were delayed until July. As in 1981-82, GLH was active in August and September. Planthopper numbers, however, were low until after the prolonged floods in October and November from two consecutive typhoons. WBPH and BPH numbers exploded in January, about two insect generations after the major flood period.

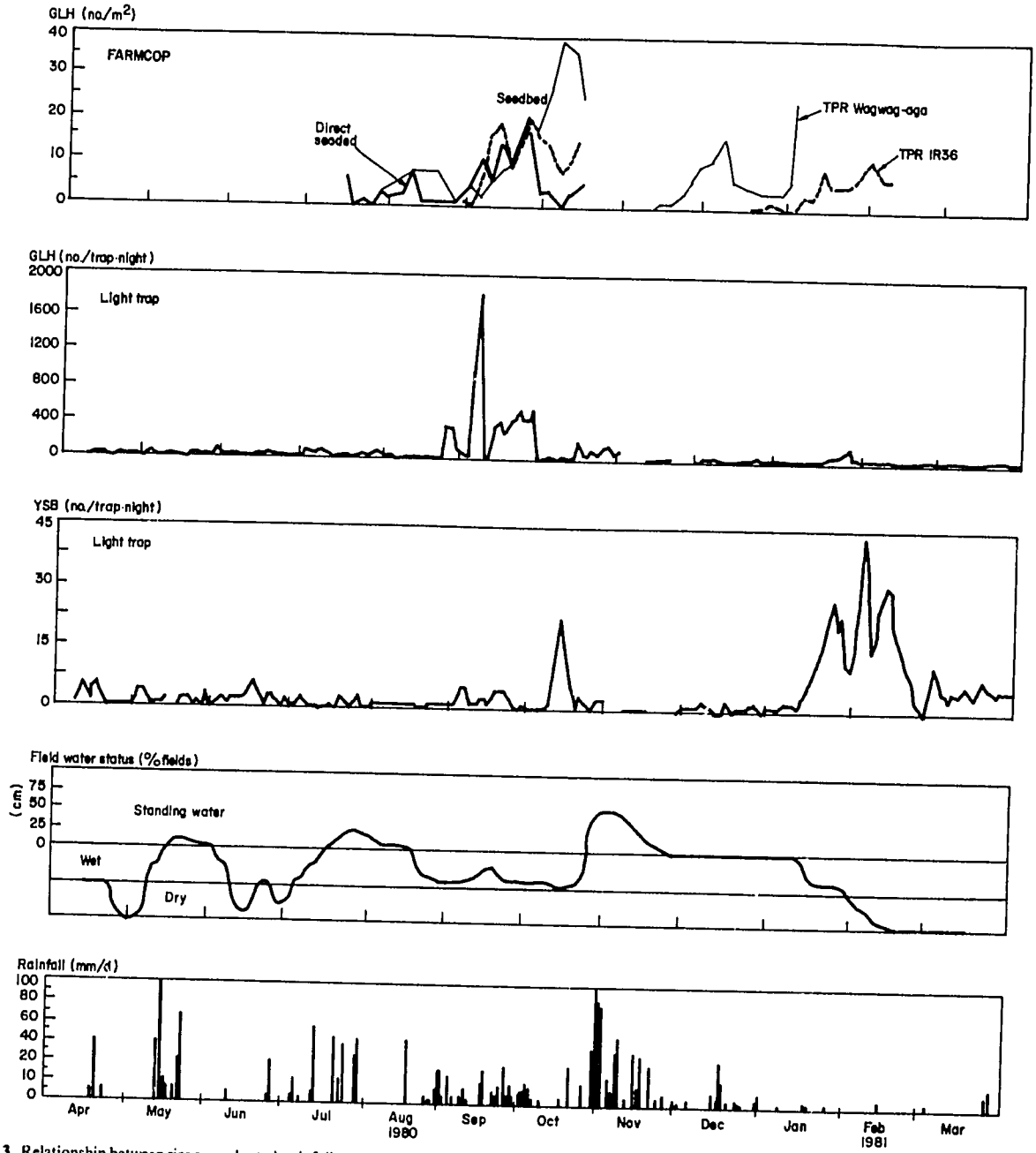
FARMCOP data show extremely low spider numbers after the typhoon. Because spiders are the principal natural enemies of planthoppers, perhaps high hopper numbers were a form of resurgence caused by spider removal. As a result, BPH caused hopperburn in about 30 ha.

Crop year 1981-82 had a highly favorable rainfall distribution and consequently higher insect numbers (Fig. 4). Rains in May and June were adequate for seedbed establishment and insect population increase in seedbeds. A dry July produced dry fields in August, but rains throughout August stimulated a burst of activity among the hoppers at transplanting time. GLH numbers reached 1,200/trap-night but populations subsequently declined on the transplanted crop probably as a result of the deep flooding from November typhoons. YSB population could not increase either.

Crop year 1982-83 was characterized by early rainfall in May and the first half of June to produce a wet moisture status suitable for sowing the dry seedbed (Fig. 5). The abnormally long dry period was broken by an October typhoon, allowing land preparation. However, the long dry spell had prolonged the age of seedlings, and many seedbeds suffered from extreme drought. Insects could not adequately recover when the rains came. The crop year had extremely low insect activity and extremely low rice yields.

Asian pre-Green Revolution records show BPH and WBPH outbreaks. Removal of their natural enemies by flooding could have been the cause. GLH population did not resurge after the flooding,

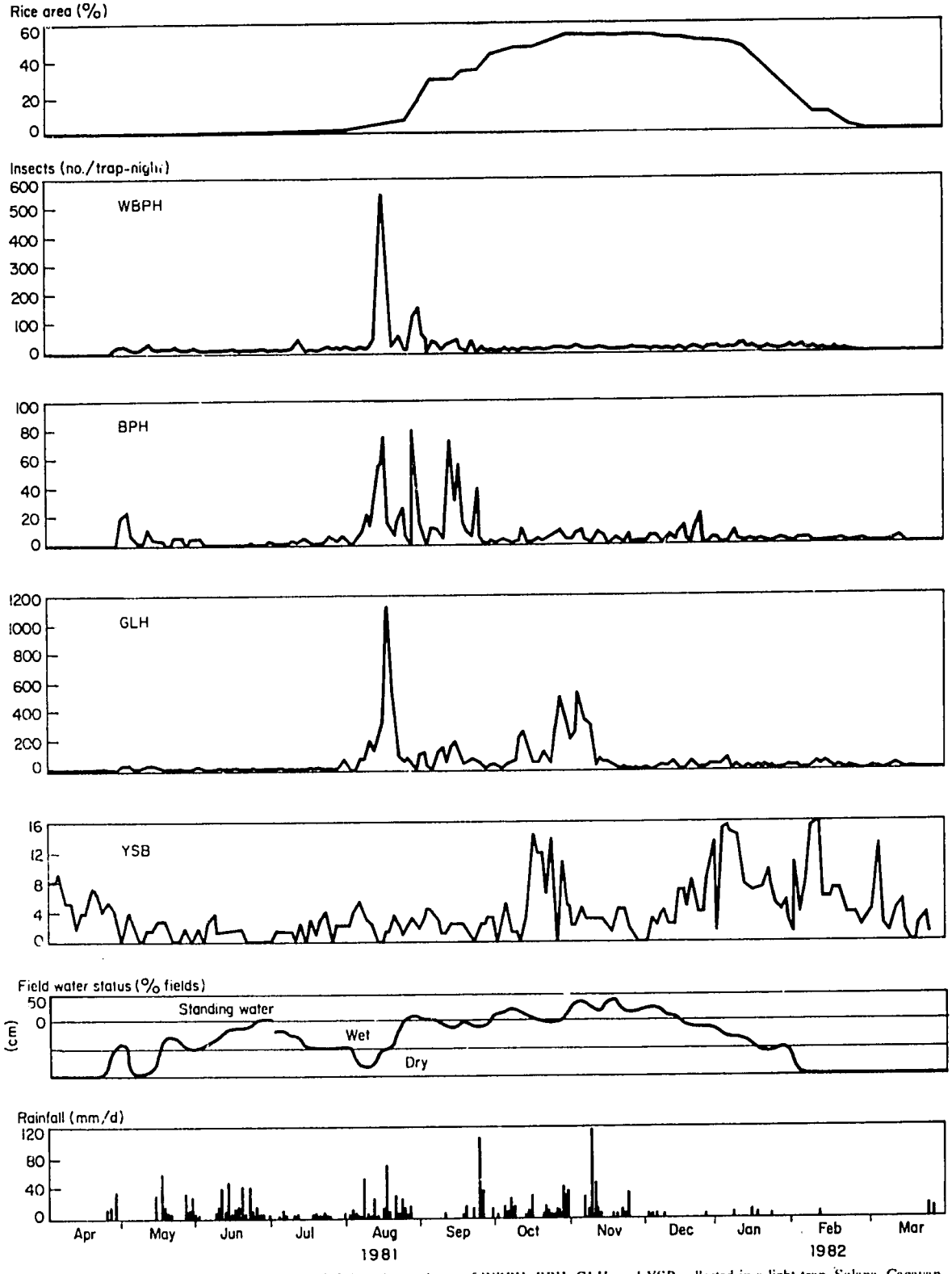

Rice area (%)
60
40
20
0
Direct seeded IR36
TPR IR36
Spiders (no./m2)
FARMCOP
Direct seeded
Seedbed
TPR Wagwag-aga
TPR IR36
WBPH (no./m2)
FARMCOP
Seedbed
Direct seeded
TPR IR36
TPR Wagwag-aga
WBPH (no./trap-night)
Light trap
BPH (no./m2)
FARMCOP
TPR Wagwag-aga
Direct seeded
Seedbed
TPR IR36
BPH (no./trap-night)
Light trap
Apr
May
Jun
Jul
Aug 1980
Sep
Oct
Nov
Dec
Jan
Feb 1981
Mar



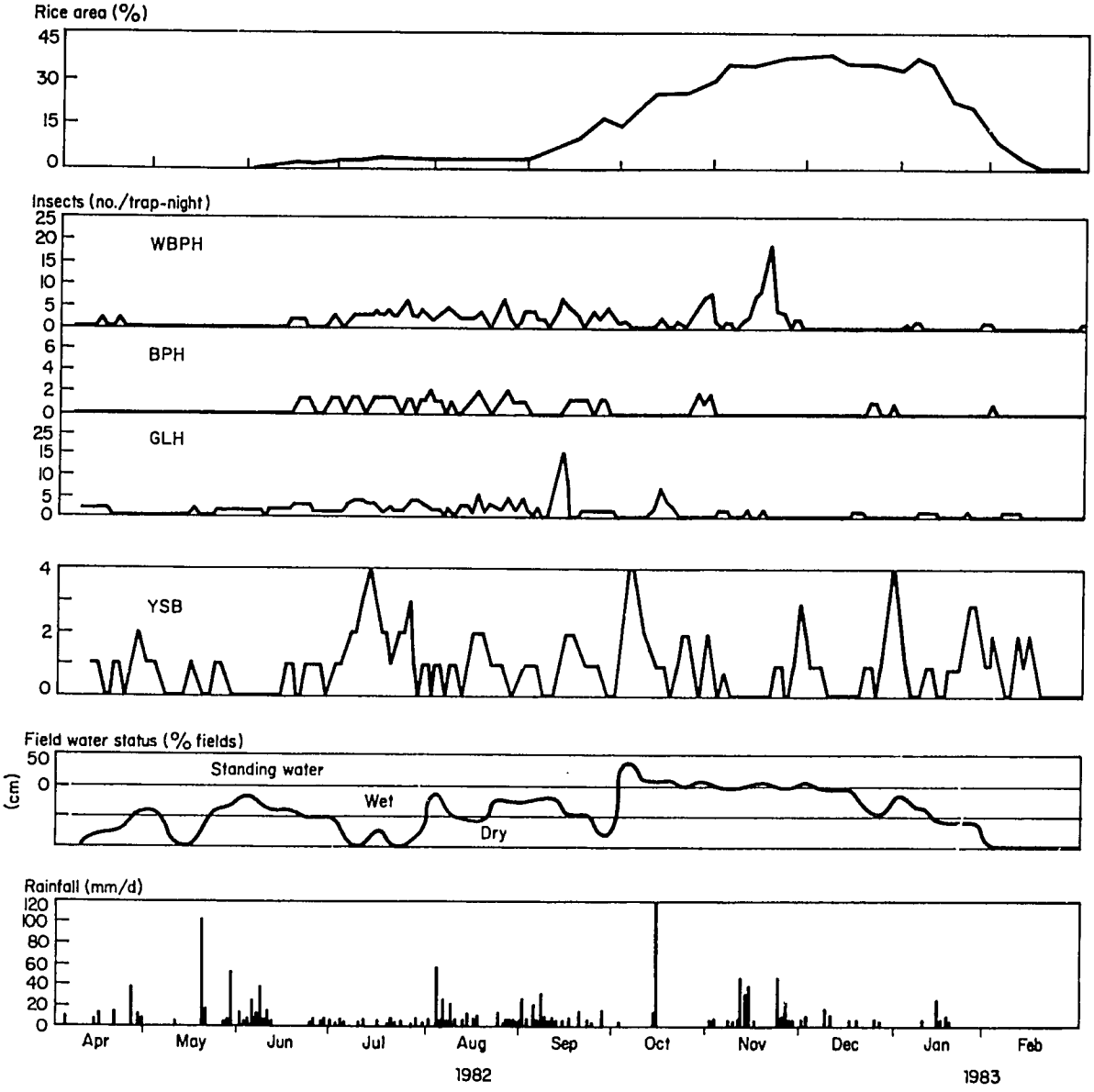
3. Relationship between rice area planted, rainfall, and spider predators, and the abundance of WBPH, BPH, GLH, and YSB collected in a light trap or in a FARMCOP suction sampler. Solana, Cagayan, Philippines, 1980-81.

perhaps indicating that natural enemies other than spiders are also important.

During the 1980-83 period, GLH was the most abundant hopper. BPH and WBPH behaved similarly when abundant, but WBPH was more prevalent. YSB is known to tolerate flooding and was most abundant after the 1980-81 flood period. Insect numbers were lower than in other sites because of the direct effects of extreme drought and flooding. The indirect effect of planting less than 50% of the rice area also reduced their numbers.



4. Relationship between rice area planted and rainfall, and abundance of WBPH, BPH, GLH, and YSB collected in a light trap. Solana, Cagayan, Philippines, 1981-82.



5. Relationship between rice area planted and rainfall, and abundance of WBPH, BPH, GLH, and YSB collected in a light trap. Solana, Cagayan, Philippines, 1982-83.

Suitability of ratoon rice for insect pests. Field and greenhouse trials compared ratoon to second TPR crop for attractiveness to, nutrition, and population buildup of insect pests. Insect-susceptible but RTV-resistant IR1917 was planted in all trials without insecticide use. Standing water was maintained.

RWM *Hydrellia philippina* did not oviposit on ratoon rice in the field, but an average of 38 eggs/100 hills and 6% damaged leaves were recorded on the transplanted second crop. Greenhouse trials, with plants infested by hand, showed low RWM survival and reduced body weight on ratoon rice (Table 1). There were not enough other vegetative stage pests in the field trial to draw conclusions. Greenhouse trials showed ratoon rice to be a poor host for CW *Nymphula depunctalis* as survival and body weight were low. Less affected were GHC *Rivula atimeta* and green semilooper *Naranga aenescens*. Developmental periods of

Table 1. Suitability of TPR and ratooned IR1917 for development of rice insect pests.[a] IRRI greenhouse, 1983.

Pest	Crop establishment method[b]	Survival[c] (%)	Developmental period[d]		Insect wt[e]	
			Days (no.)	n	mg	n
RWM	TPR	40	24.0	31	0.98	29
	Ratoon	17	24.5	12	0.32	19
	Δ	**	ns		**	
CW	TPR	65	28.3	41	10.70	32
	Ratoon	32	29.7	27	6.87	29
	Δ	*	ns		**	
GHC	TPR	88	17.8	48	16.06	57
	Ratoon	93	17.8	45	9.68	42
	Δ	ns	ns		**	
Green semilooper	TPR	37	14.9	36	22.57	43
	Ratoon	25	14.2	27	13.40	35
	Δ	**	ns		*	
YSB	TPR	27	32.3	12	10.32	48
	Ratoon	52	31.5	19	4.13	36
	Δ	**	ns		*	
LF	TPR	55	26.2	43	21.80	40
	Ratoon	60	25.8	51	16.06	42
	Δ	ns	ns		**	
BPH	TPR	78	15.1	51	1.04	54
	Ratoon	82	14.9	49	0.91	30
	Δ	ns	ns		*	
WBPH	TPR	76	13.7	45	0.72	54
	Ratoon	70	13.7	46	0.63	42
	Δ	ns	ns		ns	
GLH	TPR	57	17.9	37	1.04	42
	Ratoon	62	18.4	42	0.58	37
	Δ	ns	ns		*	

[a]Av of 6 replications, 10 insects/replication. [b]Plants infested 21 d after ratooning or transplanting. [c]For all insects except RWM where mature eggs were used, first-instar larvae or nymphs were set on plants, and allowed to develop until adulthood. [d]Only surviving insects were considered. n = no. of insects. [e]Larvae or nymphs were allowed to develop for 10 d on plants before weighing. n = no. of insects.

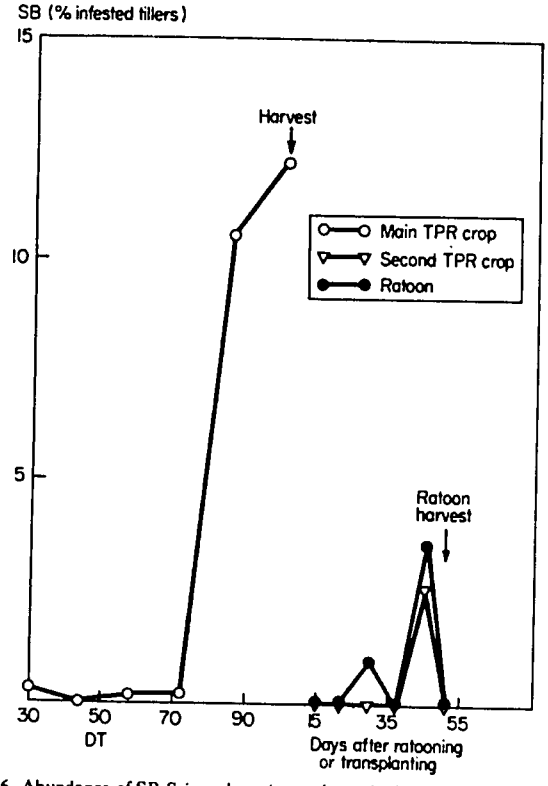
vegetative pests on ratoon and TPR did not significantly differ.

SB numbers rose dramatically at harvest, but when straw was removed to 15-cm stubble height, the populations were reduced by 91% on the subsequent ratoon crop (Fig. 6). SB population on the newly transplanted comparative crop was initially lower but built up by 45 DT to significantly higher levels in the ratoon crop. YSB *Scirpophaga incertulas* was the most dominant species on the main crop but SSB was dominant on the ratoon crop (Table 2). This was surprising because YSB larvae prefer the basal portion of the rice plant and SSB prefer upper stems.

Although less prevalent, the pink *Sesamia inferens* and dark-headed *Chilo polychrysus* SB, carried over to the ratoon but did not recolonize the transplanted second crop. In the greenhouse, significantly more YSB survived on a ratoon than on a young transplanted crop but were smaller (Table 1). Probably because of the larger diameter of stems, the ratoon appeared more suitable for SB than a transplanted crop up to 40 DT.

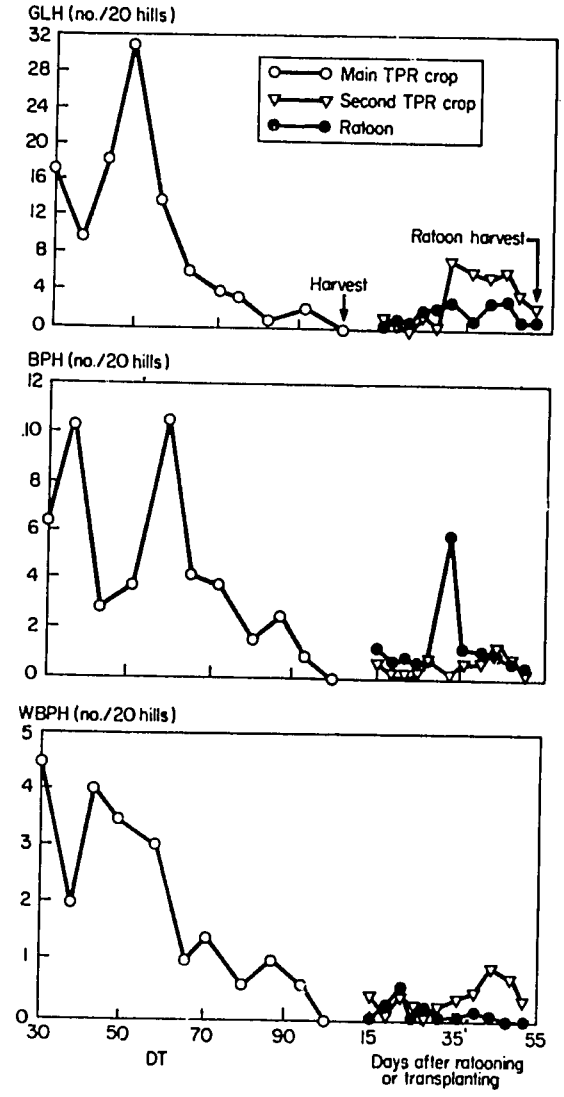
LF *Cnaphalocrocis medinalis* was not abundant in the main crop so its attraction to the ratoon could not be determined. Survival on the ratoon, however, was equal to that on a transplanted crop. The larvae were smaller than normal, indicating that ratoon rice is less nutritious than TPR.

Hopper numbers declined gradually from the mid-reproductive stage until harvest because of outward migration and predation. After harvest,



6. Abundance of SB *Scirpophaga incertulas* and *Chilo suppressalis* on the main transplanted crop and its ratoon compared to that on a transplanted second crop. IRRI, Aug-Dec 1982.

populations of BPH *Nilaparvata lugens*, WBPH *Sogatella furcifera*, and GLH *Nephotettix virescens* slowly built up in both the ratoon and transplanted second crop. No species showed a preference for either method of crop establishment (Fig. 7). Greenhouse studies confirmed that there was no apparent difference in food quality between ratoon and TPR for hoppers. The only exception was reduced body weight for BPH in the ratoon.



7. Abundance of GLH *Nephotettix virescens*, BPH *Nilaparvata lugens*, and WBPH *Sogatella furcifera* on the main transplanted crop and its ratoon compared to that on a transplanted second crop. IRRI, Aug-Dec 1982.

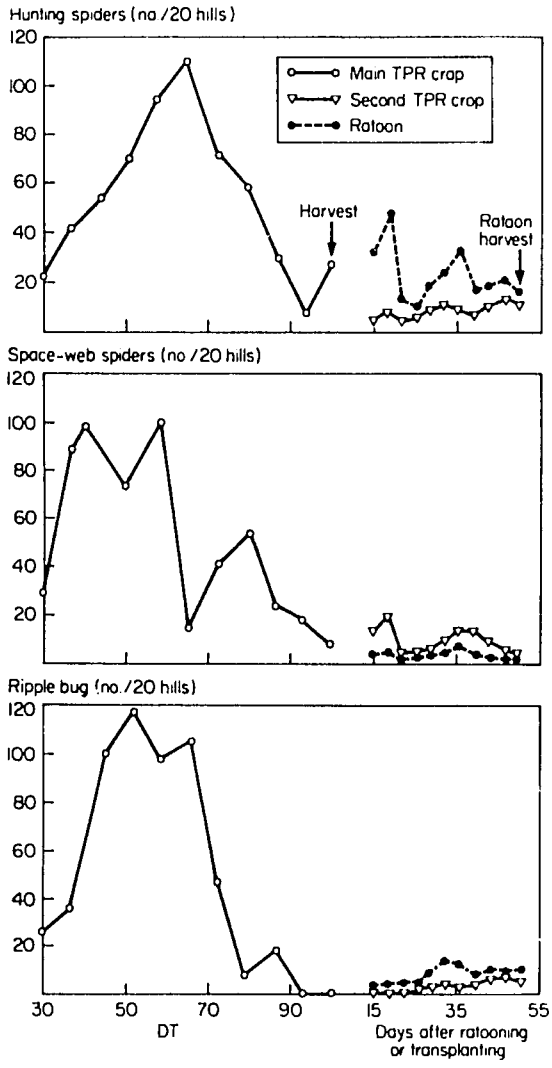
Table 2. Abundance of 4 SB species on a ratoon and a TPR second crop.[a] IRRI, Aug-Dec 1982.

SB species	Main TPR[b]		Ratoon[c]		Second TPR crop[c]	
	Larvae + pupae (no./10 hills)	Species composition (%)	Larvae + pupae (no./10 hills)	Species composition (%)	Larvae + pupae (no./10 hills)	Species composition (%)
Yellow	23	55	1.2	34	0.5	67
Striped	15	36	2.0	55	0.2	33
Pink	2	5	0.1	3	0	0
Dark-headed	2	5	0.3	8	0	0
Total	42		3.6		0.7	

[a]Av of 4 replications. [b]Sampled the day before harvest; 100-hill sample size. [c]Sampled 15, 22, and 43 d after ratooning or transplanting the second crop; 100-hill sample size.

Principal natural enemies of hoppers (the hunting and space-web spiders and the ripple bug) were highly abundant on the main crop. Significantly more of them were carried over to the less disturbed ratoon than to the transplanted second crop (Fig. 8). The predator-to-prey ratio was 6.7 in the main crop, 6.3 in the transplanted second crop, and 20.1 in the ratoon. This illustrates the benefit of sustaining predator numbers by not plowing a field.

RTV (4% infected hills) and YD (14% infected hills) virus diseases were prevalent in ratoon but did not occur in the transplanted second crop.



8. Abundance of predators (hunting spider *Lycosa pseudoannulata*, space-web spider *Callitrichia formosana*, and ripple bug *Microvelia atrolineata*) on the main transplanted crop and its ratoon compared with that on a transplanted second crop. IRRI, Aug-Dec 1982.

Symptomless infection may have occurred late in the main crop. Virus-resistant varieties are an important consideration when ratooning.

Chemical insect control on irrigated transplanted rice. The yield loss method was used to develop an insecticide recommendation for an irrigated site in Santa Maria, Laguna. IR42 was transplanted in trials on farmers' fields for the 1982 WS. The vegetative stage was attacked by RWM, which caused 97% infested leaves at 30 DT in the untreated check. YSB, which attacked the crop in the late reproductive stage, caused 3.6% whiteheads. Despite the 2 insect pest problems, yields were not significantly different between the complete control (4.40 t/ha) and untreated check (4.28 t/ha), averaged over 6 fields. The fact that high RWM infestations did not cause yield loss was substantiated by trials at IRRI which showed that yield loss caused by RWM occurs only if other pests attack at the same time. RWM was the only vegetative stage pest in Santa Maria.

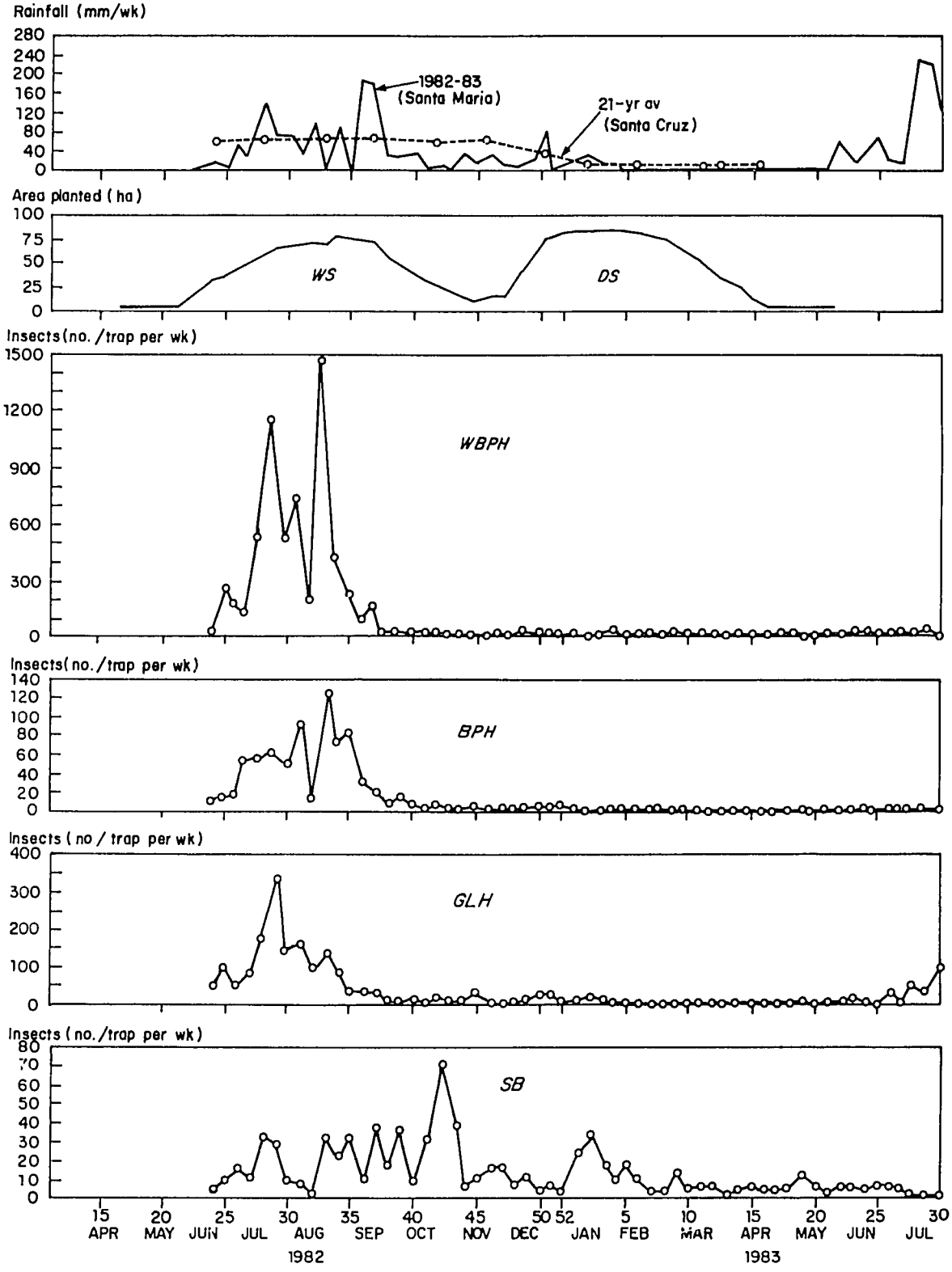
Studies elsewhere found that whitehead infestation of 3.6% should significantly decrease yield; however, that did not happen. Results suggest that a strong interaction between the environment and insect pests' damage capability prevented yield reduction in Santa Maria.

Trials in 1983 DS again did not show yield loss from insect pests on IR46. The complete control did not significantly outyield the untreated check (5.69 vs 5.26 t/ha) and no pests reached economic threshold values.

The average daily catches from two kerosene light traps in farmers' fields showed a significant decline in insect pest abundance from 1982 WS to 1983 DS (Fig. 9). The decline, particularly of leafhoppers and planthoppers, is attributed to low rainfall after Oct 1982 and the synchronous planting of the 1983 DS crop. There was no change in area planted. Despite the prolonged drought, there was sufficient irrigation water for high yields.

Results show that insecticide use for rice is uneconomical in Santa Maria. This experiment demonstrated the value of performing on-site field trials to develop insect control recommendations rather than relying on economic threshold values derived elsewhere.

Maize insects. Hybrid maize Pioneer 6181 also was severely drought stricken in Koronadal in 1983 DS. Insecticide trials showed no stand loss from



9. Abundance of WBPH *Sogatella furcifera*, BPH *Nilaparvata lugens*, GLH mainly *Nephotettix virescens*, and SB *Scirpophaga incertulas* and *Chilo suppressalis* averaged from 2 kerosene light traps set in farmers' fields in Santa Maria, Laguna, Philippines. Area planted was determined from a sample of 35 farmers. Rainfall was recorded daily in Santa Maria and compared to the 21-yr average of Santa Cruz, Laguna.

ants or other soil pests. Two unidentified species of thrips removed leaf tissue from seedlings up to the 5-leaf stage, but oriental maize borer *Ostrinia furnacalis* was the key pest on this crop. Detasseling 4 of every 6 rows before pollen shed, however, reduced the number of entrance and exit holes per stem from 2.3 to 1.6. An average of three larvae per tassel were removed from detasseled plants.

Seed treatments for maize seedling maggot. Maize seedling maggot *Atherigona oryzae* is an upland pest which causes deadhearts in rice, maize, and sorghum seedlings. Infestations recur yearly during specific months. Insecticides provide the only control. Economic thresholds cannot be used as a guide to insecticide application. By the time deadheart symptoms are noticed, irreversible damage has been done. Site experience is the best guide to the need to control maize seedling maggot.

Foliar sprays provide a poor control and require repeated applications. Granules are good but expensive. Insecticide-treated seeds are more efficient and cost less.

Field trials at the peak of infestation in Batangas showed excellent control with carbofuran and CGA73102 on all crops (Table 3). Other effective chemicals were carbosulfan, thiodicarb, and bendiocarb.

Soybean insects. Orba soybean, planted after lowland irrigated rice in Koronadal, South Cotabato, during 1983 DS, was severely affected by drought and no harvest was taken. Insecticide trials, however, showed that soil insects did not reduce plant stand.

Major aboveground pests were thrips *Thrips palmi*, bean fly *Melanagromyza sojae*, cutworm *Spodoptera litura*, aphid *Aphis glycines*, and lima bean pod borer *Etiella zinckenella*. Thrips and bean fly were primarily responsible for stunted growth (54 cm when damaged by insects vs 74 cm when protected from insects). But the most serious pest *Etiella* damaged 50-60% of green pods and was not controlled by 3 deltamethrin sprays 25-45 DE.

Chemical control on mungbean. The insect control practice of two preflowering and two postflowering sprays, developed for Pangasinan farmers, has not been readily adopted. Farmers are hesitant to apply the preflowering insecticide sprays on a young crop before damage is visible. By the time they see the damage, however, significant yield loss has occurred. Bendiocarb seed treatment was tested as a means of early protection. Bendiocarb performed as well as the recommended monocrotophos foliar sprays against flea beetle, bean fly, and thrips but not against aphid (Table 4). The monocrotophos sprays prevented aphid build-up but bendiocarb was no better than the untreated control. Neither the two monocrotophos sprays nor the bendiocarb seed treatment performed as well as the complete control of three monocrotophos sprays at double dosage. Therefore, the search will continue for more effective seed treatment compounds.

During the postflowering period, farmers were not achieving adequate control of *Heliothis* pod borer because they were underdosing. The newly developed synthetic pyrethroid compounds which are effective at 40 g ai/ha were recommended.

Table 3. Maize seedling maggot *Atherigona oryzae* control with seed treatments on upland UPRi5 rice, DMR2 maize, and Cosor 3 sorghum.[a] Tanauan, Batangas, Philippines, Aug-Oct 1983.

Chemical[b]	Deadhearts[cd] (%)	Foliage[de] dry wt (g/4.8 m²)
	Rice	
CGA73102 40 D	2 a	405 a
Carbofuran 35 ST	2 a	341 ab
Isofenphos 40	9 a	337 ab
Carbosulfan 25 ST	4 a	322 ab
UC54229-S 96 ST	6 a	250 ab
Thiodicarb 375 34 EC	17 a	233 b
Bendiocarb 50 WP	11 a	186 b
Untreated	46 b	53 c
	Maize	
Carbofuran 35 ST	3 a	329 a
Thiodicarb 375 34 EC	7 a	323 a
CGA73103 40 D	9 a	209 a
Carbosulfan 25 ST	22 a	206 a
Methiocarb 50 WP	33 a	190 a
Bendiocarb 50 WP	8 a	187 a
Untreated	46 b	48 b
	Sorghum	
Carbofuran 35 ST	3 a	1354 a
CGA73102 40 D	10 ab	1345 a
Carbosulfan 25 ST	14 b	1329 a
Bendiocarb 50 WP	14 b	1192 ab
Thiodicarb 375 34 EC	7 ab	887 b
Untreated	29 c	399 c

[a]Av of 4 replications for each trial per crop. [b]At 8 g ai/kg seed with 25% gum arabic sticker. Seeding rate/ha was 100 kg for rice, 15 kg for maize, and 14 kg for sorghum. ST = seed treatment, D = dust. [c]At 14 DE for rice and maize, average of 7, 14 and 28 DE for sorghum. [d]5-m² plots. [e]Aboveground foliage harvested 36 DE; crop suffered drought stress.

Table 4. Evaluation of seed treatment and low-volume spray technologies for mungbean, Manaoag, Pangasinan, Philippines, Dec 1982-Feb 1983[a].

Flea beetle[b] (feeding holes/plant) 16 DE	Thrips[c] (no./plant) 21 DE	Bean fly[d] (% infested plants) 21 DE	Aphid[e] infestation (grade) 25 DE	*Heliothis*[f] (no./35 plants) 55 DE	Yield[g] (t/ha)
Complete control: preflowering – 0.5 kg ai monocrotophos EC/ha 2, 9, 16 DE; postflowering – 0.03 kg ai deltamethrin EC/ha 25, 35, 45 DE					
1.3 a	5.0 ab	23 ab	1.0 a	0 a	1.31 a
No postflowering protection					
1.4 a	5.2 ab	22 a	1.0 a	5.5 c	0.66 bc
No preflowering protection					
3.9 de	5.4 ab	38 bc	3.3 c	0.5 ab	0.84 bc
Untreated					
4.7 e	8.8 b	49 c	2.7 bc	1.0 a	0.51 c
Standard recommendation: preflowering – 0.25 kg ai monocrotophos EC/ha 2, 12 DE; postflowering – 0.04 kg ai cypermethrin EC/ha 30, 40 DE, by knapsack sprayer					
3.3 cd	4.2 a	38 abc	1.0 a	0 a	0.86 b
Preflowering: seed treatment – 4 g ai bendiocarb WP/kg seed; postflowering – 0.04 kg ai cypermethrin EC/ha 30, 40 DE, by knapsack sprayer					
2.6 bc	6.6 ab	46 c	1.8 ab	0.5 ab	0.89 b
Preflowering – 0.25 kg ai monocrotophos EC/ha 2, 12 DE; postflowering – cypermethrin EC 30, 40 DE, by Electrodyn sprayer					
3.5 cde	4.8 ab	33 abc	1.0 a	0 a	0.91 b
Preflowering: seed treatment – 4 g ai bendiocarb WP/kg seed; postflowering – cypermethrin EC 30, 40 DE, by Electrodyn sprayer					
2.0 ab	5.4 ab	35 abc	2.7 bc	0 a	0.69 bc

[a]Av of 6 fields (replications). Chemicals were bendiocarb 50 WP, monocrotophos, deltamethrin, cypermethrin. [b]*Medythia suturalis:* 35-plant sample. [c]*Thrips palmi:* 35-plant sample. [d]*Ophiomyia phaseoli:* 35-plant sample. [e]*Aphis craccivora:* 35-plant sample. 1-9 scale: 1 = no aphids, 3 = adults only, 5 = small colony, 7 = many distinct colonies, 9 = many colonies running together. [f]*Heliothis armigera:* 35-plant sample. [g]From 30-m^2 crop-cut.

Heliothis control was as good with cypermethrin as with deltamethrin in the complete control. Using controlled-droplet applicators such as the electrostatic Electrodyn sprayer saves labor compared to the knapsack sprayer.

DISEASES

Plant Pathology Department

Disease surveys in wetland rice-based cropping systems. In Solana, Cagayan, leaf Bl caused by *Pyricularia oryzae* Cav. was prevalent during the 1983 rice-growing season. IR52 suffered more than IR36. However, some IR36 fields were disease-free despite *Echinochloa* sp. infection in them. One seedbed, planted to local variety Wagwag-aga, was also infected with Bl; mean incidence was 74% and severity 3.7 on a leaf basis.

IR52 was free from ShB [*Thanatephorus cucumeris* (Frank) Donk]. IR36 had higher ShB infection (<50% incidence and 3.7 severity).

As in previous years, BS (*Helminthosporium oryzae* van Breda de Haan) occurred in IR36 (severity of 2) and Wagwag-aga (severity of 5). IR46 was free from infection.

Chemical disease control. Panicle discoloration associated with unfilled grains was severe on IR36 established as DSR in Solana in 1980. Discolored grains have been observed since then, but incidence was low. An experiment in Solana determined the effectiveness of benomyl (applied at two growth stages) on grain discoloration. Data about other diseases such as leaf Bl, BS, and ShB were also gathered.

The first benomyl spray at PI significantly reduced leaf Bl incidence (Table 5). Benomyl did not provide significant ShB control and was ineffective on BS. The severity of the three diseases was unaffected by the treatment. Neck Bl, ShR, and grain discoloration incidence was low and treatment effects could not be determined (Table 5). Grain yield data were inconsistent.

Table 5. Occurrence and severity of diseases on dry-seeded IR36 with and without benomyl in drought- and submergence-prone environment. Solana, Cagayan, Philippines, 1983.

Treatment	Occurrence and severity[a]									
	BI		Neck BI[b] (%)	BS		ShB		ShR[b] (%)	Grain discoloration[b] (%)	Yield (t/ha)
	Incidence (%)	Severity		Incidence (%)	Severity	Incidence (%)	Severity			
Spray at PI	0.7	2.0	3.8	86.2	1.9	57.0	2.6	9.5	3.3	2.8
Spray at heading stage	1.7	1.0	1.9	86.6	1.7	60.0	2.3	13.4	4.7	3.2
Spray at PI and heading	0	0	2.2	80.7	2.0	55.0	2.5	10.6	6.4	2.9
No spray check	0	0	5.5	76.7	1.6	58.0	2.6	10.7	3.6	3.1

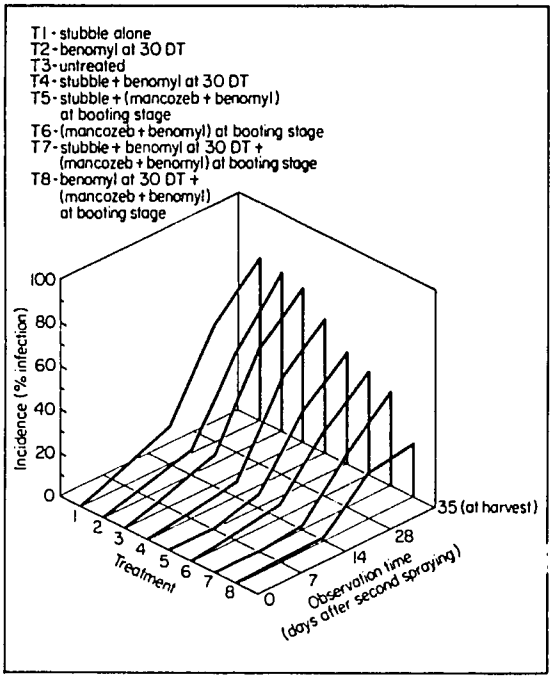
[a]Recorded at 14 d after second application of the chemical. Severity is on a scale of 0-9. [b]Recorded at time of harvest.

Soil-borne diseases in upland crops after rice. Previous studies showed that rice straw compost used for four successive growing seasons increased incidence of soil-borne diseases of cowpea. In the present study, incorporated cowpea stubbles were compared with rice stubbles to determine their effects on cowpea soil-borne diseases. Since earlier studies showed greater disease occurrence in fields with zero tillage, the influence of tillage was also investigated. The present study showed root infection or damping-off occurred earlier than expected although the incidence was lower than shoot and *Fusarium* infection. *Fusarium* infection was significantly lower in zero-tillage plots than in those with high tillage. The baiting method determined soil-borne pathogens and showed *Fusarium* spp. predominant regardless of stubble treatment. This method produced higher counts of *Fusarium* among all treatments. Soil moisture and pH appeared unaffected by the treatments. High and zero tillage differed significantly in stand count and grain yield depending on stubble management (Table 6). The plant count just before harvest was significantly lower in stubble plots at high tillage. Consequently, zero-tillage plots had significantly higher plant count and grain yield.

Integrated disease management. Surveys at outreach sites of the IRRI Cropping Systems Program showed several diseases. Cultural and chemical control methods for cropping systems have been developed and evaluated. The study tried to integrate control methods to develop a disease management scheme suitable for cropping systems. For lowland rice as the first crop, all plants remained healthy up to 14 d after which diseased plants were sprayed at 30 DT with benomyl at 1 g/litre of H_2O as a protectant. At all observation periods, plants that received single application at booting stage had lower infection than those sprayed at 30 DT but the difference was insignificant (Fig. 10, 11). As expected, two sprayings offered better control than one. The effect on ShB of stubbles combined with fungicide was erratic. With stubble alone, disease incidence slightly increased at all observation periods.

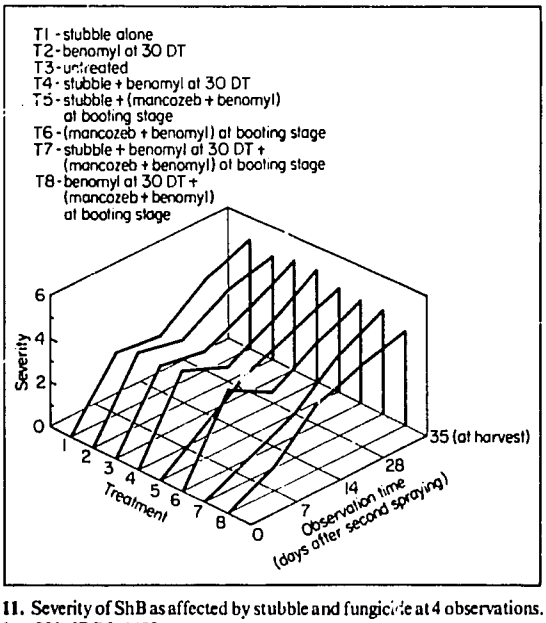
Table 6. Influence of *Fusarium* sp. on stand count and grain yield of cowpea in relation to tillage levels and straw incorporation. IRRI, 1983.

Treatment	Tillage		Difference
	High	Zero	
	Stand count		
With rice stubble	24	99	75**
With cowpea stubble	24	87	63**
Without stubble	44	91	47**
Mean	31	92	61**
	Grain yield (g/7.5 m²)		
With rice stubble	31.4	220.3	188.9**
With cowpea stubble	37.4	148.9	111.5**
Without stubble	60.7	132.2	71.5**
Mean	43.2	167.1	123.9**



10. Incidence of ShB as affected by stubble and fungicide at 4 observations. Lot 831, IRRI, 1983.

Trichoderma *sp. for treating seed in upland fields and effect on soil-borne diseases.* After cowpea seeds were treated with *Trichoderma harzianum* and sown in upland plots, rhizosphere soil samples showed little increase in the fungus populations. *T. harzianum* persisted for 2 wk in dry soil and 4 wk in wet soil. *Aspergilli, Fusaria,* and *Penicilli* were predominant in the soil. No significant differences were observed in the emergence percentage of the seedlings, disease incidence, plant stand and height, and grain yield.



11. Severity of ShB as affected by stubble and fungicide at 4 observations. Lot 831, IRRI, 1983.

Plots sown with rice seeds treated with *Trichoderma* spp. did not show any trend 0-2 WAS (Table 7). *Penicillium* sp. 1 and *Aspergillus niger* increased regardless of the presence of *Trichoderma.* Seedling emergence and ShB incidence taken at 10 and 15 WAS did not differ significantly among the treatments. ShB severity differed at 10 WAS when it was significantly lower in the check.

WEEDS

Agronomy Department

Effect of tillage, fertilizer, and weed control methods on weed growth. Since 1979, a long-term trial has examined the effects of tillage, N level, and weed control treatments on crop yield and weed growth. The study continued in 1983 to determine the residual effect of these treatments on the composition of the weed flora and crop yield.

Transplanted rice. The different tillage, weeding, and fertilizer treatments were applied to 12 successive crops of TPR. No weeding was done in any of the plots in the 13th crop.

The relative dry weight of *Echinochloa* spp. increased while that of *Monochoria vaginalis*

Table 7. Population of *Trichoderma* spp.[a] in the rice rhizosphere with fungicide-treated[b] or untreated seeds. IRRI, 1983.

	Counts of colony-forming units[c] of *Trichoderma* (hundreds/g soil)					
	PCNB			Untreated		
	0	2 wk	4 wk	0	2 wk	4 wk
T. aureoviride	0	3.0	0	20.0	1.0	0
T. hamatum	0	1.0	0	0	0	0
T. harzianum	19.0	18.0	6.0	11.0	9.0	8.0
T. koningii	0	0	2.0	0	1.0	2.0
Trichoderma sp.	3.0	1.0	0	3.0	5.0	0

[a]No. of *Trichoderma* spp. were determined by dilution plate technique on modified gallic acid medium. [b]PCNB applied at the rate of 1.4 g ai/kg seed. [c]Each figure represents means from soil samples in plots with 4 replications.

Table 8. Total weed weight and relative dry weights of different weed species as affected by tillage level and N level. IRRI, 1983 WS.

Weed species	Relative dry weight (%)					
	Minimum tillage			Conventional tillage		
	0 kg N/ha	60 kg N/ha	120 kg N/ha	0 kg N/ha	60 kg N/ha	120 kg N/ha
Echinochloa spp.	26.3	47.4	81.6	39.0	67.8	91.3
Monochoria vaginalis	48.4	8.1	2.0	42.3	17.5	6.0
Paspalum distichum	20.3	37.9	14.5	15.4	9.1	2.5
Cyperus difformis	5.0	6.5	1.9	3.3	5.6	0.2
Scirpus supinus	0.1	0.1	0	0	0	0
			Total weed weight (g/m²)			
	97.4	278.3	237.6	54.2	78.2	452.7

decreased at both tillage levels. The relative dry weight of *Paspalum distichum* decreased under conventional tillage (one plowing fb three harrowings at weekly intervals). No trend was observed when minimum tillage (1 plowing fb 1 harrowing 1 wk later) was used for land preparation (Table 8). Total weed weight increased as N level increased in the conventional tillage plots. In the minimum tillage plots, it increased up to 60 kg N/ha.

Different weed control treatments had a significant residual effect on total weed weight 45 DT (Table 9). In the minimum tillage plot, total weed weights were significantly lower in plots that were manually weeded and those that were treated with 2,4-D and butachlor. In conventional tillage plots, all those previously treated, except those treated with 2,4-D, had significantly lower weed weights than unweeded plots. Weed weights were higher in previous minimum tillage plots than in those that had conventional tillage.

Weed control treatments applied to previous crops affected grain yield (Table 10). At both tillage levels, yields were significantly higher in plots that were previously manually weeded than in those with no previous weeding. The unweeded plot yielded 61% lower than the manually weeded plot when minimum tillage was used and 41% lower with conventional tillage. The average yield of plots previously prepared by minimum tillage was 1.1 t/ha, and that of plots that received conventional tillage was 1.6 t/ha.

Yields at the highest level of applied N were lower than those at the other levels because of the luxuriant growth of *Echinochloa* spp.

Table 9. Residual effect of weed control treatments applied to the previous 12 crops on total weed weight 45 DT. IRRI, 1983 WS.

Previous weed control treatment	Total weed weight (g/m²)	
	Minimum tillage	Conventional tillage
Rotary weeding 15 DT fb HW 30 DT	107.3 a	71.8 a
2,4-D (0.8 kg/ha) 2 DT	141.5 ab	136.1 bc
Thiobencarb – 2,4-D (1.0 – 0.5 kg/ha) 2 DT	159.4 bc	85.9 ab
Butachlor (1.0 kg/ha) 2 DT	143.1 ab	93.9 a
Butachlor (1.0 kg/ha) 2 DT fb 2,4-D (0.5 kg/ha) 30 DT	167.7 bc	98.9 ab
No weeding	203.3 c	195.0 c

Table 10. Effect of tillage level and previous weed control treatments on grain yield of transplanted IR36. IRRI, 1983 WS.

Previous weed control treatment	Yield (t/ha)	
	Minimum tillage	Conventional tillage
Rotary weeding 15 DT fb HW 30 DT	1.7 a	2.1 a
2,4-D (0.8 kg/ha) 2 DT	0.9 b	1.3 b
Thiobencarb – 2,4-D (1.0 – 0.5 kg/ha) 2 DT	1.2 ab	1.8 ab
Butachlor (1.0 kg/ha) 2 DT	1.1 b	1.7 ab
Butachlor (1.0 kg/ha) 2 DT fb 2,4-D (0.5 kg/ha) 30 DT	1.0 b	1.6 ab
No weeding	0.6 b	1.2 b

Dry-seeded lowland rice. Residual effects of previous treatments were examined in the fifth crop of lowland DSR. Because of intense weed growth, each plot was split. Half was weeded once 12 DE, and the other half was weeded 12 and 35 DE.

Time of land preparation affected composition of the weed flora. Based on weed weight, *Melochia concatenata* comprised 66.9% and *Echinochloa colona* 32.6% when land was prepared during DS. When land was prepared at the start of WS, the reverse was true; *M. concatenata* accounted for 32.7% of the weed flora and *E. colona* accounted for 63.7%. The level of applied N had little effect on total weed weight or the composition of the weed flora.

Previous weed control treatments affected weed weights 12 DE (Table 11). In the plot kept weed free by tillage during DS, all previous weed control treatments except butachlor at 2 kg ai/ha reduced weed weights compared to the unweeded check. In the plots prepared at the start of WS, only butachlor at 2 kg ai/ha and butachlor fb propanil failed to reduce weed weights significantly compared to the untreated check.

Total weed weights averaged 56% higher in plots prepared at the onset of WS. The time required to weed these plots at 12 DE was 46% greater than that required to weed plots kept weed free by tillage during DS. Time required for weeding all plots that received a previous weed control treatment (except those treated with butachlor) was significantly less than the time required to weed previously unweeded plots.

Average grain yields were higher in plots previously kept weed free by tillage during DS (2.8 t/ha) than in those prepared at the onset of WS (2.2 t/ha). Plots weeded once yielded less than those weeded twice (2.1 t/ha vs 2.8 t/ha). The level of applied N did not significantly affect yield.

Different land preparation methods in dry-seeded lowland rice. An experiment in two fields determined the effect of degree of tillage on weed flora. Land preparation consisted of 1 plowing in March plus 1 rototilling 1 DBS, 1 plowing in March plus 3 rototillings at 2-wk intervals, stale-seedbed technique using shallow rototilling to kill weeds, stale seedbed using paraquat to kill the weeds, and zero tillage.

Table 11. Residual effect of weed control treatments applied to previous crops on total weed weight 12 DE of dry-seeded lowland rice. IRRI, 1983 WS.

Previous weed control treatment	Time of application	Weed weight (g/m²)	
		Weed free during DS	Prepared at start of WS
Weeded twice	14 + 35 DE	32.8 a	75.5 a
Butachlor (2.0 kg/ha)	PE	67.0 b	104.1 abc
Butachlor (2.0 kg/ha) fb HW	PE fb 30 DE	30.4 a	92.8 ab
Butachlor (2.0 kg/ha) + propanil (3.0 kg/ha)	7 DE	27.5 a	97.5 ab
Butachlor (2.0 kg/ha) fb propanil (3.0 kg/ha)	PE fb 7 DE	35.9 a	128.2 bc
No weeding	–	93.8 b	154.7 c

In the first field, weed weights 2 wk after crop emergence were significantly higher in zero tillage plots than with other land preparation methods. Weed flora also differed between tillage techniques (Table 12). Major weed species in the zero tillage plots were *Alysicarpus vaginalis* and a *Paspalum* sp. *A. vaginalis* was not present in any of the other fields but the *Paspalum* sp. was present in all other fields except those plowed once and rototilled once. A *Digitaria* sp. was extremely important in plowed plots and it was an important weed in the stale-seedbed plots treated with paraquat.

Ipomoea triloba was the major weed in the stale-seedbed plots where a harrow was used for the final land preparation, and it was important in plots that were plowed. *Cyperus iria,* which occurs in wetter conditions, was present in the stale-seedbed plots which received their final land preparation 2 wk later than other plots.

In the other field, weed weights were higher in zero tillage than in the other plots. The weed flora, which was very different from that of the first field, also varied depending on the method of land preparation (Table 13). *Panicum repens,* the major weed, and *Echinochloa procera* comprised more than 85% of the weed flora (based on weed weight) in the zero tillage plots. They were essentially absent from the other plots. *E. colona* was the

Table 12. Effect of land preparation method on total weed weight and relative dry weight in the unweeded plots 2 WE. First field, IRRI, 1983 WS.

Weed species	Zero tillage (glyphosate, 1.5 kg ai/ha)	1 plowing + 1 rototilling	1 plowing + 3 rototillings	Stale-seedbed	
				Harrow	Paraquat (0.75 kg ai/ha)
			Relative dry weight (%)		
Digitaria sp.	0	54.9	67.2	8.9	19.0
Cyperus rotundus	1.5	0	0	2.3	8.9
Ipomoea triloba	3.3	34.4	23.7	50.2	2.0
Paspalum sp.	19.4	0	0.1	17.4	19.4
Cyperus iria	0	0.3	0.3	9.6	16.5
Alysicarpus vaginalis	53.5	0	0	0	0
Others[a]	22.3 (4)	10.4 (6)	8.7 (8)	11.6 (9)	34.2 (9)
			Total weed weight (g/m²)		
	175.2 b	29.7 a	41.3 a	42.5 a	15.0 a

[a]Number of species indicated in parentheses.

major weed in all the other land preparation methods. *I. triloba* was again important in the plots that were plowed during DS, indicating the necessity of DS land preparation to break dormancy. *Cyperus rotundus* was important in the stale-seedbed plots treated with paraquat and plots that received one plowing and one rototilling. *Commelina diffusa* was also important in the stale-seedbed plots treated with paraquat.

There was little difference in the time required to hand weed plots with the different land preparation methods at 2 and 5 WE. In the first field, significantly less time was required to hand weed stale-seedbed plots that were sprayed with paraquat than those that were plowed because of the difficulty of removing *Digitaria* sp. In the second field, differences for the land preparation methods were not significant.

In both fields, no yield was obtained from the herbicide-treated plots because mixtures of butachlor, thiobencarb, and pendimethalin with propanil applied 7 DE failed to give sustained weed control. Only plots that were HW twice produced yields. Yields were low because of Bl damage. In the first field, there was no significant difference in yield (av was 1.0 t/ha) among the land preparation methods.

In the second field, the stale-seedbed plots sprayed with paraquat yielded significantly higher than those that received one plowing plus one

Table 13. Effect of land preparation method on total weed weight and relative dry weight in unweeded plots 2 WE and grain yield in the hand-weeded plots. Second field, IRRI, 1983 WS.

Weed species	Zero tillage (glyphosate, 1.5 kg ai/ha)	1 plowing + 1 rototilling	1 plowing + 3 rototillings	Stale-seedbed	
				Harrow	Paraquat (0.75 kg ai/ha)
			Relative dry weight (%)		
Echinochloa colona	3.8	47.7	60.4	76.9	35.5
Ipomoea triloba	0	13.2	14.1	0.8	3.9
Cyperus rotundus	0.7	19.9	8.0	0.5	32.4
Commelina diffusa	0.5	3.5	1.2	0.3	18.8
Eriochloa procera	11.8	0	1.4	0	0
Panicum repens	74.1	0	0.5	0.9	0
Others[a]	9.1 (5)	15.7 (9)	14.4 (6)	20.6 (6)	9.4 (6)
			Total weed weight (g/m²)		
	240.3 c	83.5 ab	110.1 bc	84.9 ab	38.0 a
			Grain yield (t/ha)		
	0 c	0.9 b	1.4 ab	1.5 ab	1.8 a

[a]Number of species indicated in parentheses.

Table 14. Effect of land preparation method on relative dry weight, weed density, weed weight, and time required for weeding 14 DE. IRRI, 1983 WS.

Weed species	Plowing (Feb) + 1 rototilling 1 DBS	Plowing + 1 rototilling 1 DBS	Plowing (Feb) + 3 rototillings (Mar, May, Jun)	Plowing + 3 rototillings 1 DBS
		Relative dry weight (%)		
Cyperus rotundus	3.7	60.2	0.4	76.7
Digitaria sp.	4.6	1.1	6.2	4.3
Ipomoea triloba	10.2	1.4	12.0	0.4
Calopogonium mucunoides	2.7	1.0	10.2	2.2
Rottboellia exaltata	75.6	36.0	67.9	15.2
Others[a]	3.2 (3)	0.3 (3)	3.3 (3)	1.2 (2)
		Total weed weight (g/m²)		
	66.1 a	72.2 a	48.3 a	84.8 a
		Weed density (no./m²)		
	178 a	182 a	123 a	199 a
		Weeding time (h/ha)		
	689 b	936 c	514 a	950 c

[a]Number of species indicated in parentheses.

rototilling (Table 13). No yield was obtained from the zero tillage plot because of poor crop establishment and severe weed competition.

Effect of time and degree of tillage on weed control in upland rice. Fourteen DE, weed density and weed biomass were not affected by land preparation method. However, composition of the weed flora and the time required for weeding were affected (Table 14). Differences in the time required for weeding were attributed to changes in the weed flora. *C. rotundus,* which is difficult to remove by hand, predominated in those plots where all land preparation was done 1 DBS. *Rottboellia exaltata* dominated in plots where land preparation began in DS.

Weed control from herbicides was inferior to that from HW but superior to the untreated check. Yields reflected the degree of weed control achieved. Regardless of land preparation method, yields were highest with 2 HWs: 1.8 t/ha averaged across land preparation methods. Yields from herbicide treatments were significantly lower: 0.5 t/ha averaged across land preparation methods and herbicide treatments. No grain yield was obtained from untreated check plots.

Mungbean. A rainfed trial at IRRI in late WS 1982 and early DS 1983 studied the effect of different N levels on yield and weed growth.

The major weed in the experimental area was *R. exaltata.* Weed growth and yield were unaffected by applied N ranging from 0 to 40 kg/ha at 3 weeding levels (weeded once 9 DE, weeded twice 9 and 18 DE, and no weeding). Weed weights decreased significantly as level of weeding increased. Yields from the twice-weeded plots were significantly higher than those from the plots that were not weeded.

Control of *Cyperus rotundus.* Several herbicides or herbicide combinations, potential preplant treatments, were applied to actively growing *C. rotundus* in an uncropped field to determine their effectiveness. Six weeks after weed emergence (2-4 wk after treatment with herbicides), plots were sampled to determine the effect of herbicide application. Immediately afterwards, each plot was rototilled. Three weeks later, the weeds were sampled again to determine the residual effects of the herbicide treatments.

At 6 wk after weed emergence, all herbicides except paraquat gave good to excellent control of *C. rotundus* (Table 15). Applying glyphosate at 4 wk after weed emergence was more effective than applying it at 2 wk. The sequential treatments of 2,4-D fb 2,4-D and bentazon fb 2,4-D were as effective in their initial control of *C. rotundus* as glyphosate applied at 4 wk.

Glyphosate had better residual effect on *C. rotundus* when it was applied at 4 wk after weed emergence. SC 0224 worked better when it was applied at 1.5 kg ai/ha. Bentazon fb 2,4-D was still

Table 15. Effect of herbicide treatments on density of *Cyperus rotundus* and other weed species. IRRI, 1983 WS.

Treatment	Rate (kg ai/ha)	Time of application (WE)	Weed density (no./m²)			
			Cyperus rotundus		Other species	
			6 WE	3 WR[a]	6 WE	3 WR[a]
Glyphosate	1.5	4	2 a	20 a	4 a	98 b
Glyphosate	1.5	2	40 b	54 cd	10 abc	72 b
SC 0224	1.0	2	58 b	76 d	8 ab	62 b
SC 0224	1.5	2	34 b	38 abc	12 ab	108 b
2,4-D fb 2,4-D	0.75 fb 0.75	2 fb 4	24 ab	42 bcd	42 cd	112 b
Bentazon fb 2,4-D	2.0 fb 0.75	2 fb 4	23 ab	24 ab	60 d	308 c
Paraquat	0.5	2	508 c	470 e	2 a	32 a
Untreated	–	–	694 c	648 e	32 bcd	18 a

[a]Weeks after rototilling.

as effective as glyphosate applied at 4 wk after weed emergence but some loss of control was observed with 2,4-D fb 2,4-D.

Six weeks after weed emergence, species other than *C. rotundus*, particularly grasses, were reduced by all herbicide treatments except sequential applications. Following rototilling, broadleaf weeds and grasses built up in all plots except the untreated check and those treated with paraquat. The competitive or allelopathic effect of *C. rotundus* prevented the buildup of the other weed species in these plots.

As expected, paraquat when applied at 2 wk after weed emergence gave excellent top kill, but the weed quickly re-established itself from underground tubers.

Butachlor degradation. Butachlor disappearance from both upland (silty clay loam) and dry-seeded lowland (loam) soils at IRRI after application at 2 kg ai/ha in July 1982 was very rapid and followed the same trend. One hour after herbicide application, 8.60-10.15 ppm butachlor was detected in the top 10 cm of soil (Fig. 12). One week after application only 2.15-3.05 ppm was detected. At 21 DAT, only about 1 ppm could be detected. Thereafter, the amount of butachlor detected gradually declined until 84 DAT when it disappeared. This explains why the weed control effect of herbicides such as butachlor is short-lived in DSR at IRRI.

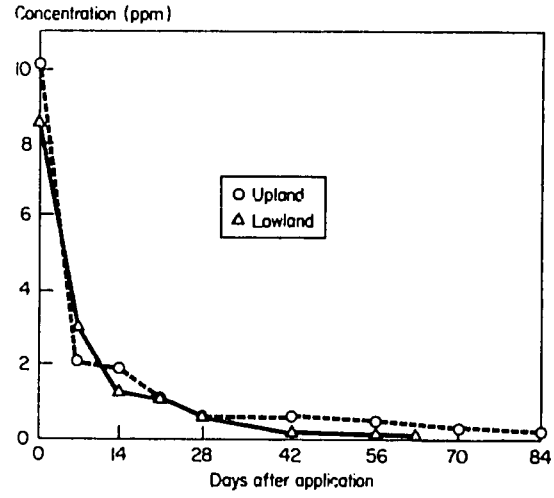
Management and control of *Scirpus maritimus*. Field experiments begun in 1974 DS continued through 1982. During DS, yields of herbicide-treated and rotary-weeded plots were similar and statistically higher than the yield of the untreated check (Table 16). The heavy population of *S. maritimus* resulted in low grain yield of the untreated check.

In a cropping pattern where maize was intercropped with soybean, weeds did not greatly affect maize and soybean yields in the untreated check.

In a cropping pattern where maize was planted alone, the yield differences between treatments were not significant. Maize competed with weeds even in the untreated check.

In the continuous TPR pattern during WS, the rotary-weeded plots had higher yields than either the herbicide-treated or the untreated plots (Table 17). Herbicide-treated plots had higher yields than the untreated.

In the upland crop - TPR pattern, yield differences were similar to those in the continuously transplanted system. Without weeding, however,



12. Butachlor degradation in upland and lowland soils. IRRI, 1982.

Table 16. Effects of weeding methods and cropping pattern on crop yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1983 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	4.9 a	0	64	120	84	0
Bentazon (2 kg ai/ha)	4.0 a	70	86	24	80	0
No weeding	0.6 b	182	80	32	426	0
Upland crop — TPR	*Maize + soybean (ears) (kg)*					
HW	16,500 a + 678 a	24	4	0	4	0
Butachlor (1.0 kg ai/ha) fb bentazon (1.0 kg ai/ha)	25,000 a + 592 a	36	28	0	18	0
No weeding	15,000 a + 335 a	114	34	14	68	0
Upland crop — rainfed bunded DSR	*Maize (ears)*					
HW	15,000 a	30	0	24	30	0
Butachlor (1.5 kg ai/ha) fb bentazon (1.0 kg ai/ha)	19,500 a	30	30	0	44	0
No weeding	3,500 a	48	92	132	8	0

[a]Av of 2 replications.

Table 17. Effects of weeding methods and cropping pattern on rice yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1983 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	4.1 a	128	14	56	42	0
Bentazon (2 kg ai/ha)	3.3 b	16	38	88	68	0
No weeding	0.3 c	24	0	56	342	0
Upland crop — TPR						
Rotary weeding	3.5 a	60	4	108	18	0
Bentazon (2 kg ai/ha)	2.5 b	64	12	120	24	0
No weeding	1.5 c	56	12	148	120	0
Upland crop — rainfed bunded DSR						
HW	3.0 a	54	4	0	0	0
Butachlor (1.5 kg ai/ha)	0 b	48	32	38	0	0
No weeding	0 b	52	12	0	0	0

[a]Av of 2 replications.

upland crop - TPR had about 1.2 t/ha more yields than the continuous TPR in the same situation.

In the pattern of dry-seeded-rainfed bunded rice following maize, yields of 3 t/ha were obtained only with HW. Because of the buildup of the broadleaf *Macroptilium lathyroides*, the untreated and the butachlor treatments gave no grain yields. *C. rotundus*, another perennial weed in this pattern for the last 8 yr, was now virtually absent in all plots.

Cropping systems program

Design and evaluation of cropping patterns

Multiple Cropping Department

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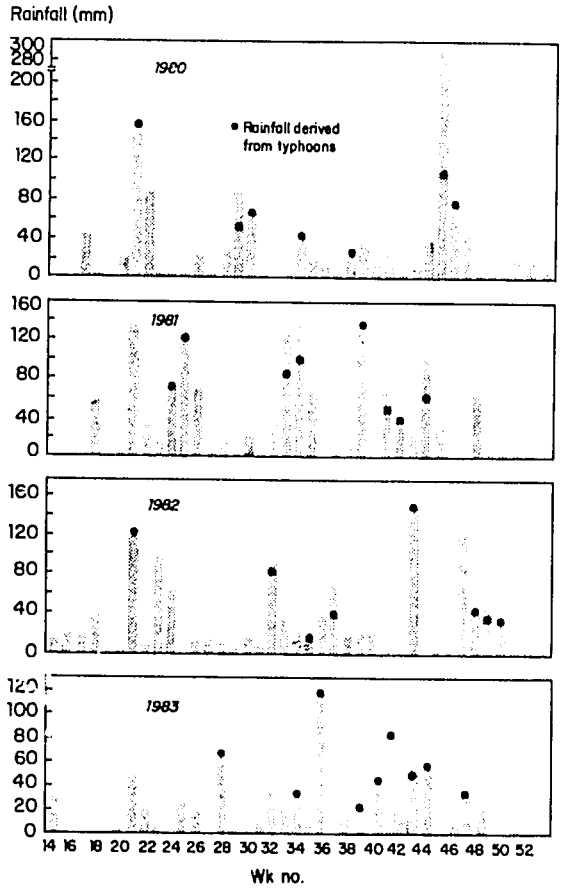
CROPPING PATTERN TESTING IN DROUGHT- AND SUBMERGENCE-PRONE ENVIRONMENT

The rainfed rice growing environment of Solana is typically drought-and submergence-prone. During the 4 yr that the Solana Cropping Systems Project was in operation, annual rainfall totaled 1,357, 1,659, 1,147, and 887 mm. Weekly rainfall for 1980-83 is shown in Figure 1. In these 4 years, 58, 40, 48, and 55% of growing season rainfall was derived from typhoons. When typhoon centers passed near Solana, rainfall was intense and reached 257 mm/4 d in Oct 1980. A peak windspeed of 130 kph was recorded in Oct 1982. In all years, erratic rainfall distribution within the cropping year was a greater problem than total rainfall. Submergence, caused by brief intervals of intense rainfall, and drought directly affected yields and also influenced the timing of field operations to the detriment of crop performance.



1. Weekly rainfall at the Solana Cropping Systems Project site in Cagayan, Philippines, 1980-83.

Mungbean. Cropping pattern tests showed that in the first 3 yr (1980-82) flooding during May-Jun made mungbean a risky crop, especially in stratum II (Table 1). Losses from flooding in stratum I were about 50%. Yields from fields that survived flooding averaged 630 kg/ha.

In 1980, 1981, and 1982, farmer cooperators planted mungbean within the recommended planting dates, but dry conditions kept them behind schedule in 1983. Only 9 of 20 cropping pattern fields scheduled for mungbean plantings between 21 Apr and 7 May were planted because the soil was dry in early WS. Seeding for the nine fields was later than 7 May. Two fields that suffered severely from drought were harvested (av yield, 358 kg/ha). Plants in the remaining seven either did not emerge or emerged and died.

Performance of rice in designed cropping patterns. Table 2 shows mean rice yields over all cropping pattern fields (all strata, all methods of planting, both first and second crops) including those that failed. In the first 3 yr, about one-fifth of all rice crops failed although most crops were planted as scheduled. Analysis of cropping pattern monitoring data from the first 3 yr showed that 87% of the failures were caused by submergence, usually on crops that were in the postheading stage when floods occurred (Fig. 2). About one-third of all TPR crops were delayed beyond their scheduled planting interval in these 3 yr. Drought was the most frequent cause of delayed transplanting (Fig. 3). Another was delayed first crop harvest because drought prolonged field duration. As shown in

Table 1. Harvested and unsuccessful mungbean crops in 1980-83 and mean yields of all planted fields over all years in Solana, Cagayan, Philippines.

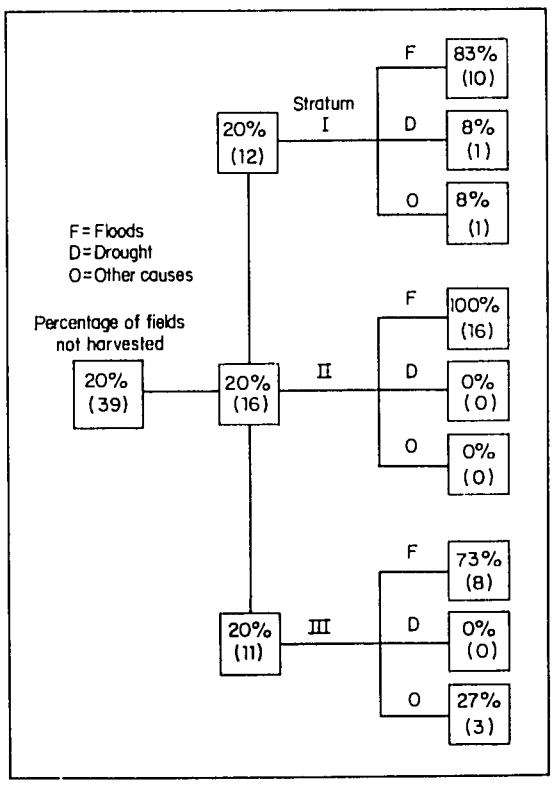
Year	Crop status	Fields (no.)	
		Stratum I	Stratum II
1980	Harvested	3	1
	Failed	10	7
1981	Harvested	11	6
	Failed	5	3
1982	Harvested	6	4
	Failed	5	6
1983	Harvested	2	–
	Failed	7	–
Mean yields over all planted fields (kg/ha)		272	130

Table 2. Mean yields of all planted rice crops and number of harvested crops. Solana, Cagayan, Philippines, 1980-83.

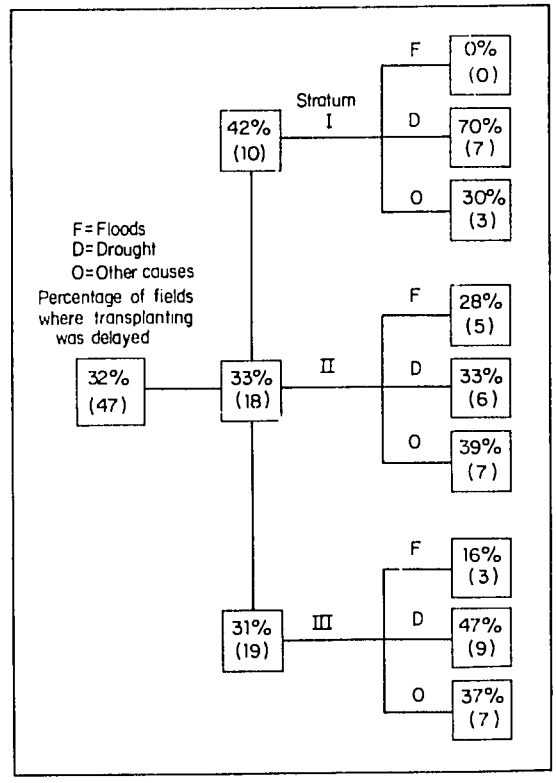
Year		Stratum I	Stratum II	Stratum III	Means or totals
1980	Mean yield (t/ha)	0.9	0.9	1.5	1.1
	Planted fields (no.)	28	26	22	76
	Harvested (no.)	19	16	17	52
1981	Mean yield (t/ha)	3.1	2.4	2.7	2.7
	Planted fields (no.)	15	29	15	59
	Harvested (no.)	15	26	14	55
1982	Mean yield (t/ha)	1.2	1.6	1.6	1.5
	Planted fields (no.)	17	25	17	59
	Harvested (no.)	14	22	12	48
1983	Mean yield (t/ha)	0.7	0.8	–[a]	0.7
	Planted fields (no.)	21	18	–	39
	Harvested (no.)	15	13	–	9

[a]In 1983, no testing was conducted in stratum III.

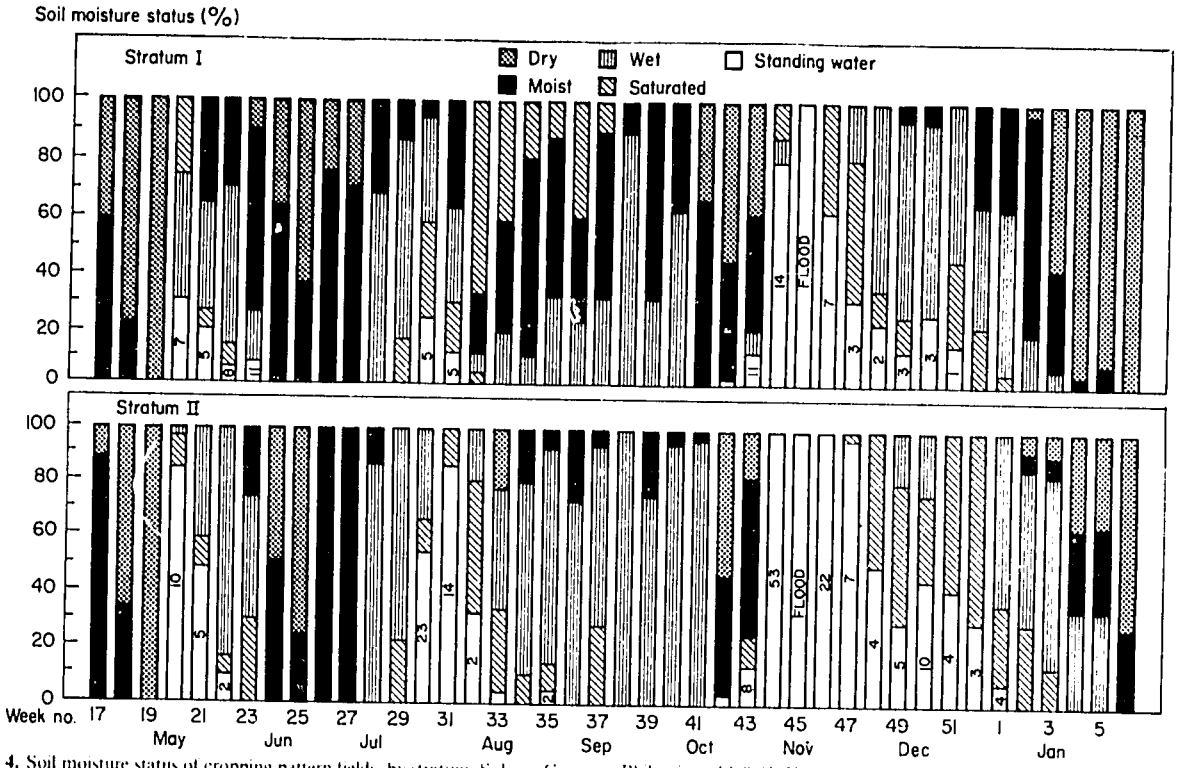
Figures 4, 5, and 6, sufficient water in strata I and II, to permit puddling for transplanting, became reliably available only in September or October. For crops scheduled to be planted earlier, extended drought made it necessary to transplant old seedlings on many fields, which usually decreased yields. In crop year 1983-84, all cropping patterns had a traditional photoperiod-sensitive variety scheduled for transplanting in early October before expected flooding. Traditional varieties were to be



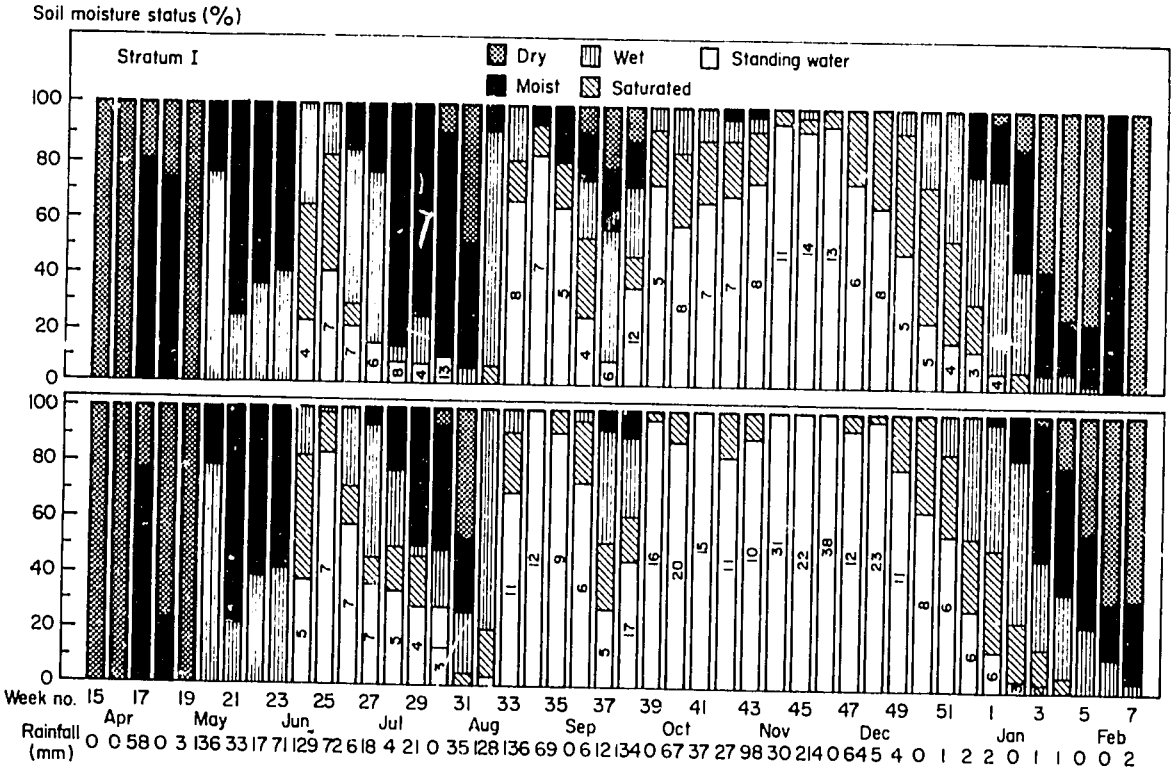
2. Summary of causes of rice crop failures, by stratum. Solana, Cagayan, Philippines, 1980-82. Numbers in parentheses are observations in each class.



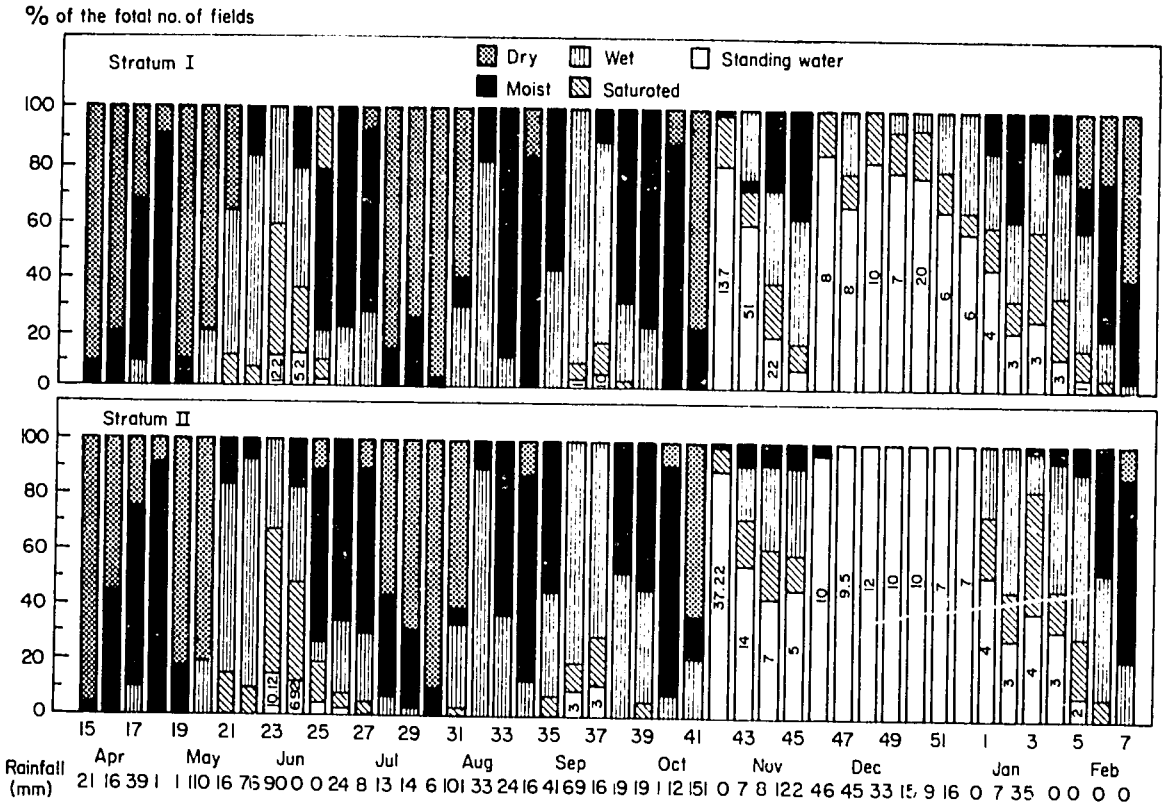
3. Summary of causes of transplanting delays, by stratum. Solana, Cagayan, Philippines, 1980-82. Over 3 yr, 149 transplanted yields were observed. Numbers in parentheses are observations in each class.



4. Soil moisture status of cropping pattern fields, by stratum, Solana, Cagayan, Philippines, 1980-81. Numbers in open bars indicate standing water in centimetres.



5. Soil moisture status of cropping pattern fields, by stratum, Solana, Cagayan, Philippines, 1981-82. Numbers in open bars indicate standing water in centimetres.



6. Soil moisture status of cropping pattern fields, by stratum. Solana, Cagayan, Philippines, 1982-83. Numbers in open bars indicate standing water in centimetres.

used: their yields are insensitive to seedling age, and they are tall and late flowering and avoid flooding damage better than MVs.

In 1983, water never became reliably available for transplanting in either stratum I or II (Fig. 7). Because of severe drought, only 12 of 41 fields were transplanted. The early end of WS severely damaged crops and only 1 was harvested, yielding 804 kg/ha.

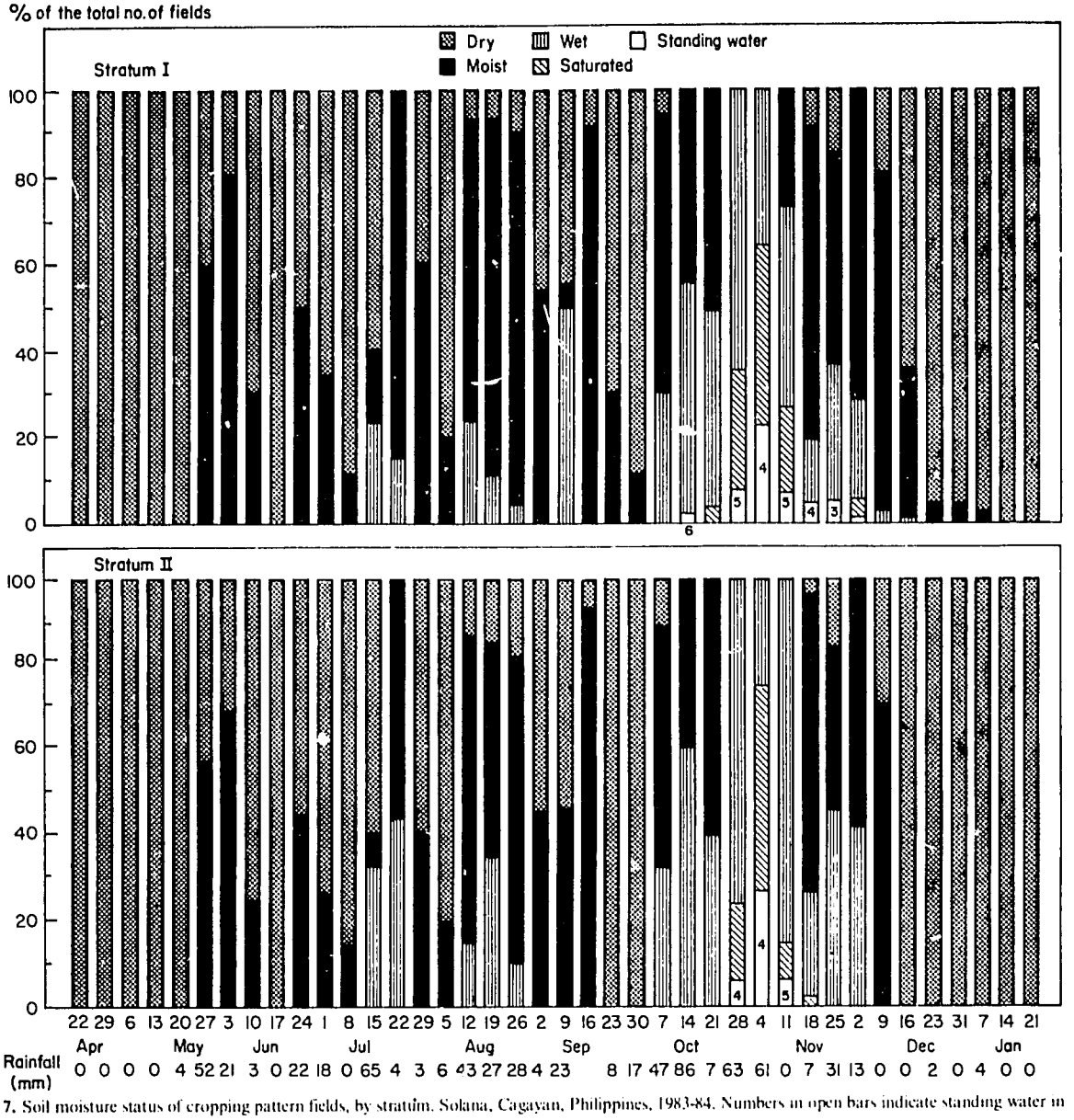
To cope with erratic Solana rainfall, dry seeding was tested as an alternative planting method. It enabled farmers to seed without depending on puddling and to use high-yielding, photoperiod-insensitive varieties to avoid the risk of transplanting old seedlings.

In the first 3 yr, DSR was tested in strata I and II by 34 farmer-cooperators. The crop failed in 30% of the cases (Table 3). Flooding caused half of the failures. Drought and weeds caused low yields, but the crops were harvested earlier than traditional rices and were generally higher yielding.

In 1983, 31 cropping pattern fields were scheduled for dry seeding between 15 May and 7 Jul (before TPR in stratum II) and between 21 Jul and 15 Aug (after mungbean in stratum I). IR36 was planted in stratum I and IR46 in stratum II at the rate of 100 kg seed/ha. Twenty-seven DSR fields were planted ahead or within the specified planting dates, but all had to be reseeded because rainfall was sparse. Only 19 plantings were harvested. Yields averaged 1.4 t/ha (Table 4) with IR46 yielding slightly more than IR36, and stratum I slightly more than stratum II. Low DSR yields were attributed to severe moisture stress prevalent in 1983 (Fig. 7). Most fields in both strata were in the dry or moist soil moisture class throughout the normal WS. Because fields were never submerged, severe weed problems also contributed to lower yields.

RATIONALE OF THE CULTIVATION OF PHOTOPERIOD-SENSITIVE RICE

Most farmers resist replacing low yielding traditional rice varieties with MVs because of the difficulty in synchronizing optimum seedling age



7. Soil moisture status of cropping pattern fields, by stratum. Solana, Cagayan, Philippines, 1983-84. Numbers in open bars indicate standing water in centimetres.

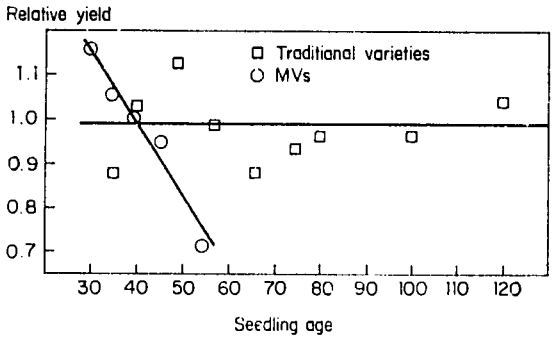
Table 3. Planted and harvested DSR crops, frequency of drought and flooding, and mean yields at Solana, Cagayan, Philippines, 1980-83.

	1980	1981	1982	1983
DSR planted (no.)	16	6	12	27
Harvested (no.)	11	6	7	19
Frequency (%) of				
Drought	25	0	42	100
Flooding	75	0	42	0
Mean yield (t/ha) excluding flood- and herbicide-destroyed fields	1.0	3.3	0.7	1.0

Table 4. Yields of harvested DSR crop by variety and stratum. Solana, Cagayan, Philippines, 1983-84.

Variety	Yield[a] (t/ha)		
	Stratum I	Stratum II	Average
IR36	1.6 (7)	0.8 (2)	1.4
IR52	1.3 (2)	1.3 (5)	1.3
IR36	–	1.7 (3)	1.7
Av	1.5	1.3	1.4

[a]Figures in parentheses indicate no. of observations.



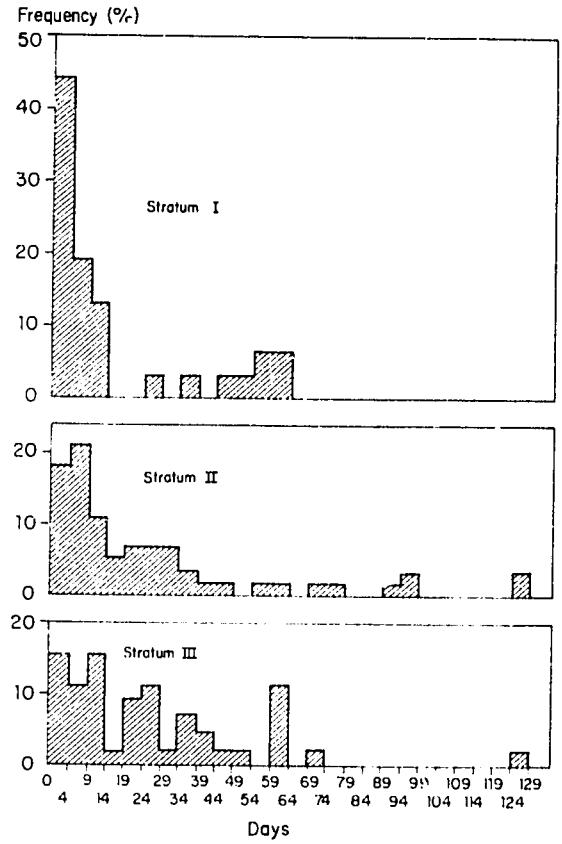
8. Relative grain yield of modern and traditional rice varieties (expressed as ratios relative to yields from 40-d-old seedlings). Solana, Cagayan, Philippines, 1983.

with field water conditions suitable for puddling and transplanting. Seedlings of traditional variety Wagwag fino grow tall and fast and provide the plant with better tolerance to flooding even at early growth stages. Furthermore, seedlings of traditional varieties can be held for 4 mo in seedbeds until fields attain sufficient soil moisture for transplanting. In Solana, the age of traditional variety seedlings transplanted by farmers ranged from 30 to 125 d. Mean seedling ages were 92 d in 1980 and 63 d in 1981. Within cropping pattern test fields, ages of MVs ranged from 13 to 58 d. Although yields from young MV seedlings were generally high, yields from old seedlings were seldom high. Figure 8 summarizes results from three experiments in Solana in which seedling age was a factor. Yields from 40- to 120-d seedlings of traditional varieties did not differ appreciably. Table 5 shows, however, that while the yield of the traditional

Table 5. Effect of seedling age on grain yield, productive tillers, total DM yield, and HI of Wagwag fino.[a] Solana, Cagayan, Philippines, 1982-83.

Seedling age (d)	Grain yield (t/ha)	Productive tillers (no./hill)	Total DM yield (g/hill)	HI
40	2.8	11	49 ab	0.31
80	2.7	11	51 ab	0.33
100	2.6	12	41 b	0.30
120	2.9	12	47 ab	0.30

[a]Means over 3 plant population levels and 3 replications.



9. Frequency of time gap (d) between first plowing and transplanting in cropping pattern fields, by stratum. Solana, Cagayan, Philippines, 1980-82.

variety in Figure 8 was insensitive to seedling age, a very high proportion of its DM (67 to 70%) was in vegetative plant parts. Analysis of field moisture data from across the 3 strata showed that seedlings less than 30 d old would be successfully transplanted only 35% of the time. The greatest success rate (60%) would be in stratum III and the least in stratum I (17%). Data showed that farmers can and do plow and transplant fields within a single day. This practice is prevalent in stratum I where standing water is least reliable (Fig. 9).

Farmers face the double hazard of postheading submergence and an inability to schedule field operations that would allow transplanting of photoperiod-insensitive MV seedlings when they are at the optimum age. Therefore, it appears rational for them to rely heavily on photoperiod-sensitive varieties in Solana and other areas with similar physical environments.

Cropping systems program

Selecting and testing varieties for rice-based cropping patterns

Rice Farming Systems Program

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IRRI tests upland crops to identify varieties that fit well before and after rice crops. Those tested were mungbean, cowpea, bush sitao, soybean, peanut, maize, sorghum, and sweet potato. In 1983, a trial on pigeonpea was also initiated. Test varieties come from the collaborative breeding and screening programs of IRRI and the Institute of Plant Breeding (IPB), national programs, and international centers and institutes responsible for those crops. Promising selections are turned over to IRRI for multiplication, distribution, and testing in the ARFSN and Philippine cropping systems sites.

In 1982-83, Philippine test sites at Los Baños and Solana, Cagayan, were directly managed by IRRI personnel. Those at the Regional Integrated Agricultural Research System (RIARS) stations managed by the Philippine Ministry of Agriculture were in Isabela, Nueva Ecija, Pangasinan, Ilocos Sur, and Iloilo, and cropping systems research sites in Capiz, Bukidnon, Davao del Sur, and Agusan del Sur. Trials in the last three stations were destroyed by drought.

UPLAND CROPS BEFORE RICE

Mungbean. Sixteen new mungbean selections from IPB were grown before rainfed wetland rice at IRRI. Ten varieties were also evaluated at Maligaya Rice Research and Training Center (MRRTC) in Nueva Ecija and in Vigan, Ilocos Sur. Data on the promising varieties are in Table 1.

Yields were low because a typhoon destroyed the first flush of flowers during flowering and pod formation. Maturity was also delayed. Pag-asa was the earliest to mature and had the shortest plants (53 cm high). Pods per plant, number of seeds per pod, and 1,000-seed weight differed significantly among selections. Pag-asa 2, a yellow-seeded variety, produced the most number of pods per plant (10) but had the lowest 1,000-seed weight (35 g) while IPB M79-13-70 had the heaviest (53 g).

At MRRTC, too much rain during the flowering and harvesting stages caused low yields. Yields in Vigan were relatively high.

Cowpea. As a crop before rice, 13 cowpea varieties were evaluated at IRRI for green pod, dry bean, and fodder yield. Nine varieties were also tested in Vigan. At IRRI, TVx 4262-014D was the highest yielder of green pods (4.20 t/ha) (Table 1). Dry bean yield ranged from 0.25 to 0.75 t/ha with TVx 3236-01G yielding highest. The typhoon also caused low yields in this trial. For fodder production, TVu 3629 was the outstanding entry, outyielding all other varieties with 15.6 t of fodder/ha after 2 primings of dry pods. The other promising varieties were TVx 4262-014D and TVx 4577-02D. Plant height ranged from 40 to 51 cm with CP4-2-3-1 the shortest and TVx 4577-02D the tallest.

In Vigan, CP-2-3-1 had the highest dry bean yield.

Bush sitao. Eight improved bush sitao varieties were also evaluated for planting before rice at IRRI, MRRTC, and Vigan during 1983 WS. The IRRI trial was discarded because of poor plant stand caused by the typhoon. Most plants, already in the flowering and pod formation stages, were also attacked by Fusarium stem and root rot after the typhoon. At MRRTC, BS_1 (6-14 R × AS) was the top yielder of green pods (Table 1). BS_1, which matures in 67 d, has whitish green fleshy pods highly preferred by consumers.

In Vigan, BS_3, UPL BS_4, and BS_1 were the highest yielders.

Soybean. Five soybean varieties from AVRDC, IPB, and other ARFSN countries were tested at IRRI for adaptability before rice cultivation. UPL SY-2 yielded highest (Table 1). G2261 was earliest to mature (82 d). Plant height ranged from 68 cm (1682-1343-1-10) to 122 cm (UPL SY-2). Soybean can be grown before rice if it is intended for green pod or vegetable soybean. Farmers will find it unacceptable for growing for dry beans before rice because of poor seed quality (rotten seeds and purple stain disease on grains).

Maize. Seven glutinous and eight sweet and supersweet maize varieties were evaluated for planting before rice at IRRI. Among the glutinous types, two varieties significantly outyielded Macapuno, the local check variety. Glutinous Syn. #41 and Los Baños Lagkitan were the highest yielders of marketable ears (Table 1). Macapuno yielded only 2.24 t/ha, but was the earliest to mature (67 d). Other varieties were harvested 72 d after planting. Sweet and supersweet maize varieties did not significantly differ in ear yield. Bxj Comp. #1

Table 1. Yield and d to maturity of upland crop varieties found promising for planting before rice, 1983 cropping season.

Crop	Location	Variety	Yield (t/ha)			Maturity (d)
			Green pod	Grain	Fodder	
Mungbean	IRRI	IPB M79-13-60		0.83		68
		IPB M79-13-70		0.82		69
		IPB M79-17-79		0.75		69
	MRRTC	CES 2G-4 (Pag-asa 3)		0.44		65
		CES 2N-4		0.40		63
		CES 2F-1 (Pag-asa 2)		0.39		66
	Vigan, Ilocos Sur	CES 1F-5		1.36		63
		CES 1D-21 (Pag-asa 1), CES U-1		1.28		63
Cowpea	IRRI	TVx-4262-014D	4.20	0.29	10.0	82
		TVx-4577-02D	3.60	0.35	12.5	85
		TVx-3236-01G	3.60	0.75	14.0	85
		TVu-3629	2.70	0.32	15.6	84
	Vigan, Ilocos Sur	CP-2-3-1		2.19		63
		All Season		1.94		62
		CP-4-2-3-1		1.59		62
Bush sitao	MRRTC	BS_1 (6-14R X AS)	4.01			67
		LBBS #1	3.60			62
		EG BS_2	3.50			60
	Vigan, Ilocos Sur	UPL BS_4		2.10		60
		BS_3 (6-14R X AS)		2.00		61
		BS_1 (6-14R X AS)		1.80		60
Soybean	IRRI	UPL SY-2		1.53		89
		1682-1343-1-10		1.26		92
		G2261		1.23		82
Maize (green)	IRRI	Glut. Syn. #41		3.65[a]		71
		Los Baños Lagkitan		3.65[a]		70
		Bxj Comp. #1 (Supersweet)		3.57[a]		71
		SW DMR Comp. Popn 31B		3.42[a]		70

[a]Marketable ears.

(supersweet) had the highest yield of marketable ears (3.57 t/ha), and Sweet Composite #1 yielded lowest (2.21 t/ha). Maturity ranged from 71 to 76 d, but most varieties were harvested at 72 d.

UPLAND CROPS AFTER RICE

Mungbean. Eleven mungbean varieties were tested after lowland rice under zero tillage at IRRI, and 12, including the farmers' variety, were tested under high tillage at MRRTC, Nueva Ecija; Ilagan, Isabela; San Jacinto, Pangasinan; Jamindan, Capiz; and KABSAKA, Sara, Iloilo.

At IRRI, yields ranged from 1.07 to 1.59 t/ha. CES 1F-5 was the highest yielder (Table 2), and MG 50-10A(G) yielded lowest. Days to maturity ranged from 60 to 63 d, with CES 1T-2 the latest. CES U-1 plants were tallest (87 cm) and those of CES 2F-1 the shortest (67 cm). Most varieties exhibited moderate resistance to Cercospora leaf spot but CES 2G-4 (Pag-asa 3) was most resistant.

Under high tillage, the highest yield was obtained in Capiz from CES 1F-5 (Table 3). The farmers' variety ranked 5th with 1.7 t/ha. Other varieties also yielded more than 1.5 t/ha which is attributed partly to good rainfall distribution during growth duration of the crop.

At Sara, yields ranged from 1.36 to 1.65 t/ha with Pag-asa 1 as the top yielder followed by CES 55 (1.64) and Aa (1.60 t/ha). In Jamindan, Pag-asa 3 (CES 2G-4) ranked 5th with 1.56 t/ha and Pag-asa 2 (CES 2F-1) 8th at 1.51 t/ha. The farmers' variety yielded lowest (1.36 t/ha). Maturity ranged from 65 d with Pag-asa 1 to 72 d (farmers' variety).

In Ilagan, Pag-asa 1 was also the highest yielder (Table 3) and the farmers' variety ranked second

Table 2. Yield of promising varieties of upland crops evaluated for planting after rice under zero tillage at IRRI, 1983 cropping season.

Crop	Variety	Yield (t/ha)	Maturity (d)
Mungbean	CES 1F-5	1.59	60
	CES 3N-1	1.48	62
	Pag-asa 2	1.43	62
	Pag-asa 3	1.38	61
Cowpea[a]	EG #2	7.28	64
	All Season	6.10	64
	TVx-289-4G	5.62	65
	TVx-7-5H	3.18	73
Bush sitao[a]	BS_1 (6-14R X AS)	9.80	62
	BS_3 (6-14R X AS)	9.00	61
	BS_4 (MP X 21)	7.20	58
Peanut	Kidang, CES 101	2.00	100,101
	UPL PN-2	1.98	102
	F334-33	1.98	100
Soybean	50106-4-7	1.80	90
	Guntur	1.60	89
	UPL SY-2	1.50	90
	Lokon	1.42	90
Field maize	Early DMR Comp. 2	2.00	96
	Poza Rica 7931	2.00	99
	Pirsabak 7930	1.90	98
	Tocumen 7931	1.90	98
Sorghum	CS 226	4.71	102
	CS 110	3.51	100
	CS 292	3.18	98
Sweet potato[b]	Minesuya	15.90	110
	Tinipay	14.50	108
	BNAS 51	14.10	105
	Minuras	11.63	110

[a]Green pods. [b]Marketable tubers.

with 0.54 t/ha. Low yields were caused by powdery mildew. In San Jacinto, CES 1T-2 yielded highest (1.28 t/ha); the farmers' variety ranked fourth with 1.14 t/ha. At MRRTC, Pag-asa 1 ranked 5th with 1.26 t/ha.

Cowpea. Ten varieties were evaluated for planting after rice under zero tillage at IRRI and Solana, and six varieties under high tillage in Ilagan, San Jacinto, MRRTC, and Sara. At IRRI, both green pod and dry bean yield were measured (Table 2); in Solana, only green pod yield was taken. In Ilagan, dry bean and fodder yield were taken while in Sara, San Jacinto, and MRRTC, only grain yield was measured.

There were no significant differences in dry bean yield among entries at IRRI. TVx 7-5H and TVx 289-4G were the highest yielders with 1.20 t/ha. Maturity ranged from 64 to 73 d with All Season and EG #2 the earliest to mature. Plant height ranged from 55 to 68 cm, with TVx 1850-01E the shortest. In Solana, CP 4-2-3-1 (3.65 t/ha) and CP 2-3-1 (3.3 t/ha) had the highest green pod yield. Both varieties are determinate in growth habit and early maturing (53 d).

Under high tillage (Table 3), the highest grain yield was obtained in Ilagan, with Vita 4 producing 2.64 t/ha. TVx 1836-19 (7.80 t/ha), TVx 66-2H (7.61), and TVx 2939-01D (7.10) had the highest fodder yields and also the longest growth duration (82 d). In San Jacinto, EG #2 matured earliest (78 d). In Sara, the promising All Season and V59-41 matured in 68 to 70 d.

Under upland conditions, two international trials of cowpea varieties were conducted at IRRI during the 1982-83 DS (Table 4). One trial was composed of 10 white-seeded varieties and the other had 16 brown-seeded varieties. Among the white-seeded varieties, TVu 3629 had the highest dry bean yield with 1.5 t/ha. Fodder yield after 3 primings of dry pods was highest in TVx 4659-03E (19.25 t/ha). Maturity ranged from 63 to 68 d with V59-41, the local check, maturing earliest.

In the brown-seeded group, TVx 3381-02F yielded 1.77 t/ha and Vita 7, 1.73 t/ha. Both significantly outyielded all other entries. The lowest yielder was TVx 1836-013J (0.90 t/ha). Fodder production also differed significantly among varieties with the highest yield from TVx 2724-01F (13.6 t/ha). Maturity ranged from 67 to 72 d with TVx 133-16-D2 the earliest to mature.

Bush sitao. Ten varieties were tested under zero tillage at IRRI and under high tillage in Ilagan, MRRTC, Cabatuan, and Sara.

At IRRI, BS_1 (6-14R × AS) and BS_3 (6-14R × AS) significantly outyielded six other entries (Table 2). The lowest yielder was UPL BS_4 (4.20 t/ha).

There were no significant differences in dry bean yield among varieties. However, BS_7 (LBBS #1 × Co_1) 4-1-1-2 yielded highest (1.07 t/ha) followed by EG BS #2, BS_3, and BS_1 (0.09 t/ha). In Ilagan, UPL BS_4 was the top yielder of dry beans (2.13 t/ha) (Table 3). BS_1 and BS_3 had the highest fodder yield after three primings of dry pods. At MRRTC, BS_1 was also the best yielder of green pods (Table 3). The lowest yielder was UPL BS_4 (1.67 t/ha). In Cabatuan, the highest dry bean yield was obtained with BS_4 (MP × 21) (1.71 t/ha), BS_1 (1.69), and BS_3 (1.64). In Sara, top yielders of dry beans were EG BS_2 (0.50 t/ha), BS_1 (0.49), and BS_3 (0.48).

Table 3. Yield of promising varieties of upland crops evaluated for planting after rice under high tillage, at 6 sites in the Philippines, 1983 cropping season.

Crop	Ilagan, Isabela		MRRTC, Nueva Ecija		San Jacinto Pangasinan		Vigan, Ilocos Sur		Sara, Iloilo		Jamindan, Capiz	
	Variety	Yield (t/ha)	Variety	Yield (t/ha)	Variety	Yield (t/ha)	Variety	Yield (t/ha)	Variety	Yield (t/ha)	Variety	Yield (t/ha)
Mungbean	Pag-asa 1	0.63	CES 55	1.55	CES 1T-2	1.28			Pag-asa 1	1.65	CES 1F-5	2.4
	CES 1F-5	0.48	CES 1F-5	1.30	CES 2F-1	1.21			CES 55	1.64	CES 1F-2	2.2
			CES 3N-1	1.29	CES 2N-4	1.17			Aa	1.60	CES U-1	2.0
											Pag-asa 3	1.7
Cowpea	Vita 4	2.64	TVx 7-5H	2.18	EG #2	1.00			All Season	1.67		
	TVx 7-5H	2.06	Vita 4	1.97	TVx 66-2H	0.98			V59-41	1.61		
	EG 32	2.03	TVx 1836-19E	1.85	TVx 2939-09D	0.91						
Bush sitao[a]	UPL BS_4	2.13	BS_1 (6-14R x AS)	3.25					BS_4 (MP x 21)	1.71		
	BS_1 (6-14R x AS)	2.06	LBBS #1	2.50					BS_1 (6-14R x AS	1.69		
	BS_3 (6-14R x AS)	1.87	EG BS_2, BS_3	2.40								
Peanut	CES 101	1.97					CES 2-25	0.90				
	UPL PN_2	1.85					CES 101	0.73				
	Kidang	1.74					F334-33	0.69				
Soybean	7207-1	2.64					30050-2-77	3.08				
	50106-4-7	2.63					7207-1	2.78				
	11-4	2.00					50106-4-7	2.86				
	UPL SY-2	1.81					UPL SY-2	2.43				
Sorghum	CS 182	6.40	CS 253	2.06	CS 110	2.98	CS 110	5.2				
	CS 110	5.67	CS 268	1.93	CS 116	2.65	CS 116	4.3				
	UPL SG-5	5.20	CS 110, UPL SG-5	1.86	IS 2940	1.76	IS 2940	3.9				
					UPL SG-5	1.17	UPL SG-5	3.6				

[a]Green pod yield.

Table 4. Yield of promising varieties of upland crops evaluated under upland, high tillage condition. IRRI, 1982-83 DS.

Crop, variety	Yield (t/ha)		Maturity (d)
	Grain	Fodder	
Cowpea (brown-seeded)			
TVx-3381-02F	1.77	12.8	69
Vita 7	1.73	12.5	69
TVx 4678-03E	1.68	12.4	72
TVx 2724-01F	1.05	13.6	72
Cowpea (white-seeded)			
TVu 3629	1.50	7.42	66
TVx-3671-7C-02D	1.36	11.71	64
TVx-32 36-01G	1.35	6.54	68
TVx-4659-03E	1.31	19.25	66
Chickpea			
ICCC 38	0.64	–	107
ICCL 78055	0.60	–	107
ICCL 81018	0.48	–	107

Low yields were caused by limited moisture during growth.

Soybean. In 1982-83 DS, 10 soybean varieties were tested under zero tillage at IRRI and under high tillage in Ilagan and Vigan. At IRRI, 50106-4-7 (1.8 t/ha) was the outstanding entry (Table 2). G 2261, the earliest maturing variety (82 d) with the shortest plant height (50 cm) yielded 1.4 t/ha.

At Ilagan and Vigan, highest yielders were 7207-1 (2.64 t/ha) and 30050-2-77 (3.08 t/ha). Other results are shown in Table 3. Line 30050-2-17 produced the highest number of pods per plant (64) and had the shortest plants (32 cm). Three applications of irrigation water contributed to the high yields.

Peanut. Yield trials of 10 peanut varieties were conducted under zero tillage at IRRI and under high tillage in Ilagan and Vigan.

Entries at the IRRI test did not significantly differ in bean yield and maturity (Table 2). UPL

PN-2, the variety used in cropping pattern testing, ranked 5th (1.89 t/ha). The lowest yield came from M10 (1.55 t/ha).

Results further proved the suitability of growing peanut after rice. In the last 3 testing seasons at IRRI, peanut yielded more than 2 t. However, sufficient moisture is necessary particularly during the flowering stage to enable pegs to enter the soil. Harvesting is laborious because of hard soil.

Under high tillage in Ilagan, the farmers' variety yielded highest (2.08 t shelled beans/ha) but matured latest (112 d). Other varieties were harvested at 108 d. CES 2-25 yielded highest in Vigan (Table 3).

Maize. Ten early-maturing field maize varieties from IPB, CIMMYT, Thailand, and Indonesia were planted after lowland rice with zero tillage at IRRI during the 1982-83 DS (Table 2).

Maturity ranged from 95 to 101 d. Ranjuna, TFE 139, and Early DMR Composites 1 and 2 matured the earliest (95 d) and they also had the shortest plants (176 cm). Most varieties showed moderate resistance to maize borer with KUC #2 F_1 as the most resistant.

Sorghum. Ten sorghum varieties were tested under zero tillage at IRRI and 11 under high tillage in Ilagan, Vigan, San Jacinto, and MRRTC (Table 3). CS 226 (4.71 t/ha), CS 110 (3.51 t/ha), and CS 292 (3.18 t/ha) were the most promising entries. UPL-SG-5, used in cropping pattern testing, ranked 10th with 2.36 t/ha. The earliest to mature was CS 268 (97 d). Plant height ranged from 125 to 169 cm with CS 226, the tallest.

In Ilagan, all varieties yielded more than 4 t/ha. High yields were caused by a very favorable environment and 638 mm of evenly distributed rainfall, especially during the reproductive stage.

In Vigan, most varieties also yielded more than 3 t/ha (Table 3). The top yielders in Vigan were also the top yielders in San Jacinto.

Sweet potato. Of the 10 sweet potato varieties evaluated under zero tillage at IRRI, 7 outyielded BNAS 51, the local check variety (Table 2). Minesuya had the highest vine yield of 32 t/ha, followed by (Japan × US_2)-5 (29.8) and Tinipay (29.1).

Chickpea. An international trial of semishort-duration chickpea varieties was conducted under upland conditions during the 1982-83 DS. But because of poor plant stand caused by collar rot disease, yield data were collected for only a few varieties. Seven that survived the disease matured in 107 d (Table 4).

Cropping systems program

Agronomic management in rice-based cropping systems

Multiple Cropping Department

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COMPARATIVE ABILITIES OF UPLAND CROPS TO TOLERATE TEMPORARY WATERLOGGING AND TO EXTRACT AND UTILIZE SOIL WATER

Potential upland crops for sequential planting with lowland rice must often tolerate temporary waterlogging during the seedling stage and be able to utilize soil water during DS. In 1983, a small number of crops were compared under two environmental conditions.

Tolerance of four upland crops to controlled waterlogging. A preliminary experiment tested crops for tolerance to different degrees of soil waterlogging in a minimal amount of space. A pit (4.8 m long, 3.4 m wide, and 1.0 m deep) was dug and a box with 25% slope gradient was placed inside. The box, constructed of 2-cm plywood, was 3.8 m long, 2.4 m wide, and 0.4 m deep at the lowest point and 1 m deep at the highest. It was filled with a soil-sand mixture. This design permitted 0.5 m clearance on each side of the box so that water could be added to the pit from an irrigation hydrant. Before planting, the pit was filled with water, which saturated the soil in the box, and then drained through a 10-cm pipe outlet.

After draining, seeds of maize (DMR2), sorghum (hybrid Goldfinger), mungbean (CES55), and cowpea (Vita 3) were sown in hills (3 seeds/hill) 3 cm below the soil surface. Each crop was planted in 2 rows 30 cm apart and oriented along the gradient, at 20 cm between hills. At 5 DE, plants were thinned to 1/hill.

The pit for trial 1 was flooded to the 1-m level 14 DAS so that all hills were submerged. This level was maintained until the third day, at which time water was drained to the 0.4-0.5 m level. Hills in the lower portion of the gradient were subjected to severe waterlogging which gradually changed to a normal condition at the upper portion. No additional water was supplied to plants in the upper portion and by 23 DE when the experiment terminated, those plants were slightly drought stressed.

Trial 2 was modified by reflooding the pit 21 DAS for 5 d since species differences were not as apparent as in the first trial. The water level was the same in the lower portion but hills in the upper part were sprinkle-irrigated to alleviate drought stress. Plants were harvested 35 DE.

Shoot length and dry weight were determined and expressed as means from 3 consecutive hills along the gradient (i.e., hills 1-3, hills 4-6, etc.). Root weight and length were determined after removing the soil from the box and carefully washing the roots.

Because trial 1 plants were markedly impaired by flooding and stands were not optimally uniform, only percent survival was measured. Sorghum was superior in both trials, with all plants surviving flooding. Even those nearly submerged at the lower portion were moderately vigorous at the end of the trials.

Maize ranked next, followed by cowpea and mungbean. Plants at the flooded end of the gradient did not survive. All species survived the 3-d initial submersion followed by draining.

Trial 2 had the same crop ranking for percent survival, but values were much higher for the two legumes. Cowpea had 56% survival for trial 1 and 87% for trial 2, while mungbean had 43% and 82%. Sorghum had higher values for shoot length and weight at the lower flooded portion than at the upper dry part (Table 1). Although root length was erratic, the lower set of hills had the lowest root weight. Stress from insufficient water could have been a factor for better growth at the upper portion. This was clearly observed in maize shoot

Table 1. Shoot and root length and weight of 4 crops subjected to controlled waterlogging in trial 2. IRRI, 1983 DS.

Crop	Hills[a]	Shoot length (cm)	Shoot wt (g)	Root length (cm)	Root wt (g)
Sorghum	1-3	55	1.2	12	0.24
	4-6	62	1.6	14	0.27
	7-9	78	1.9	15	0.27
	10-12	78	1.9	17	0.27
	13-15	75	1.7	12	0.20
Maize	1-3	62	3.0	17	0.41
	4-6	69	2.5	18	0.36
	7-9	68	2.9	19	0.46
	10-12	66	2.3	14	0.52
	13-15	63	1.9	15	0.31
Cowpea	1-3	32	2.7	17	0.27
	4-6	36	2.9	19	0.29
	7-9	32	2.9	19	0.30
	10-12	32	1.7	13	0.19
	13-15	40	1.2	11	0.13
Mungbean	1-3	23	1.7	13	0.14
	4-6	25	1.5	15	0.14
	7-9	28	1.9	19	0.19
	10-12	20	0.7	11	0.10
	13-15	16	0.3	9	0.11

[a]1-3 is highest in the gradient, 13-15 is lowest.

Table 2. Agronomic details on 10 upland crops. IRRI, 1983 DS.

Species	Variety	Plant population (no./ha)	Row width (cm)	Fertilizer NPK (kg/ha)
Maize	IPB-1	64,000	60	100-40-40
Sorghum	Cosor 3	105,000	60	100-40-40
Pearl millet	ICMS7703	110,000	60	100-40-40
Wheat	Trigo I	–[a]	30	100-40-40
Sweet potato	W99	55,000	60	100-40-40
Mungbean	CES-1D	300,000	30	0-40-40
Cowpea	All Season	300,000	30	0-40-40
Soybean	UPLSY-2	300,000	30	0-40-40
Peanut	Kidang	200,000	30	0-40-40
Pigeonpea	ICPL-147	200,000	30	0-40-40

[a]Seeded at 120 kg seed/ha.

height, but not so noticeable in shoot dry weight. Waterlogging stress was evident for maize.

Flooding reduced shoot dry weight of legumes more than that of cereals. Cowpea was more tolerant of flooding than mungbean. Root lengths and weights were also markedly reduced at the lower level.

This system for testing the ability of crops or varieties to withstand varying degrees of waterlogging provides a gradient from extreme waterlogging stress to no stress. It allows time and duration of flooding to be accurately controlled. An enlarged version will be evaluated in 1984 when cowpea and mungbean tolerance will be examined.

Water depletion patterns and performance of 10 upland crop species following rainfed lowland rice. An experiment was designed to compare water depletion patterns and yields of 10 upland crop species planted after rice. Crops were compared for their abilities to exploit soil water as the water table receded.

Land was disk plowed and then rotary hoed. Crops were planted in 4 replications in a randomized complete block design (RCBD) on 2 Dec 1982 and irrigated with 15 mm of water to aid emergence. No further water was applied. Fifteen DAS, plants were thinned to appropriate plant densities (Table 2) and given adequate crop protection measures. Data on row widths and fertilizer rates are included.

During the second week of December, 94 mm of rain replenished the soil profile. During the next 6 wk, another 81 mm fell, between 13 and 24 mm/wk. Less than 13 mm fell during the remainder of the trial.

A neutron moisture meter determined soil water content with one access tube installed in each plot. At 7- to 10-d intervals, measurements were made at 25, 40, 55, 70, 85, 100, and 115 cm depths. A pressure chamber determined LWP using the youngest fully expanded leaf between 1300 and 1400 h at 40 and 50 DAS. Canopy temperature was measured using a hand infrared thermometer on the 4 replications between 1300 and 1400 h at 40, 50, and 61 DAS.

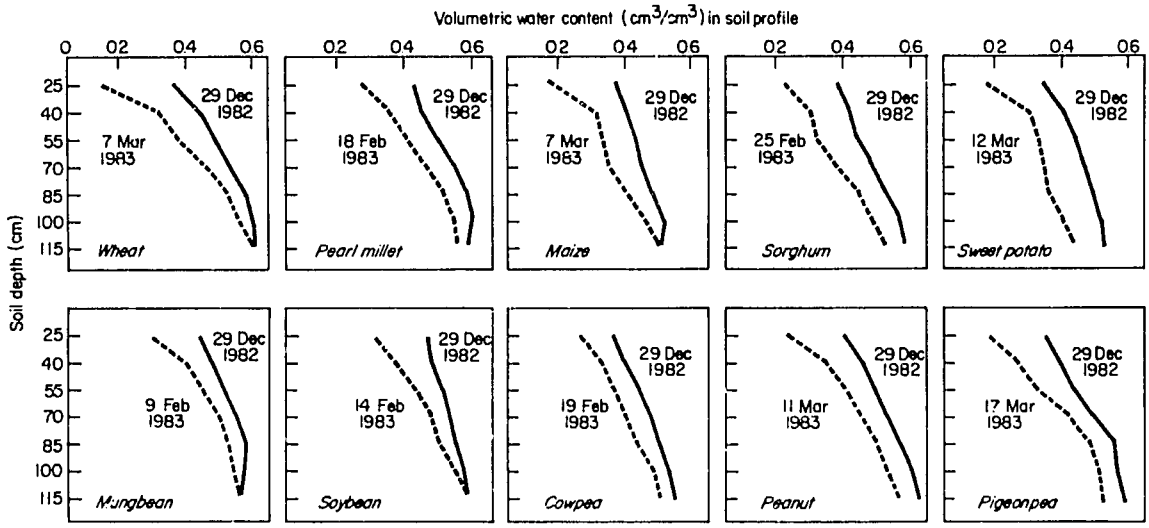
LWP, canopy temperatures, and total and economic yields are given in Table 3. Yields were determined at maturity.

Soils showed markedly different patterns of water depletion, or total evapotranspiration and drainage loss (Fig. 1). Depletion was highest under

Table 3. LWP and canopy-air temperature differential of 10 crop species. IRRI, 1983 DS.

Crop	Plant water potential (–bars)		Canopy-air temperature differential		Yield (t/ha)	
	40 DAS	50 DAS	40 DAS	50 DAS	Total DM	Economic yield[a]
Maize	7.0 c	10.7 c	-0.2	1.7	6.12	2.63
Sorghum	10.7 b	14.5 b	0	-0.6	6.11	2.69
Pearl millet	11.8 b	13.8 b	0	4.0	4.88	1.95
Wheat	14.5 a	16.5 a	0.2	4.6	2.14	0.75
Sweet potato	5.5 d	3.0 f	-1.1	-0.4	5.55	2.94
Mungbean	5.5 d	6.5 d	0	2.9	1.62	0.68
Soybean	4.4 de	6.3 d	-1.9	5.9	1.87	0.72
Cowpea	3.3 ef	6.3 d	-1.3	0.9	2.80	1.12
Peanut	2.3 f	3.7 f	-2.7	0.6	2.33	1.14
Pigeonpea	4.2 de	4.8 e	-2.2	2.3	3.00	1.73

[a]At 14% moisture content.



1. Soil water content for 10 upland crops planted after rainfed lowland rice on 29 Dec and at harvest. Means of 4 replications. IRRI, 1983 DS.

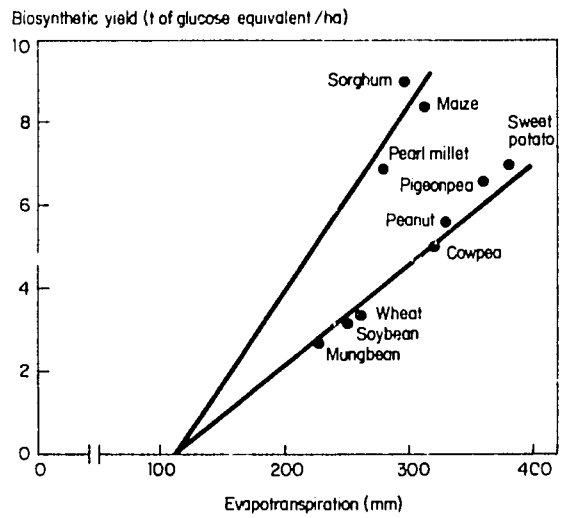
sweet potato and lowest with mungbean (Table 4). Among cereals, water use efficiency (kg grain/mm water) computed from water depletion after 29 Dec was highest for sorghum and lowest for wheat; among legumes, pigeonpea had the highest and soybean, the lowest.

Yield comparisons were based on biosynthetic cost of plant parts expressed as tonnes of glucose equivalent at harvest. The relationship between biosynthetic costs and water depletion are presented in Figure 2. Yields from the seven crops with the Calvin (C3) photosynthetic pathway showed a linear relationship with total water. Yields from the three C4 carbon pathway species were clearly above this line.

Water use efficiency of C4 crops ranged from 4.3 to 4.9 g/m² per mm; that of C3 crops, from 2.0 to 2.8. The low apparent efficiencies of wheat, soybean, and mungbean were probably caused by drainage losses which were a part of total water depletion. Pigeonpea, peanut, cowpea, and sweet potato appeared to have removed soil water from

Table 4. Total water depletion and apparent water use efficiencies for 10 crops. IRRI, 1983 DS.

Crops	Total water depletion (mm)	Apparent water use efficiency (kg/ha per mm)	Water use efficiency for biosynthetic straw + glucose equivalent of seed (kg/ha per mm)
Maize	304 c	8.6	28.1
Sorghum	291 cd	9.2	29.3
Pearl millet	277 de	7.0	25.2
Wheat	258 f	2.9	11.6
Sweet potato	373 a	7.4	17.0
Mungbean	226 g	3.0	10.7
Soybean	255 f	2.8	11.5
Cowpea	266 ef	4.2	14.8
Peanut	329 b	3.5	17.5
Pigeonpea	341 b	5.1	17.8



2. Relationship between biosynthetic yield and evapotranspiration for 10 upland crops grown after lowland rice. IRRI, 1983 DS.

depths greater than 115 cm. Therefore, their high efficiencies are probably a result of underestimation of water depletion.

Grain legumes and sweet potato usually maintained higher LWP than the cereals. At 40 DAS, peanut, pigeonpea, soybean, cowpea, and sweet potato had cooler canopy temperatures than mungbean and cereals. At 50 DAS, canopy temperatures of sweet potato, sorghum, peanut, and cowpea were within 1° of ambient air temperature but those of pearl millet, wheat, and soybean had risen 4° or higher.

RESPONSE OF COWPEA AND MUNGBEAN VARIETIES TO MOISTURE GRADIENTS

In rainfed areas, mungbean and cowpea are often grown after the monsoon with erratic and rapidly diminishing rainfall and residual soil moisture. The crops encounter varying degrees of moisture stress, particularly during reproductive stages.

Two experiments, one on mungbean and the other on cowpea, were conducted during DS to examine varieties for yield performance along a moisture gradient. A line source sprinkler system imposed gradients by applying decreasing quantities of water at increasing distances from the sprinkler line.

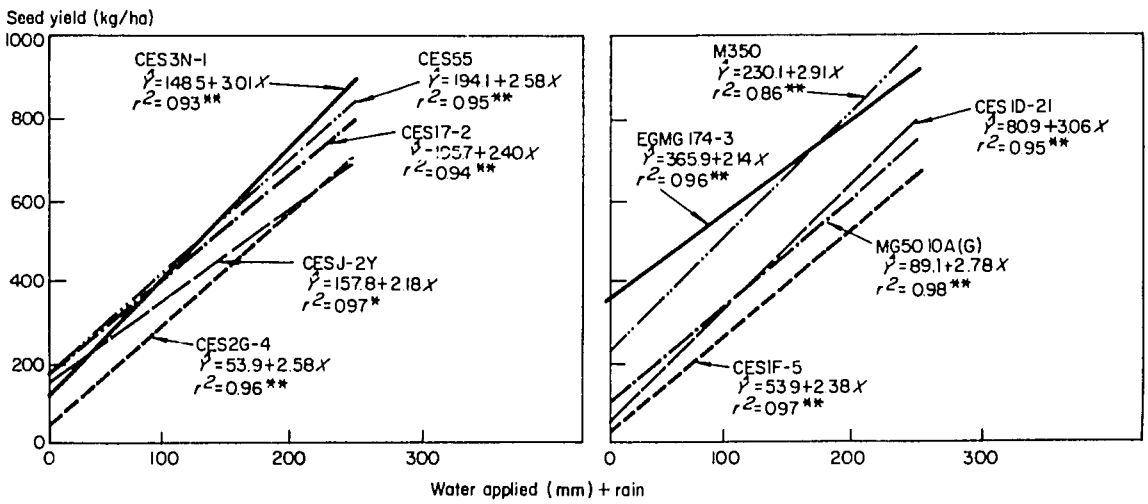
Mungbean. Ten mungbean varieties were planted on a fully recharged soil profile 10 Jan 1983. The wettest regime (1) was closest to the sprinkler line and the driest (6) was farthest. The experimental field was irrigated (15 mm) after planting to ensure uniform crop emergence. The crop was overseeded and thinned to about 300,000 plants/ha at 12 DE. Pests and diseases were adequately controlled.

Line source irrigation treatments were started 15 DE and were repeated at different intervals thereafter. Applied water equalled 0.6 pan evaporation. Soil moisture status at 20, 40, 80, and 100 cm was determined before and after each irrigation, using a neutron scattering device in aluminum access tubes installed in each moisture regime in 2 replications. Root length density in the wettest and driest regimes was determined at 59 DE with a soil core sampling technique. Leaf area was measured with an automatic leaf area meter at 51 DE.

Across the moisture gradient, EGMG 174-3 and M350 yielded more than the other varieties (Fig. 3). M350 yielded more at the wet end and EGMG 174-3 yielded more at the dry end of the gradient. CES1D-21, a commonly grown variety, yielded poorly at the dry end but responded favorably to irrigation.

LAI of all varieties decreased sharply with increased water stress (Table 5). LWP decreased and canopy temperature increased for all genotypes as the crops progressed into the growing season. EGMG 174-3, M350, and MG50-10A had higher LWP than the other varieties (Table 5).

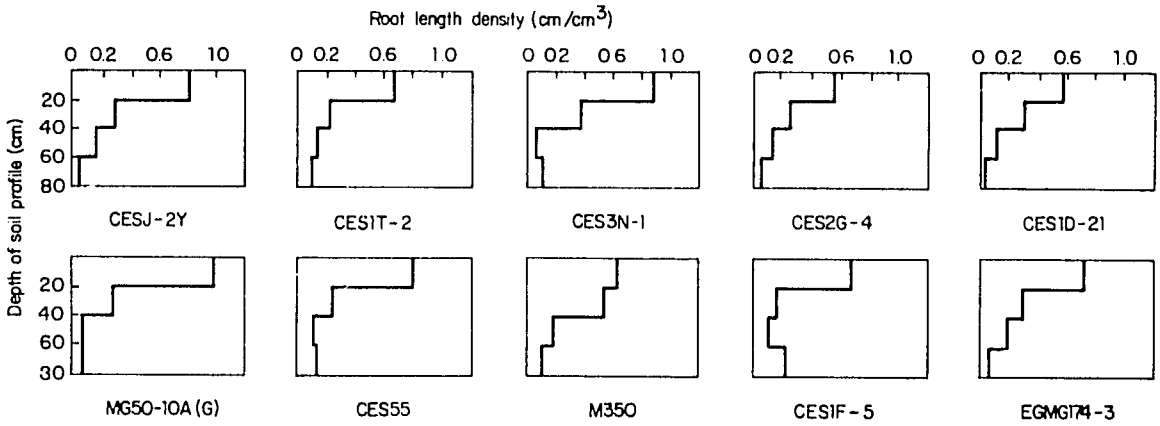
Root densities were measured at 59 DE (Fig. 4). In the dry regime (R6), the top yielders M350 and EGMG 174-3 had higher densities in the 40-80 cm



3. Relationship between water application and seed yield of 10 mungbean varieties under an irrigation gradient. IRRI, 1983.

Table 5. LAI at DE and LWP on 23 Feb and 10 Mar of 10 selected mungbean varieties under nonstress (R1) and stress (R6) conditions. IRRI, 1983 DS.

Variety	LAI		Reduction (%)	LWP (-ψ)			
				14 Feb		10 Mar	
	R_1	R_6		R_1	R_6	R_1	R_6
MG50-10A (G)	1.12 bcd	0.28	75	1.83 b	3.77 c	2.33 b	3.50 f
CES 2G4	1.51 ab	0.23	85	1.87 b	4.67 abc	2.60 b	5.83 ab
CES J-2Y	1.43 ab	0.23	84	1.67 b	4.67 abc	3.17 a	6.13 a
EGMG174-3	1.53 a	0.37	76	2.07 b	5.60 a	2.57 b	3.50 f
CES IF-5	0.78 d	0.21	73	1.80 b	5.00 ab	2.17 b	5.50 abc
CES IT-2	1.45 ab	0.35	76	1.70 b	4.47 bc	2.53 b	4.87 cde
M350	1.15 abcd	0.24	79	1.83 b	3.90 c	2.27 b	5.17 bcd
CES-55	1.55 a	0.44	72	2.50 a	3.93 c	2.17 b	4.27 e
CES 3N-1	1.23 abc	0.24	80	2.60 a	4.53 bc	2.67 ab	4.50 de
CES 1D-21	0.97 cd	0.19	80	1.93 b	4.17 bc	2.27 b	3.17 f



4. Root length density of 10 mungbean varieties 59 DE at 45 soil depths at the dry end (R6) of the moisture gradient. IRRI, 1983.

soil layer which may be responsible for their higher seed yields and better LWP.

Cowpea. Ten cowpea varieties (including three bush sitao subspecies) were planted on a fully recharged soil profile on 15 Jan 1983. Experimental methods were similar to those for the mungbean experiment.

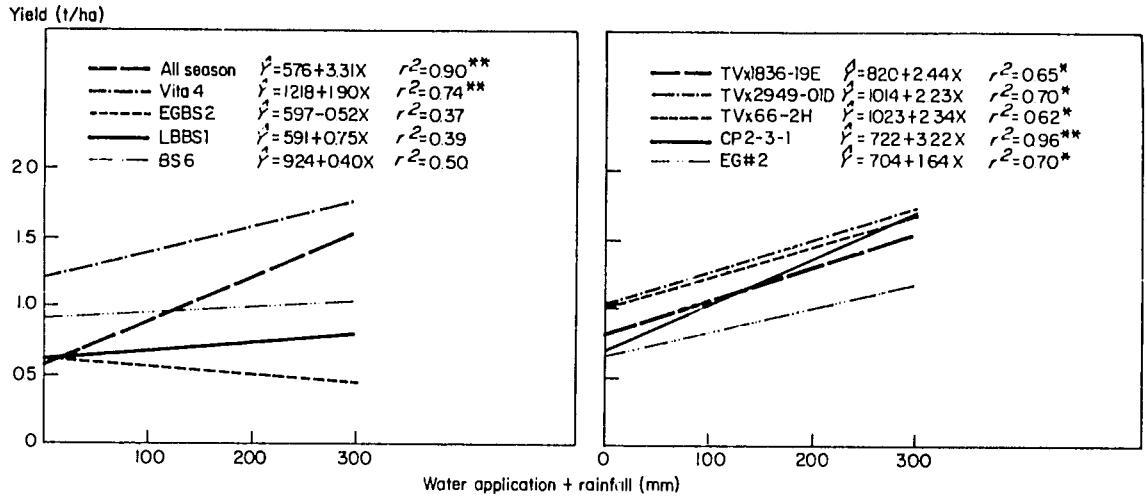
Vita 4 yielded highest at both ends of the moisture gradient. Bush sitao varieties did not exhibit clear responses to increasing levels of applied water as did the grain-type cowpeas. In the wet area, EGBS2 produced lowest yield followed by LBBSI (Fig. 5).

The cumulative LWP (sum of measurements made on 21 Feb, 2 Mar, 23 Mar 1983) correlated with seed yield; varieties with high LWP yielded higher. Varieties differed in quantities of moisture extracted. Vita 4, TVx2949-01D, and TVx1836-19E extracted the most soil water at the dry end of the gradient.

MAIZE MANAGEMENT

Experiments investigated varietal responses, especially those of commercial hybrids and high quality protein maize, to plant densities and applied N. WS and DS effects on N efficiency were also compared as were maize and sorghum responses in DS.

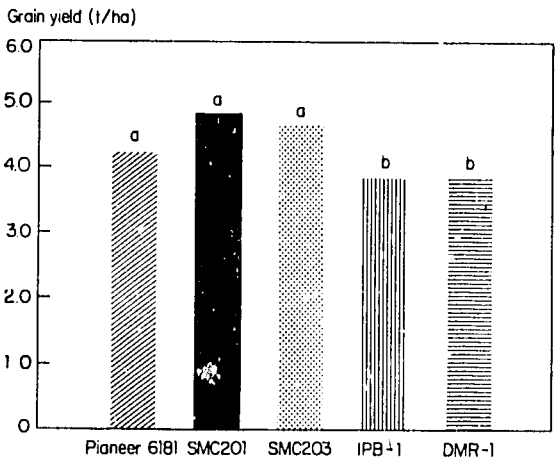
Responses of maize hybrids and open-pollinated varieties to increasing plant densities. A field experiment evaluated the response of 3 maize hybrids (Pioneer 6181 and SMC hybrid 201 and 203) and 2 open-pollinated varieties (IPB-1 and



5. Relationship between water application and seed yield of 10 cowpea varieties in an irrigation gradient. IRRI., 1983.

DMR-1) to 4 plant densities: 50,000, 75,000, 100,000, and 125,000 plants/ha. Three replications of a split-plot design (plant density in main plots and varieties in subplots) were planted on 8 Nov 1982. Fertilizer N at 150 kg/ha was applied: one-third basal, one-third 30 DAS, and one-third at tasseling. Adequate plant protection measures were taken.

Open-pollinated varieties yielded significantly lower than hybrids (Fig. 6). Hybrids did not differ significantly. Increasing plant density from 50,000 to 125,000 plants/ha did not increase yield significantly, and the interaction between variety and density was not significant.



6. Performance of 3 hybrid and 2 open-pollinated maize varieties in DS. Means over 3 plant densities and 3 replications. IRRI, 1983.

Responses of a maize hybrid and an open-pollinated variety to nitrogen and plant density. All factorial combinations of 4 N levels (0, 75, 150, and 300 kg/ha), 3 plant densities (53,000, 64,000, and 80,000 plants/ha), and 2 maize varieties (IPB-1 and hybrid Pioneer 6181) were planted in an RCBD with 4 replications on 15 Nov 1982. One-third of the N was applied at planting, one-third 30 DE, and one-third at tasseling. Crop protection measures were adequate.

The hybrid was significantly superior to the open-pollinated variety as N level and plant density increased (Table 6). It yielded highest at 80,000 plants/ha and 150 kg N/ha.

Table 6. Performance of 2 maize varieties at 3 plant populations and 4 N levels. IRRI, 1983 DS.

N levels (kg/ha)	Yield (t/ha)		
	53,000 plants/ha	64,000 plants/ha	80,000 plants/ha
	IBP-1		
0	2.5 i	2.0 i	2.2 i
75	4.2 h	4.6 fgh	5.0 efgh
150	4.6 fgh	5.4 cdefg	5.0 efgh
300	4.5 gh	5.2 def	5.5 cde
	Pioneer 6181		
0	2.4 i	2.4 i	2.5
75	4.9 efgh	5.2 defg	6.2 abc
150	5.2 defg	5.5 cde	6.8 a
300	5.5 cde	6.0 bcd	6.6 ab

Performance of CIMMYT quality protein maize varieties. An experiment, started on 20 Mar 1983, compared the performance of 10 quality protein maize varieties at 75 (moderate) and 150 (high) kg N/ha rates during DS. Four replications of an RCBD were planted on an upland field. N fertilizer was split-applied: one-third at planting and two-thirds at 25 DE. The crop was well irrigated and adequately protected from pests.

Five varieties [Ferke (1) 7940, Guanacaste 7940, Poza Rica 8140, Los Baños 8140, and Across 8140] responded to additional 75 kg N/ha, but they were also the lowest yielding at 75 kg N/ha. Grain yields, percent protein, and lysine yields are presented in Table 7.

Yields were moderate, especially when compared to the 7 t/ha or more frequently obtained with 150 kg N/ha applied to locally adapted hybrids. However, this experiment was planted more than 60 d later than ideal. Therefore, mean maximum and minimum temperatures over the growing period were higher (34.5 and 23.2°C) than expected. Growth durations were shorter (90-95 d) possibly because of warmer weather.

Maize response to fertilizer. Two experiments (WS and DS) were conducted to determine maize (IPB-1) responses to inorganic N, P, and K fertilizers. There were 4 replications of an RCBD on a field in which the surface soil contained 1.33% organic C, 0.14% total N, 34 ppm available P (Olsen method), and 0.93 meq exchangeable K/kg.

Table 7. Grain yields, protein percentages, and lysine yields from 10 CIMMYT quality protein maize varieties.[a] IRRI, 1983 DS.

Variety	Grain yield (t/ha)		Protein (%)	Lysine yield (kg/ha)
	75 kg N/ha	150 kg N/ha		
Tuxpeno	4.93 a	4.73 a	8.4	16.8
Tuxpeno Caribe	4.45 abc	4.85 a	9.2	14.4
La Posta	4.78 abc	5.09 a	9.0	15.5
Mezcla Tropical Blanca	4.91 ab	4.52 a	8.8	15.9
Amarillo Dentado	4.57 abcd	4.35 a	9.2	13.5
Ferke (1) 7940	4.19 bcd	4.47 a	9.5	16.9
Guanacaste 7940	4.12 cd	4.61 a	9.5	16.9
Poza Rica 8140	4.06 cd	4.54 a	9.4	16.1
Los Baños 8140	3.94 d	4.49 a	9.7	14.3
Across 8140	4.27 abcd	4.85 a	9.2	13.5

[a]Means over 2 N fertilizer levels and 4 replications for protein and lysine yields.

The WS experiment was planted on 20 Jun 1982 and the DS on 15 Nov 1982. N was at 0, 50, and 100 kg/ha; P at 0, 13, and 26 kg/ha; and K at 0 and 50 kg/ha. Crop protection measures were adequate in both seasons

As expected on high P and K soils, neither P nor K affected maize yields in either season. In both seasons, linear N effects were significant. Mean yields from 0, 50, and 100 kg N/ha over 3 P levels were 1.39, 2.37, and 2.81 t/ha in WS, and 1.75, 2.74, and 4.03 in DS. N efficiency was higher in DS.

Maize and sorghum responses to fertilizer management. Experiments compared the responses of maize (IPB-1) and sorghum (SG5) to NPK and P placement methods. In both seasons, four replications of an RCBD were planted on well-prepared land. Crops were planted on 75-cm rows at densities of 56,000 plants/ha for maize and 200,000 for sorghum. Maize was planted on 18 Nov 1982 and sorghum on 10 Dec 1982.

P and K did not significantly affect yields of either crop. Mean sorghum yields were 5.0 t/ha at 60 kg N/ha, 4.6 t/ha at 30 kg N/ha, and 2.9 t/ha in the absence of N. The corresponding maize yields were 4.5, 4.0, and 3.2 t/ha. The mean efficiency for sorghum was 35 kg grain/kg N; for maize it was 22.

SORGHUM MANAGEMENT

As a crop to follow rice in monsoon areas, sorghum has much to offer. It grows well under tropical conditions, is tolerant of drought, and not as susceptible to occasional flooding as other annual food crops. Experiments determined the influence of planting date and applied N on the performance of sorghum main and ratoon crops, examined cultural techniques which would improve stand establishment reliability, and compared the performance of tall and dwarf varieties intercropped with soybean.

N level and planting date effects on sorghum main and ratoon crop. To compare the N response of two sorghum varieties (Cosor 5 and Hybrid 67A × CS 174 which has Cosor 5 as the male parent) under contrasting weather conditions, treatments were planted on 31 Aug, 7 Oct, and 29 Dec 1982, and 3 Feb 1983. Three N rates (0, 60, 120 kg N/ha) were applied to the main crop. Three replications of a split-split-plot design with planting dates as the main plot factor, N rate as the subplot factor, and

variety as the subsubpopulator were seeded and thinned to a plant density of 200,000 plants/ha. One-third of the N was applied at planting and the remainder before interrow cultivation. Crop protection measures were adequate. The experiment was irrigated as needed to prevent drought stress. At harvest, the stalk of the main crop was cut at the third node aboveground.

Analysis of variance showed that only the main effects of planting date and N level influenced main crop grain yield. Highest yields from all N rates were obtained from the 29 Dec planting (Table 8). Efficiency from the first N increment (0-60 kg N/ha) averaged 20 kg grain/kg N applied. From the second increment, efficiency was only 4 kg grain/kg N.

Ratoons of the third and the fourth plantings were damaged by a severe typhoon on 15 Jul 1983. Many effects and interactions were significant, but most were of minor agronomic importance. Ratoon yields from the August planting were higher than from the October planting. Although N responses in the main crop did not influence ratoon yields, the efficiency of N applied directly to the ratoon was low: average of 13 kg grain/kg N from the first 60-kg increment and 8 kg grain/kg N for the second.

Establishment of sorghum after lowland rice. Three experiments compared alternative tillage and planting methods for establishing Cosor 5 sorghum after puddled lowland rice.

Five methods of sorghum seeding were tested following harvest of lowland rice. The experiment was planted in four completely randomized blocks. Four planting methods were applied on untilled rice stubble: 1) broadcast presprouted seed at 9 kg/ha, 2) broadcast presprouted seed at 18 kg/ha, 3) rolling injection planter (RIP) on stubble, and 4) shallow (2.5 cm) furrows opened by drag stick followed by hand seeding. In a fifth treatment (conventional), land was plowed and rototilled, and seeds were furrow-planted. For treatments 1 and 2, seed was soaked in tap water for 24 h, at which time the radicle started to emerge. The RIP was calibrated to plant 4.5 kg/ha. In treatment 4, the drag stick was attached to the frame of a power tiller. The conventional treatment was subsequently thinned to 200,000 plants/ha because of its much higher emergence percentage. All plots were top-dressed with 50 kg N/ha as broadcast urea 30 DAS.

The highest percentage of planted seeds emerged when the soil was tilled after lowland rice harvest (Table 9). Seeding rates of 9 kg/ha were obviously too high in the tilled treatment for optimum stands (150,000 to 200,000 plants/ha), but produced adequate stands in the no-till treatments. Broadcast seeding at twice the normal rate did not appear to increase plant density.

The RIP established good stands, showing that a 4.5 kg/ha seeding rate was satisfactory for obtaining 200,000 plants/ha and 50% emergence. Drag stick seeding was also effective. Data suggest that a seeding rate of 9 kg/ha is at or above maximum for growing sorghum after lowland rice in DS on residual soil moisture. Although the emergence rate was only 36%, the resultant 296,000 plants/ha stand was probably too high, and seeding rate should have been lower.

Yields from conventional tillage plots were significantly better than from other treatments (Table 9). Drag stick planting tended to be better than the RIP but not significantly. In this experiment, broadcasting presprouted seed did not appear to be a satisfactory method for postrice sorghum culture. Conventional and drag stick methods

Table 8. Grain yields at 3 N levels of sorghum main crop planted on 4 dates. IRRI, 1982-83.

N level (kg/ha)	Grain yield[a] (t/ha)			
	1982			1983
	Aug	Oct	Dec	Feb
0	1.98 b	1.63 b	2.39 b	1.71 c
60	3.43 a	2.88 a	3.59 a	2.60 b
120	3.75 a	2.70 a	3.85 a	3.19 a

[a]Means over 2 varieties and 3 replications.

Table 9. Emergence and grain yield of sorghum planted after lowland rice by 5 seeding methods. IRRI, 1983 DS.

Treatment	Emergence (%)	Plant population (thousand/ha)	Yield (t/ha)
Broadcast (9 kg/ha)	24 cd	200 b	0.5 c
Broadcast (18 kg/ha)	15 d	250 b	0.8 bc
RIP (4.5 kg/ha)	50 b	206 b	0.8 bc
Drag stick (9 kg/ha)	36 bc	296 b	1.2 b
Conventional (9 kg/ha)	72 a	600 a[a]	1.8 a

[a]Thinned to 200,000 plants/ha.

produced better yields than RIP, but their power requirements are greater. The RIP was effective for establishing sorghum in lowland paddy soils, and tillage aided establishment.

Another experiment tested the RIP as an implement for placing sorghum seed into tilled and untilled soil after rice in a lowland field. The effect of rice straw mulching (at a rate sufficient to cover the soil surface) was also determined. The RIP was used to seed sorghum in hills 15 cm apart (3-4 seeds/hill) on 50-cm rows, using split-plot design with four replications. Tillage treatments (plowing and rototilling vs no tillage) were in the main plots, and mulch treatments (with vs without) in the subplots. Urea at 50 kg N/ha was broadcast on each plot.

Tillage significantly increased yields (Table 10). Plant densities were not recorded, but low yields from the untilled treatments were caused by inadequate stands. A 2-d delay between seeding this and the previous experiment allowed the soil to dry excessively in the untilled plots and resulted in poor emergence. Yields were reduced compared to those from similar treatments in the previous experiment. Mulch produced yields similar to those cited in Table 9.

Mean yields were higher from tilled plots, but the difference was much less when mulch was applied. Moisture conservation caused by reduced evaporation was probably the primary influence. Cooler soil temperatures under mulch may have also benefited root growth in the extreme heat of DS.

The original RIP had no way to cover the seeds after they were placed in the soil and seed-soil contact was not adequate to obtain satisfactory stands.

Table 10. Grain yield of sorghum planted by RIP on tilled or untilled lowland paddy soil, with and without rice straw mulch.[a] IRRI, 1983.

Tillage treatment	Grain yield (kg/ha)		
	With mulch	No mulch	Mean
With tillage	1560	1306	1433 a
No tillage	880	376	628 b
Mean	1220 a	841 b	

[a]Separation of means in a row or in a column by Duncan's multiple range test at the 5% level.

Table 11. Plants established with or without tillage, using an RIP with or without a disk covering device, at 5 soil moisture levels. IRRI, 1983 WS.

Day	Plants (no./2-m row)					
	Tillage			No tillage		
	Surface soil moisture	With disk	Without disk	Surface soil moisture	With disk	Without disk
1	29.4	26	22	30.0	6	10
2	28.4	31	23	29.0	14	6
3	27.0	15	13	28.1	6	6
4	25.7	17	10	27.0	2	2
5	24.7	9	6	26.1	0	0
Mean		19.6	14.8		6.0	4.8

Overall means of treatments			
With disk	12.8	Tillage	17.2
Without disk	9.3	No tillage	5.4

The Department of Agricultural Engineering constructed a covering device consisting of an 8-cm disk attached directly behind the seeding wheel to move soil into the hole after the seed was in place. The device was tested for tilled and untilled conditions in four replications of a split-split-plot design. To initiate the experiment, the field was flooded for 1 d and drained. Starting 2 d after drying, sorghum was planted on each of 5 consecutive d in 4 replications for each treatment. Soil samples to 10 cm were taken every other day to determine moisture content which was plotted to estimate values by interpolation for days not sampled. Six days after the last planting, plant densities were determined.

Table 11 shows that although a significant advantage was obtained by using the covering disk in either tilled or nontilled soil, the advantage was more pronounced in tilled soil. All factors (tillage, covering, and days of drying) significantly influenced plant density. The tillage and covering factors also interacted significantly with days of drying, effectively altering the trends in plant densities as the soil dried.

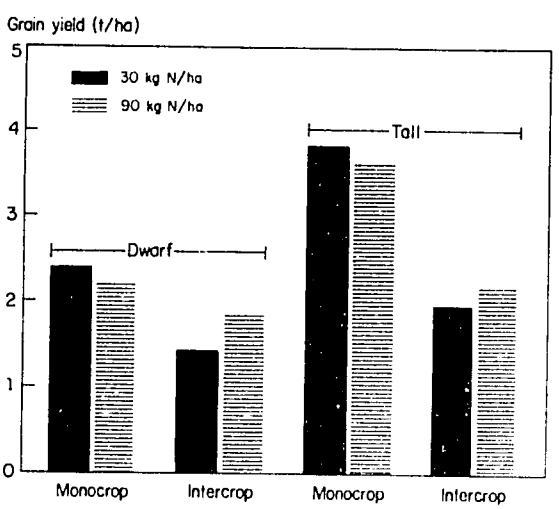
Day 2 (3 d after draining) was the most desirable moisture level for obtaining stands with the RIP. The soil was wet on day 1 and posed a problem for this implement. Soil dry down was approximately linear (Table 11), being about 1%/d for both tilled and untilled conditions. Although the difference of 10 cm moisture content between day 1 and day 2

was only 1%, the important point is that the drier surface allowed the machine to work more efficiently. Poor stands in the last 2 planting days were caused by lack of moisture in the top 3 to 4 cm where the seed is placed.

The experiment demonstrated that the covering device gave a significant advantage in obtaining stands of sorghum planted in lowland rice soils after harvest, that the RIP works better in tilled fields regardless of the covering disk, and that soil moisture is critical. Very little delay in planting could be tolerated even with the disk attachment.

Intercropping normal and dwarf sorghum varieties with soybean. To determine if a dwarf sorghum would compete less than a tall variety with intercropped soybean, an experiment with two factors (sorghum varieties and N levels) was started on 7 Dec 1982. Sorghum varieties differed primarily in height genes. Intercropped sorghum was planted in 150-cm rows, with 2 intervening 50-cm rows of soybean. Monocropped sorghum (100,000 plants/ha) in 75-cm rows and monocropped soybean in 50-cm rows were grown for comparative purposes. For both species, within-row plant densities were constant in the monocropped and intercropped plots. One-half of the fertilizer treatments (30 and 90 kg N/ha) was applied at planting; the remainder was broadcast before interrow cultivation. Tall sorghum matured in 116 d, dwarf sorghum in 107 d, and soybean in 81 d.

The sorghum varieties differed in mean yields and in response to applied N (Fig. 7). The tall variety was higher yielding as monocrop and intercrop. It did not respond to the extra 60 kg N/ha. When the dwarf sorghum was intercropped, its yields were not as depressed as those of the intercropped tall variety; neither were they any higher.



7. Grain yields of tall and dwarf sorghum varieties as monocrop or intercropped with soybean across 2 N levels. IRRI, 1983.

Neither sorghum height nor N fertilizer rate influenced intercropped soybean yields. When planted under short daylengths, soybean yielded low. Monocropped yields were 0.48 t/ha and intercropped yields (0.25 t/ha) were less than two-thirds of the monocropped, showing that competition with sorghum depressed yields.

WHEAT PERFORMANCE AND IRRIGATION RESPONSES

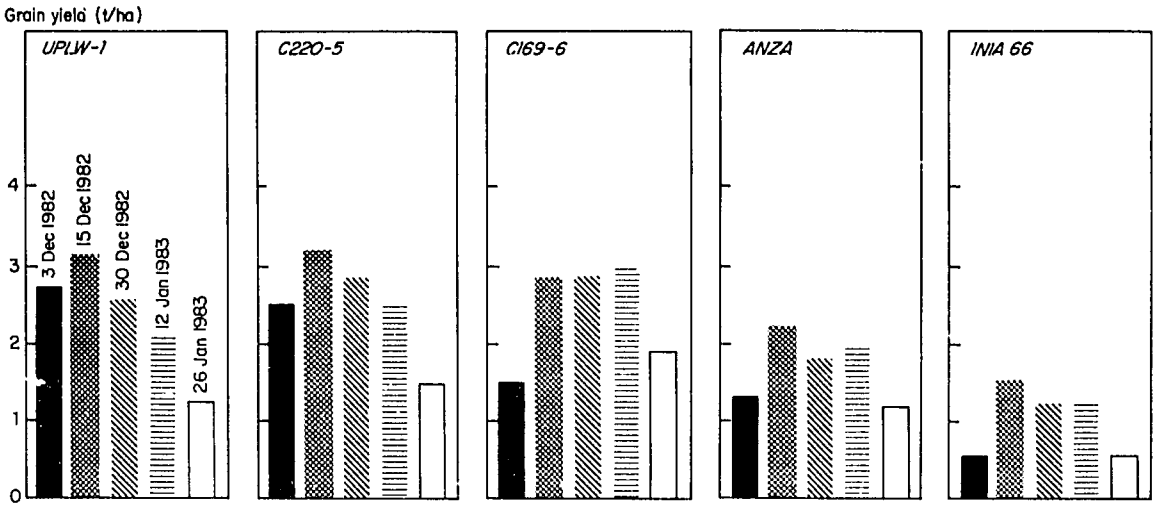
Wheat can be grown after lowland rice, but because it is not a crop common to the warmer monsoon climates, its performance and cultural requirements need examination.

Sensitivity of five wheat varieties to early dry season planting dates. Spring wheat varieties are sensitive to excess moisture and high nighttime temperatures. Therefore, planting should be delayed to avoid heavy late WS rainfall but not so much that grain filling is forced into a period of rising nighttime temperatures.

To examine adaptation to post-WS cultivation, five varieties (UPLW-1, IN1A66, ANZA, C220-5, and C169-6) were planted on 1, 15, and 29 Dec 1982 and 12 and 26 Jan 1983. To compare treatments, 4 replications of a split-plot design were seeded at 125 kg/ha on a well-prepared field. On each planting date, 80 kg N/ha was incorporated and main plots (planting dates) were lightly irrigated to establish the crop. Two additional irrigations prevented drought stress. The experiment was adequately protected against diseases.

Statistical analysis showed that planting dates, varieties, and their interaction contributed to grain yield variation. C220-5 and UPLW-1 were better adapted than other varieties when planted early in December (Fig. 8). C169-6 was the best adapted to delayed plantings. Yields from all varieties were low when planting was delayed until 26 Jan. Late January plantings forced grain-filling periods into April, when night temperatures exceeded 23° C.

Delayed planting significantly decreased plant height and 1,000-grain weight (Table 12). The



8. Mean wheat yield for 5 planting dates. IRRI, 1983 DS.

highest number of grains per spikelet was in the 29 Dec planting. Although planting date did not significantly affect the number of spikelets per square metre, data show early and late plantings decreased spikelet numbers. Results indicate that three varieties are moderately well-adapted to early post-WS plantings but the favorable planting period is less than 1 mo.

Influence of irrigation timing on wheat yields. On 3 Dec 1982, an experiment compared wheat (UPLW-1) responses to seven flush irrigation times: crown root initiation (CRI); CRI and booting; CRI and milk; CRI, booting, and milk; bootings; milk; and tillering. One plot in each of the four replications of an RCBD was maintained as an unirrigated control. The crop was seeded at 100 kg/ha on a well-prepared field with basal application of 80 kg N/ha.

Yields differed significantly (Table 13). No single irrigation application effectively increased yield. However, yield from the application at booting was significantly greater than unirrigated treatments. Highest yields were obtained from CRI + booting applications and CRI + booting + milk. Application at booting either singly or combined was most effective for increasing yields.

PIGEONPEA MANAGEMENT

Production of early-maturing pigeonpea varieties developed by ICRISAT is a possible addition to the rice-based cropping systems. Pigeonpea is drought tolerant, and should perform well in DS after rice harvest.

Pigeonpea main crop and ratoon performance. Twenty pigeonpea varieties maturing in 90 to 120 d

Table 12. Mean plant height and yield components of wheat from 5 sowing dates. IRRI, 1983 DS.

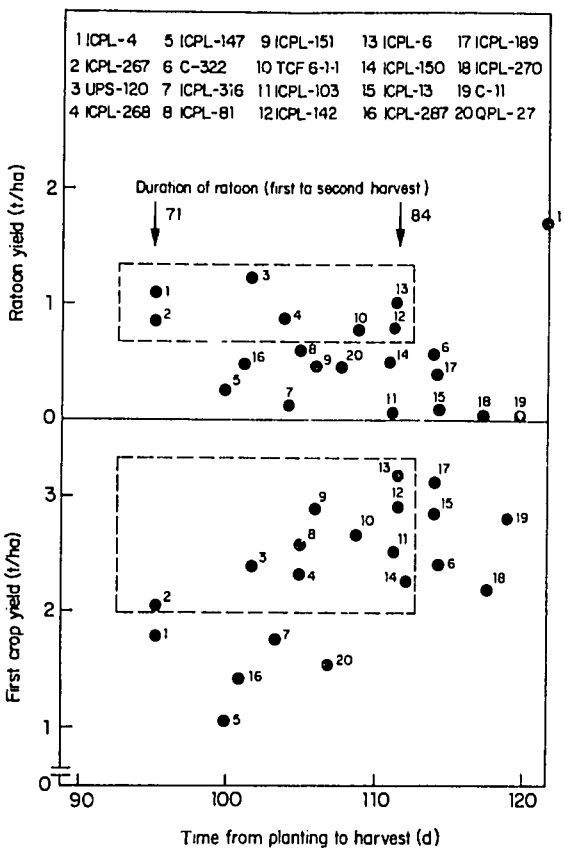
Date	Plant height (cm)	Spikelets (no./m²)	Grains (no./spikelet)	1,000-grain weight (g)
3 Dec	80 a	468 a	27 d	30 a
15 Dec	86 a	480 a	29 c	30 a
29 Dec	85 a	488 a	31 a	29 b
12 Jan	77 a	500 a	30 b	28 b
26 Jan	61 b	464 a	26 e	25 c
CV (a) %	13	14	4	4

Table 13. Grain yield of wheat UPLW-1 as affected by time of irrigation. IRRI, Dec 1982-Mar 1983.

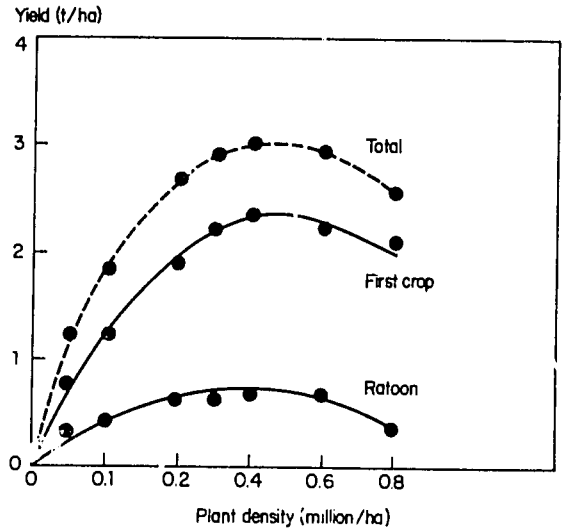
Time of irrigation	Grain yield (t/ha)
Control (rainfed)	1.7 d
CRI	1.5 bcd
Tillering	1.7 bcd
Booting	1.8 abc
Milk	1.7 bcd
CRI + booting	1.9 ab
CRI + milk	1.6 cd
CRI + booting + milk	2.0 a
CV %	9

were planted on 3 Dec 1982 in an RCBD replicated twice. ICPL-6, 142, 151, and 189 yielded more than 2.5 t/ha in 110 d (Fig. 9). Ratoon yields were measured after the varieties were pruned at the lowest pod-bearing node. UPS 120 produced the highest ratoon yield followed by ICPL-4 and 6. Early-maturing varieties demonstrated that pigeonpea can make effective use of land after rice harvest.

Responses to plant density. An experiment examined the effect of plant density on the yield of an early-maturing variety (ICPL-147) in rainfed fields. By varying plant density within the row, 5 plant densities (0.1, 0.2, 0.4, 0.6, and 0.8 million plants/ha) were compared in 30-cm rows. Three replications of an RCBD were planted on 4 Dec 1982. The highest main crop yield was at 400,000 plants/ha (Fig. 10). The combined main crop and ratoon yield was also highest at this density. Soil water was probably a yield limiting factor at higher plant densities.



9. Relationship of seed yield and duration of 20 varieties of pigeonpea. IRRI, 1983. Varieties within the rectangles appear promising.



10. Effect of plant density on rainfed pigeonpea (ICPL-147) yield. IRRI, 1983.

NITROGEN RESPONSES IN RICE - RICE CROPPING SEQUENCES

Two successive rice crops were grown between 13 Feb and 3 Sep 1983. The chemical and physical descriptions of the experimental field are presented in Table 14. As first crop, IR36 was broadcast at 120 kg seeds/ha and fertilized with 4 N rates (0, 60, 120, and 180 kg N/ha), replicated in 24 blocks of an RCBD. At 10 d after the first crop harvest, the second crop was transplanted using 24-d-old IR36 seedlings. Each replication of the first experiment became the main plot of the second experiment and received one of the 6 N levels (0, 35, 70, 105, 140, and 175 kg N/ha). Each main plot treatment was replicated four times in a split-plot design.

Table 14. Surface soil chemical and physical characteristics of the experimental site. IRRI, 1983.

Attribute	Value[a]
pH (1:1)	6.4
Organic C (%)	1.03
Total N (%)	0.112
Exchangeable K (meq/100 g)	1.33
CEC (meq/100 g)	34.1
Olsen P (ppm)	12.0
Particle size (%)	
Clay	43
Silt	38
Sand	19

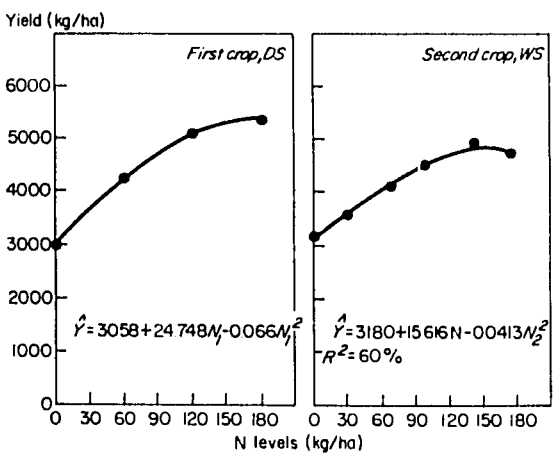
[a]Mean of 8 samples.

Grain yield was determined by harvesting a 2-× 3-m sampling area from each plot. N uptake also was determined.

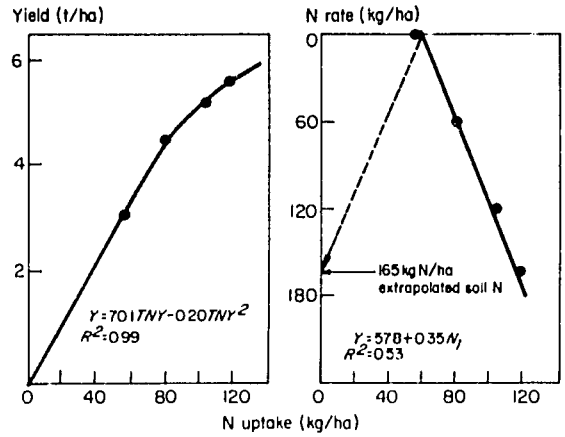
Analysis of variance showed that N rates significantly increased grain yield. N response of the first crop was highly linear (93% of the N sum of the squares), suggesting that the highest N rate did not produce the plateau yield (Fig. 11). The efficiency of the first increment of applied N was 24.7 kg grain/kg N and dropped to about 13 kg grain/kg N at the 180-kg rate.

N response of the second crop was almost linear. No residual N effect from the first crop was detected. Interaction between the current and previous N application was also absent. Unfertilized plots produced about 3.2 t yield/ha. The efficiency of the first increment of N applied was comparatively low (15.6 kg grain/kg N).

To investigate the low N efficiency and the absence of residual responses, data were analyzed to distinguish between inefficiency from low apparent N recovery and poor utilization following normal recovery. For the first crop, the curve relating N uptake and yield was a quadratic function which was forced to pass through the origin (Fig. 12). The initial portion of the curve was straight, indicating that each unit of N uptake was converted to grain with about equal efficiency. The initial slope was 70 kg grain/kg N, an uptake of about 80 kg N/ha. With higher uptake, the linearity diminished and other growth limiting factors began to reduce N utilization.



11. Yield of IR36 as affected by N level. IRRI, 1983.

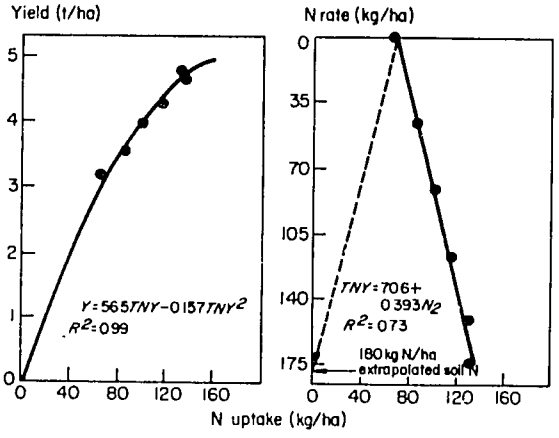


12. N uptake (TNY)-grain yield and N rate-N uptake functions of the first crop in the rice - rice cropping sequence. IRRI, 1983 DS. TNY = total N yield. Points shown are treatment means. All data were used in the regression analysis.

The graph (Fig. 12) shows the relationship between the amount of N applied and N uptake. The curve is a straight line over the full range of application, suggesting that uptake and losses of N from the soil were proportional to the concentration of N in the soil solution. The uptake from the unfertilized plot was 57.8 kg N/ha, reflecting the N supplying capacity of the soil. By extending the regression line to the N rate axis, a value of 165 kg N/ha is obtained. That represents soil N (fertilizer equivalent) absorbed by the unfertilized crop. The regression coefficient was 0.35 which is the apparent recovery.

Evaluation of the N uptake-grain yield function for the second crop (Fig. 13) shows that the initial slope was only 57 kg grain/kg N, lower than that observed on the first crop. The N-supplying capacity of the soil, estimated by extrapolating the regression line to the N rate axis of the lower graph, was 180 kg N fertilizer equivalent/ha. The apparent recovery was 39%, slightly higher than in the first crop. The high soil N and high uptake efficiency indicate that crop uptake was not the limiting factor in N efficiency during the second crop.

The growth period of the first crop was February-May and that of the second crop was June-September. Average daily irradiance was only 446 mWh/cm^2 for the second crop and 556 mWh/cm^2 for the first crop. Lower irradiance may explain lower N utilization efficiency.



13. N uptake (TNY)-grain yield and N rate-N uptake functions of the second crop in the rice - rice cropping sequence. TNY = total N yield. IRRI, 1983 WS. Points shown are treatment means. All data were used in the regression analysis.

Table 15. Maize and rice yields as affected by N rate and crop residue.[a] IRRI, 1982-83 WS and DS.

N rate (kg/ha)	Yield (t/ha)			
	No residue	With residue	Residue returned	Means
		Maize		
0	1.4	1.7	1.5	1.5 c
60	2.6	2.9	2.9	2.8 b
120	3.8	3.8	4.2	3.9 a
Means	2.6 a	2.8 a	2.9 a	
		Rice		
0	1.2	1.1	1.3	1.2 b
60	2.3	2.2	2.6	2.4 a
120	2.5	2.6	2.6	2.6 a
Means	2.0 a	2.0 a	2.2 a	

[a]Crop residue was in a standard application of 2 t/ha.

A crop that uses accumulated N inefficiently, as in the second crop, is unlikely to respond to the residual N from the first crop.

CROP RESIDUE EFFECTS IN AN UPLAND RICE - MAIZE SEQUENCE

In the second year of the rice - maize sequence, an experiment examined responses to inorganic N (0, 60, and 120 kg N/ha) and crop residue applications (all residue removed and returned in a standard application of 2 t residue/ha). Maize (IPB-1) was seeded on 8 Nov 1982 and harvested 28 Feb 1983. Upland rice (UPL Ri5) was seeded on 10 Jun 1983 and harvested on 22 Oct 1983. Maize was over-seeded and thinned to obtain 53,000 plants/ha, and upland rice was seeded at 120 kg/ha. Uniform applications of P (17 kg/ha) and K (33 kg/ha) were incorporated at planting. Pests were adequately controlled.

N significantly increased maize and rice yield (Table 15). Neither residue treatment affected yields significantly, although there was a positive trend. A partition of the sum of squares from N showed a strongly linear response for maize and a significant quadratic effect for rice. Rice yields from 0, 60, and 120 kg N/ha showed a distinctly lower N efficiency from the second 60 kg N increment. When all crop residues were returned, maize yields were 0.3 t/ha higher and rice yields 0.2 t/ha higher than when all residues were removed. This suggests that some benefit may come from residues but their effects were too low to be detected at the sensitivity levels of this experiment (CV = 16%).

CONTRIBUTION OF A SHORT-DURATION GREEN MANURE CROP TO RICE GRAIN YIELDS AND N UPTAKE

N is the fertilizer nutrient most commonly applied by Asian rice farmers. Well-adapted tropical grain legumes accumulate large quantities of N in a 70-80 d growth cycle. Rapid N accumulation, whether from soil N or biological fixation, should enable a green manure crop incorporated after 30-40 d growth to contribute a yield-increasing quantity of N to rice. If green manure is used, it will probably be grown when there is limited opportunity to grow upland crops or rice. The 20 to 50 d transition between DS and WS is such a period. This study tried to determine N accumulation by fast-growing tropical legumes during 20 to 45 d in late DS - early WS, the influence of selected management practices on N accumulation, the apparent recovery of the incorporated N, and the efficiency with which the recovered N was used to produce grain.

One experiment, repeated for 3 yr (1981, 1982, 1983), tested green manure growth duration (20, 30, and 40 DE) and application of inorganic N

Table 16. N accumulation in mungbean at 3 ages. Experiment 1, IRRI, 1981-83.

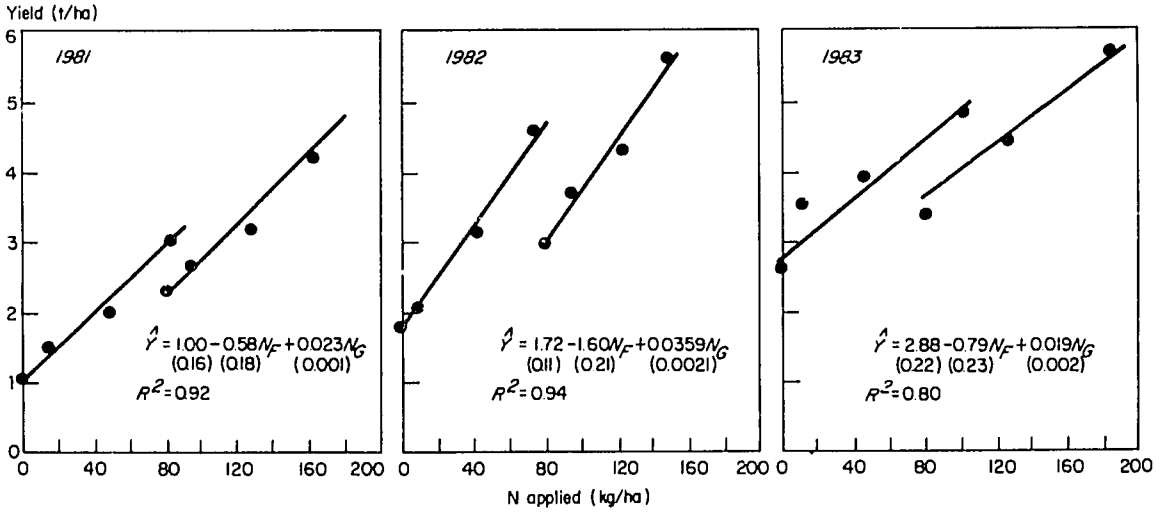
Green manure growth duration (d)	1981	1982	1983	Mean
	N accumulation (kg/ha)			
20	13	11	12	12
30	50	41	48	47
40	80	75	102	86
	Mean square			
	4492**	4084**	8347**	
CV (%)	11	4	18	

fertilizer. Each year, mungbean was planted on 16 Apr and incorporated at 40 DE. Crops incorporated at 30 and 20 DE were planted 26 Apr and 6 May. A clean fallow was the control (0 growth duration). Mungbean green manure plots plus fallowed plots were arranged in eight replications of an RCBD. For the rice crop, two adjacent replications in the mungbean experiment were combined as two main plots of a split-plot design replicated four times. One main plot received 80 kg N/ha in split applications. Table 16 shows N accumulation in mungbean. The 3 yr averaged

Table 17. Yields of transplanted IR36 in response to incorporation of mungbean at 3 ages and 2 inorganic N levels. Experiment 1, 1981-83 WS.

Green manure growth duration (d)	Yield (t/ha)							
	1981		1982		1983		Mean	
	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha
0 (fallow)	1.06	2.25	1.68	2.96	2.27	3.30	1.67	2.84
20	1.33	2.57	2.08	3.64	3.60	4.16	2.34	3.46
30	2.01	3.08	3.19	4.26	3.93	4.33	3.04	3.89
40	2.94	4.26	4.52	5.67	4.72	5.44	4.06	5.12

Source of variation		*Mean square*	
Inorganic N (N)	11.6**	12.8**	3.7*
GM duration (G)	5.9**	11.7**	7.1**
N X G	0.02 ns	0.9 ns	0.14 ns
CV_a (%)	21	[illegible]	10
CV_b (%)	13	11	6



14. Yields as functions of applied N (inorganic and green manure N). Experiment 1, IRRI, 1981-83 WS. Data points are means across 4 replications.

only 12 kg N/ha during the first 20 DE but 39 kg/ha between 30 and 40 DE.

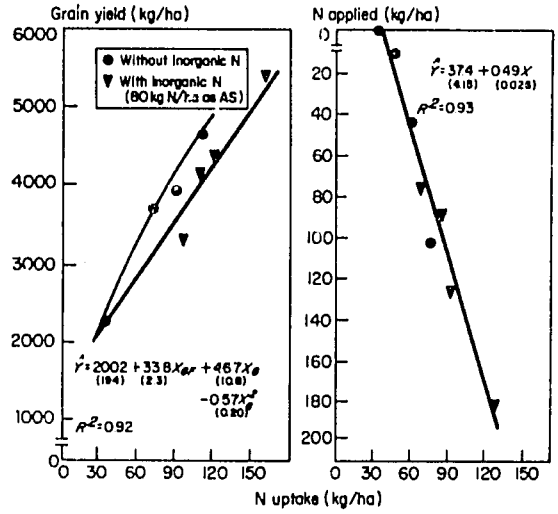
Green manure duration and inorganic N application did not interact in any year (Table 17). The mean grain response to the incorporation of a 40-d-old mungbean crop was 2.3 t/ha, and the mean response to 80 kg N/ha was 1.05 t/ha.

Based on the N response for individual years, N from inorganic fertilizer was less efficient than that from green manure (Fig. 14). Regression analysis showed that grain yield responses to applied N were satisfactorily expressed by a single partial regression coefficient in both the presence and absence of inorganic N. Taking the coefficient for the inorganic N dummy variable in Figure 14 into account, the mean response was 14 kg grain/1 kg inorganic N per ha, and 26 kg grain/1 kg green manure N per ha. The three model parameters were highly variable over 3 yr, suggesting that environmental effects, management variations, and perhaps soil changes were important factors in determining yields.

The difference between extreme quantities of N uptake was more than threefold (Table 18). Analysis of variance showed that the main effects of green manure growth duration and inorganic N application, but not their interaction, influenced N accumulation. Apparent recovery was not influenced by N source, and utilization of accumulated inorganic N was inferior (Fig. 15). N concentration, total DM yields, and productive tiller counts suggest that when inorganic N was applied, it accumulated faster than it could be effectively used

Table 18. N uptake by rice in response to incorporation of green manure at 3 ages and 2 inorganic N levels. Experiment 1, IRRI, 1983 WS.

Green manure growth duration (d)	N uptake (kg N/ha) 0	80 kg N/ha
0 (fallow)	34.4	69.9
20	49.2	87.8
30	60.2	95.9
40	84.5	129.6
Analysis of variance		
Source	*df*	*Mean square*
Inorganic N (N)	1	12016**
GM duration (G)	3	4244**
N X G	3	40 ns
CV (a)		16
CV (b)		9



15. Relationships between N yield and N applied, and between grain yield and N yield. Experiment 1, IRRI, 1983 WS. Data points are means across 4 replications.

for growth (Table 19). At maturity, straw and grain in treatments receiving inorganic N had 37% and 18% higher N concentration than those in treatments without inorganic N.

The regression of N uptake on applied N showed that soil N contributed 34 kg N/ha, and apparent recovery of applied N was 49%. This apparent recovery may reflect residual N from 1981 and 1982 or N remaining in soil from the root systems of incorporated green manure plants. Future experiments will examine trends in apparent recovery.

In a second experiment, mungbean was planted on 12 May 1983 and incorporated 67 DE (following the second priming). Crops incorporated at 60 and 40 DE were seeded 7 and 27 d later. On each planting date, mungbean was seeded in three plots per replication to form factorial combinations with three inorganic N timing treatments during the rice cultivation phase. Fifty kg inorganic N/ha was applied to rice in three timing treatments: all B&I at planting; all topdressed at PI; and one-half B&I at planting followed by one-half topdressed at PI. For rice cultivation, plots fallowed during mungbean cultivation received 0, 50, 100, and 150 kg N/ha. One-half N was B&I and one-half was topdressed at PI. To each of 2 additional fallow plots, 50 kg N/ha was applied in single applications (either all B&I before planting or all topdressed at PI).

Table 19. Total DM yield, productive tillers, and N concentrations of rice following incorporation of green manures at 3 ages and 2 inorganic N levels. Experiment 1, IRRI, 1983 WS.

Green manure growth duration (d)	Total DM yield (t/ha)		Productive tillers (no./m²)		N concentration (%)							
					Most recently expanded leaf				Maturity			
					Max tillering		20 DAF[a]		Straw		Grain	
	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha	0	80 kg N/ha
0 (fallow)	3.1	5.9	340	416	4.8	5.5	2.9	3.3	0.72	0.84	1.25	1.44
20	4.1	7.2	363	449	5.1	5.6	2.9	3.5	0.68	0.87	1.23	1.47
30	5.3	7.3	381	456	5.5	5.9	3.0	3.5	0.68	0.97	1.29	1.53
40	7.6	9.2	425	475	5.6	5.9	3.2	3.7	0.74	1.15	1.34	1.60

Analysis of variance

Source of variation			*Mean squares*			
Inorganic N (N)	46.2*	41328**	1.66*	1.87**	0.531**	0.437**
Green manure duration (G)	21.8*	7105**	0.55**	0.17**	0.050**	0.027*
N X G	1.0 ns	472 ns	0.06 ns	0.004 ns	0.032*	0.001 ns
CV (a)	12.0	2.7	4.4	4.2	12.0	6.0
CV (b)	11.6	8.3	4.3	3.6	11.9	6.7

[a]Days after flowering.

A typhoon damaged immature pods on mungbean plants 7 d before they were to be incorporated at 67 and 60 DE. The first priming (0.98 t/ha) from the 67-d-old crop was taken before the typhoon, and the second priming (0.13 t/ha) was taken after the typhoon. Yield from the first priming of the 60-d-old crop, taken after the typhoon, was only 0.22 t/ha. The amount of N incorporated and the N concentrations after the three mungbean growth durations are shown in Table 20. About 3 times as much N was incorporated in the 40 DE mungbean crop as in the 67 DE crop and twice that in the 60 DE crop.

Table 20. N accumulation and percent N in mungbean at 3 ages before incorporation as a green manure. Experiment 2, IRRI, 1983 WS.

Green manure growth duration (d)	N accumulation (kg/ha)	N concentration (%)
40	92.5	2.64
60	53.3	1.92
67	30.9	1.48

Analysis of variance

Source		*Mean square*
Growth duration	3898**	1.38**
CV (%)	7	3

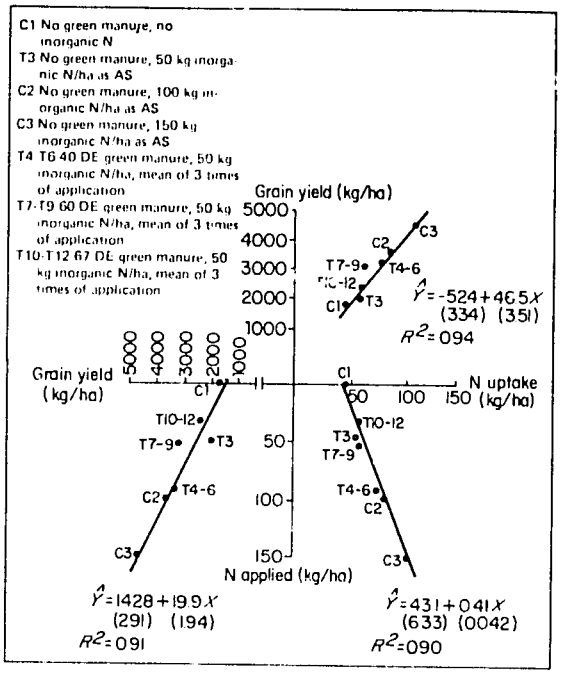
Table 21. Rice yields after incorporation of mungbean at 40, 60, 67 DE and 3 inorganic N (50 kg/ha) timing treatments. Experiment 2, IRRI, 1983 WS.

Time of N application	Grain yield (t/ha)				
	0 (fallow)	40 DE	60 DE	67 DE	Mean
All at PI	2.19	3.35	3.21	2.46	2.80
½ at planting + ½ at PI	1.95	3.19	3.01	2.20	2.59
All at planting	1.89	3.07	2.96	2.13	2.51
Mean	2.01	3.20	3.06	2.26	2.63

Analysis of variance[a]

Source	*df*		*Mean square*
Crop age (A)	3		
Fallow vs green manure		1	6.280**
40 DE vs 60 and 67 DE		1	2.354**
60 DE vs 67 DE		1	3.850**
Time of N application (T)	2		
All at PI vs all at planting		1	0.706**
Remainder		1	0.050
T X A	6		0.003
Error	41		0.029[b]
CV = 6%			

[a]The treatment mean squares in this table were computed for only 12 crop age-time of application treatment combinations. [b]Error mean square was computed from the full experiment except for one missing value.



16. Grain yield-N uptake-N applied relationships. Experiment 2, IRRI, 1983 WS. Data points are means across 4 replications.

Partition of the sum of squares for green manure growth duration and time of inorganic N application showed several influences on rice yields. The interaction between green manuring and time of application was not significant. Among the herbage incorporations, yields following the 40-d-old crop were highest. Among the inorganic N timing treatments, application of all N at PI increased grain yield more than a single application at planting or a split application (Table 21). The response to inorganic levels (0, 50, 100, and 150 kg N/ha, 1/2 B&I at planting and 1/2 topdressed at PI) was linear although deviations from linearity were significant (Fig. 16).

Analysis of variance on N taken up by rice revealed that uptake after incorporation of the 40-d-old green manure was significantly higher than uptake after the fallow period or incorporation of either 60- or 67-d plants. As anticipated, N uptake after incorporation of the 60-d-old crop was numerically but not significantly greater than that after the 67-d-old crop. N uptake after the single topdressed application at PI was significantly greater than that after a single application incorporated at planting or split application.

Regressions (Fig. 16) correspond to the relationships between grain yield and N uptake, N uptake and applied N, and grain yield and applied N for the split-applied inorganic N fertilizer series at 0, 50, 100, and 150 kg N/ha. Other data points (means over time of N treatments) are shown for comparison. Uptake of soil N was 45 kg N/ha and recovery of split-applied inorganic N was 41%.

Over the observed range, utilization of accumulated inorganic N was low. N uptake after incorporation of the 40- and 67-d-old green manures was near the inorganic N regression line. But N uptake after incorporation of the 60-d-old crop was utilized slightly more effectively as indicated by its position above the line. The difference in efficiency may have been caused by an N release pattern more favorable than that of either the more N rich or N poor incorporated materials.

Rice had less N uptake after incorporation of the 60-d-old mungbean crop. However, total DM, productive tiller counts, and N concentrations (Table 22) suggest that the mineralization pattern must have coincided more closely with the N uptake pattern than with that of other incorporated plant materials.

Efficiency of applied N reflects the joint effect of apparent recovery and utilization. The efficiency of

Table 22. Rice DM yields, productive tillers, and N concentration after incorporation of green manure at 3 ages (40, 60, 67 DE).[a] Experiment 2, IRRI, 1983 WS.

	0 (fallow)	40 DE	60 DE	67 DE	CV (%)
Total DM (t/ha)	4.62 b	6.30 a	5.10 b	5.12 b	10
Productive tillers (no/m²)	249 c	382 a	328 b	301 b	5
N concentration (%) in					
Flag leaf at flowering	2.84 c	3.18 a	2.83 c	2.98 b	3
Straw at maturity	0.80 a	0.95 a	0.90 a	0.90 a	10
Grain at maturity	1.35 b	1.46 a	1.39 ab	1.39 ab	4

[a]Means over 3 times of inorganic N applications and 4 replications. Separation of means in a row by Duncan's multiple range test at 5% level.

the split-applied inorganic N was 19 kg grain/kg N. Although the efficiency of N from 60 DE mungbean incorporation approached that of inorganic N, N efficiencies from shorter and longer mungbean growth duration were lower.

In the third experiment, mungbean to be incorporated 40 DE was planted on 2 May 1983. Crops planted 10 and 20 d later were incorporated 30 and 20 DE. On all planting dates, mungbean was overseeded in 20- and 40-cm rows and thinned for densities of 300,000 and 600,000 plants/ha. During mungbean cultivation, two plots were clean fallowed. During rice cultivation, one of the two clean fallowed plots in each replication was maintained as an unfertilized control. On the other fallowed plots, 27 kg inorganic N/ha was B&I before transplanting and 53 inorganic N/ha was topdressed at PI.

As expected, mungbean DM yields and N accumulation were greater from the dense plant population but percent N was lower (Table 23). A significant interaction between green manure growth duration and density was detected on total DM yields but not on the other attributes. Although more than twice as much N had accumulated in the denser population by 20 DE, 10 d later the N accumulation difference (on a relative basis) had diminished sharply. Nevertheless, linear interpolation between data points suggests that 100 kg N/ha would accumulate in 35 d from 600,000 plants/ha and in 40 d from 300,000 plants/ha.

Partition of the sum of squares of the factorial

Table 23. Total DM, %N, and N accumulation of mungbean at 3 ages and at 2 plant densities (300,000 and 600,000 plants/ha). Experiment 3, IRRI, 1983 WS.

Green manure growth duration (d)	Total DM (kg/ha)		N (%)		N accumulation (kg/ha)	
	300,000	600,000	300,000	600,000	300,000	600,000
20	435	1110	4.0	3.5	17.4	38.5
30	2237	2725	3.1	3.0	69.3	81.8
40	3568	4710	2.8	2.5	99.9	117.8
Mean	2080	2845	3.3	3.0	62.2	79.4
Source of variation			*Mean squares*			
Green manure density (D)		351517**		0.5*		1775**
Green manure duration (A)		22734383**		2.5**		13466**
D X S		228908**		0.1 ns		34 ns
CV (%)		5		10		12

Table 24. E[illegible] on rice yield and yield attributes of N fertilization and green manure at 3 ages and 2 plant densities (300,000 and 600,000 plants/ha). IRRI, 1983 WS.

Green manure growth duration (d)	Yield (t/ha)		Total DM (t/ha)		N uptake (kg/ha)		Productive tillers (no./m²)	
	300,000	600,000	300,000	600,000	300,000	600,000	300,000	600,000
0 (fallow, no inorganic N)	3.44		5.9		60.1		310	
0 (fallow, 80 kg inorganic N /ha)	4.61		8.0		86.6		455	
20	3.52	3.69	7.0	7.5	73.9	77.6	363	377
30	3.84	4.04	6.9	8.6	78.4	89.0	353	404
40	4.55	4.70	8.2	9.0	95.0	106.6	419	422

Analysis of variance

Source of variance	*df*		*Mean squares*		
Green manure density (D)	1	0.81 ns	5.94**	460*	2948 ns
Green manure duration (A)	2	4.32**	4.04**	1332**	11689**
D X A	2	0.002 ns	0.98 ns	32 ns	2292 ns
Fallow, with vs without inorganic N	1	2.71**	8.42**	1404**	
CV (%)		11	11	11	8

Table 25. Effect of N fertilization and green manure at 3 ages and 2 plant densities (300,000 and 600,000 plants/ha) on N concentration in the leaves, straw, and grain. IRRI, 1983 WS.

Green manure growth duration (d)	N concentration (%)					
	Leaves		Straw		Grain	
	300,000	600,000	300,000	600,000	300,000	600,000
0 (fallow, no inorganic N)	1.86		0.87		1.10	
0 (fallow, 80 kg inorganic N/ha)	1.83		0.86		1.25	
20	1.96	2.01	0.87	0.85	1.24	1.25
30	1.97	2.01	0.90	0.84	1.32	1.27
40	2.08	2.15	0.90	0.98	1.36	1.36

Analysis of variance

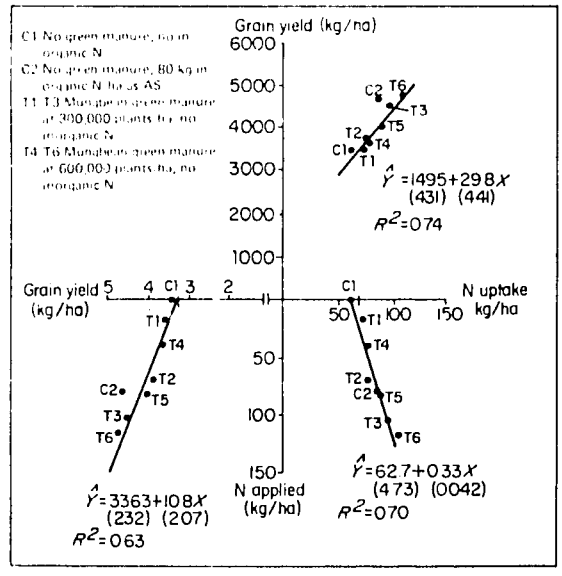
Source of variance	*df*	*Mean squares*		
Green manure density (D)	1	0.02 ns	0.000004 ns	0.002 ns
Green manure duration (A)	2	0.05 ns	0.015 ns	0.025*
D X A	2	0.005 ns	0.010 ns	0.015 ns
Fallow, with vs without inorganic N	1	0.002 ns	0.003 ns	0.047**
CV (%)		6	10	5

treatments (three green manure growth durations and two plant densities) revealed that plant density and the interaction between growth duration did not influence rice yield but grain yield increased as green manure growth duration increased (Table 24). Compared to 300,000 plants/ha, 600,000 increased the total DM yield of rice (8.4 vs 7.4 t/ha); however, it did not significantly influence productive tillers/ha and N concentration in the flag leaf at flowering or in the straw or grain at harvest (Table 25).

The regression of grain yield on applied N (Fig. 17) showed that the yield response from added N was predominantly linear over the N range regardless of source. However, efficiency was only 10.8 kg grain/kg N.

The regression of N uptake on N added indicated that uptake was essentially linear, that apparent recovery was 33%, and that 63 kg N/ha was derived from the soil. The equation from the regression of grain yield on N uptake, excluding N taken up after application of 80 kg inorganic N/ha, is shown in Figure 17. Grain yield-N uptake data points from the 300,000 plants/ha density tend to lie above the corresponding points from the 600,000 plants/ha. However, statistical analysis did not indicate that N from the lower density was used more effectively.

In a fourth experiment, cowpea and *Sesbania aculeata*, 2 leguminous crops which tolerate excess soil moisture conditions better than mungbean, were incorporated as green manures at 21, 33, and 45 DE. The longest duration crops were planted on 2 Jun 1982. The 33- and 21-d-old crops were planted 12 and 24 d later. Green manure crops were grown on the fields in which they were incorporated (*in situ* manuring) and on adjacent fields (green leaf manuring). One plot, fallowed during the green



17. Grain yield-N uptake-N applied relationships. Experiment 3, IRRI, 1983 WS. Point C2, corresponding to 80 kg inorganic N/ha, was excluded from regressions. Data points are means across 4 replications.

manure growth, was used as an unfertilized control, and a second was used as an inorganic N-fertilized (80 kg N/ha) control.

Analysis of variance showed that all three factors (crop species, growth duration, and *in situ* vs green leaf manuring) affected N accumulation in the green manures (Table 26). The interaction between species and duration was also significant.

The three factors affected rice yields (Table 27), but the influence of growth duration was greatest. The 80 kg N/ha application to fallow plots increased yield by 600 kg above the control.

Figure 18 shows that with increasing growth duration, *S. aculeata* increased yields more than cowpea. Figure 19 shows that the soil contributed 54 kg N/ha and that recovery of applied N in the green manures was only 27%. Recovery of inorganic N was not apparently different from recovery of green manure N. Utilization of recovered inorganic N was less efficient than that of recovered green manure N.

In a fifth experiment, cowpea and *Sesbania rostrata* planted on 9 Feb 1983 were flooded during the last 17 d of a 45-d growth duration. Flooding simulated potential damaging effects of early and heavy WS rainfall. Cowpea N accumulation was affected by flooding. Cowpea accumulated 36 kg N/ha in the nonflooded treatment and 26 kg N/ha in the flooded. Flooding had no apparent effect on N accumulation of *S. rostrata* which averaged only 18 kg N/ha in the flooded and unflooded treatments. This low value may be associated with limited vegetative growth during short days and delayed nodule development. Subsequent *S. rostrata* studies show that vegetative growth is more vigorous during longer days. *S. rostrata* did not begin acetylene reduction until 23 DE while

Table 26. N added by cowpea and sesbania at different ages. Experiment 4, IRRI, 1983 WS.

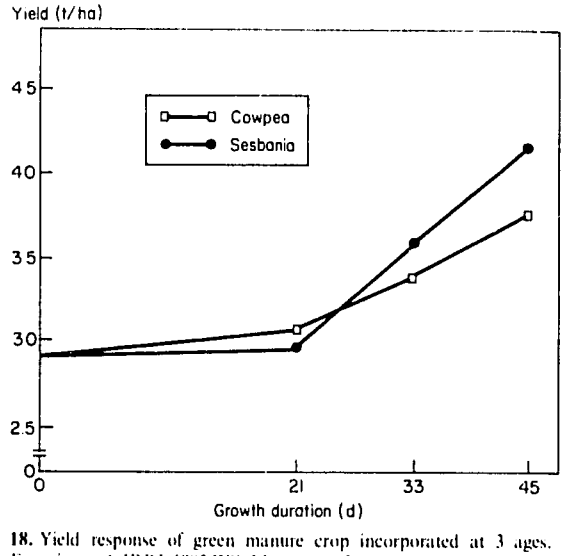
Age (d)	N added (kg/ha)				
	In situ		Green manuring		Mean
	Cowpea	Sesbania	Cowpea	Sesbania	
21	4.4	10.1	3.4	6.7	6.1
33	22.8	38.2	17.8	34.3	28.4
45	33.9	78.9	30.5	78.1	55.3
Mean	20.3	42.6	17.2	39.7	

Source of variation	*F-value*
Manuring (M)	8.8**
Green manuring crops (GMC)	482.0**
M X GMC	0.0
Growth stages (GS)	781.6**
M X GS	0.7
GMC X GS	149.8**
M X GMC X GS	0.5
CV = 12%	

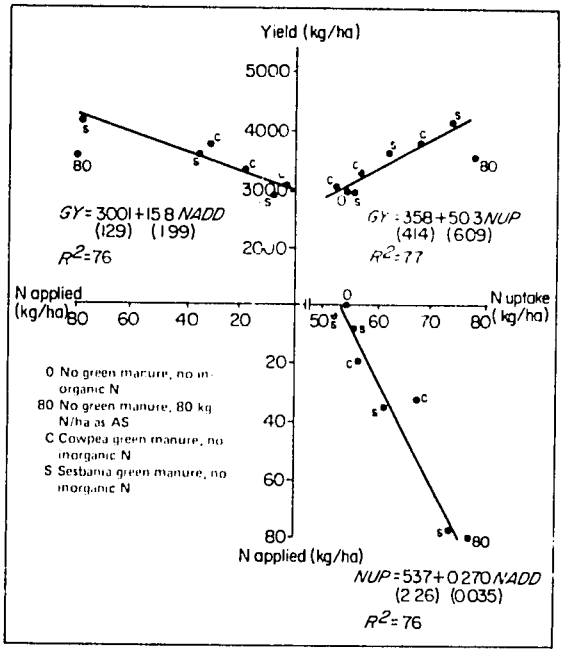
Table 27. Effect of cowpea and sesbania at different ages, incorporated *in situ* and as green leaf manure, on yield of rice. Experiment 4, IRRI, 1983 WS.

Age (d)	Yield (t/ha)				
	In situ		Green leaf manuring		Mean
	Cowpea	Sesbania	Cowpea	Sesbania	
21	3.1	3.0	3.0	3.0	3.0
33	3.5	3.7	3.3	3.5	3.5
45	3.8	4.3	3.7	3.9	3.9
Mean	3.5	3.7	3.3	3.5	
Without green manure application					
0 kg N/ha					3.0
80 kg N/ha					3.5

Source of variation	*F-value*
Manuring (M)	4.8*
Green manure crops (GMC)	4.7*
GM X GMC	0.1
Growth stages (GS)	41.1**
M X GMC	0.2
GMC X GS	2.4
M X GMC X GS	1.0
0 vs 80 kg inorganic N/ha	8.0**
CV = 8%	



18. Yield response of green manure crop incorporated at 3 ages. Experiment 4, IRRI, 1983 WS. Means over 2 green manure production methods and 4 replications.



19. Grain yield-N uptake-N applied relationships. Experiment 4, IRRI, 1983 WS. Points 0 and 80 are checks to which green manures were not applied, but the latter point received 80 kg inorganic N/ha. Points indicated by 0, C (cowpea green manure), and S (sesbania green manure) were included in the regressions. Data points of 0 and 80 are means across replications. C and S data points are means across 2 methods of green manure cultivation and across 4 replications.

cowpea began 8 DE. Both green manure crops increased rice grain yields. Yields after fallowing, *S. rostrata*, and cowpea averaged 3.2, 3.6, and 4.0 t/ha (means over 5 replications, 2 inorganic N levels, and 2 flooding levels on the green manures). Rice yield was 4.2 t/ha when cowpea was not flooded and 3.9 t/ha when it was flooded.

GROWTH AND NITROGEN FIXATION BY *SESBANIA* SPECIES UNDER DIFFERENT FLOODING DENSITIES

Growing a legume as a green manure crop before rice, or between rice and the following crop, could increase available soil N through recycling and N fixation. The legume crop should be able to stand probable waterlogging at some time during growth.

Sesbania species are well known for tolerance to flooding and can be used as a green manure for rice. An experiment assessed the differences between N fixation abilities of two *Sesbania* species: *Sesbania sesban* and *Sesbania rostrata*. The latter develops stem nodules, considered an adaptation to waterlogged environments.

The two species were planted in six alternating rows on sloping soil in a pit where flooding could be controlled. After a peat-based inoculant was placed in the open 20-cm rows, seeds were sown. *S. rostrata* stems were inoculated with a spray at 12 and 20 DAS.

During two artificial floodings, all plants were submerged. The first flooding (25 DAS) lasted 1 d. Water then receded until only plants at the lower end of the slope were waterlogged for the next 14 d. The second flooding was applied 40 DAS and lasted 3 d. Waterlogging was maintained at the lower edge of the slope for the next 7 d. Plants were harvested 50 DAS.

For all measurements during growth and at harvest, the slope was divided from bottom to top into four sections designated I to IV.

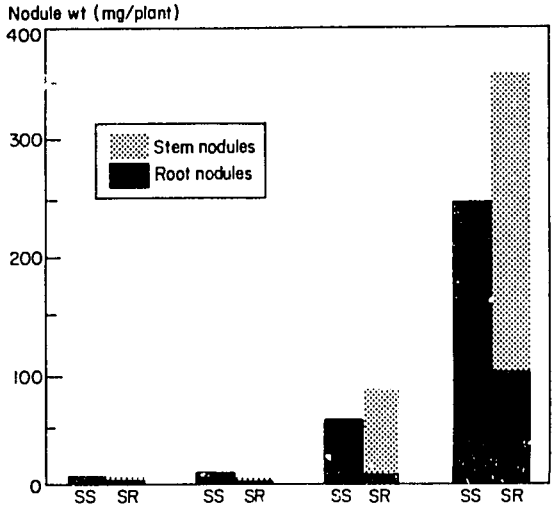
Acetylene reduction of root and stem nodules was determined by incubating roots or stems in 500-ml bottles. Gas samples were analyzed by gas chromatography.

Flooding reduced *S. sesban* population by 20% and *S. rostrata* by 10%. Plant losses were determined as the difference between counts made before flooding and at harvest (Table 28).

Production per plant was higher in *S. sesban* in the top two positions, but on a per-area basis, *S. rostrata* was superior. In the lower sections, production per plant and per area were higher in *S. rostrata*. *S. sesban* seeds showed poor germination

Table 28. Effect of plant position on the slope on DM production at harvest. IRRI, 1983.

Area	*Sesbania sesban*		*Sesbania rostrata*	
	Total production (g/m²)	Production/plant (g)	Total production (g/m²)	Production/plant (g)
IV (top)	506.0 ± 152.5	13.5 ± 5.0	621.2 ± 242.5	8.9 ± 2.9
III	325.4 ± 97.5	13.5 ± 6.0	320.7 ± 200.6	6.3 ± 3.4
II	61.6 ± 61.6	3.2 ± 1.8	199.5 ± 106.2	3.4 ± 1.9
I (bottom)	35.87	2.1 ± 1.4	89.4	5.7 ± 3.6

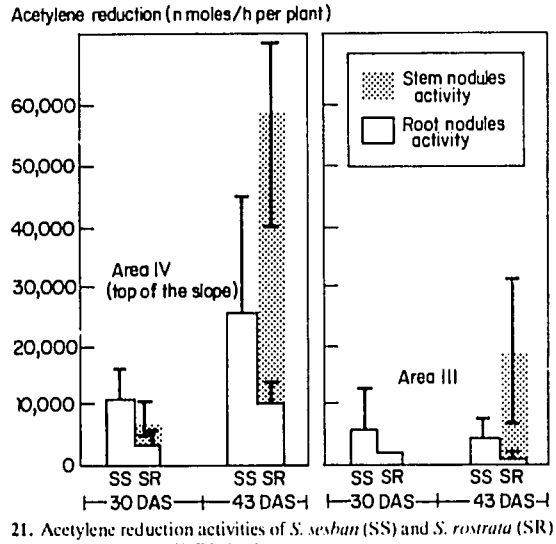


20. Nodule weight of *S. sesban* (SS) and *S. rostrata* (SR) after 43 d. IRRI, 1983.

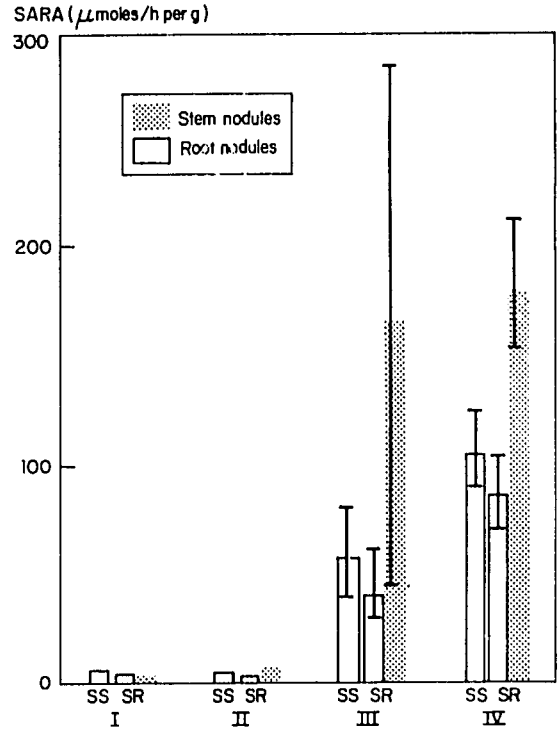
and expected density was not obtained, which was partially responsible for the yield differences.

Slope position also affected root nodule formation and growth (Fig. 20) with *S. rostrata* more sensitive to flooding. However, stem nodules enabled *S. rostrata* to produce a greater nodule mass. Results also suggest that *Rhizobia* infection of the stems, which leads to nodule formation, is not directly linked with flooding since nodule mass did not increase in plants in the lower sections.

At 30 DAS, *S. sesban* nodules were more active (Fig. 21). By 43 d, *S. rostrata* stem nodules were numerous and active and could fix more N than *S. sesban*. Acetylene reduction by root or stem nodules was negligible in the two bottom sections.



21. Acetylene reduction activities of *S. sesban* (SS) and *S. rostrata* (SR) at 2 dates in 2 areas. IRRI, 1983.



22. Specific acetylene reduction activity (SARA) of *Sesbania sesban* (SS) and *Sesbania rostrata* (SR) after 43 d. IRRI, 1983.

$$\text{SARA} = \frac{\text{ARA}}{\text{nodules dry wt}}.$$

Area I is at the bottom of the pit; area IV, at the top.

At 43 DAS, specific acetylene reduction activities (SARA) were computed to determine how root and stem nodules were affected by flooding and the soil moisture range (Fig. 22).

Root nodule SARA of the two species was similar and was affected only by plant position on the slope and consequent waterlogging. Stem nodule SARA on *S. rostrata* was similar in the two top sections. In areas I and II, the low nodule activity was attributed to poor physiological status of the whole plant after the water stress.

When the acetylene reduction activity measurements were made, the plants were recovering from a 3-d flooding and a moisture gradient existed. The data suggest that stem nodules recovered faster and enabled *S. rostrata* to fix more N than *S. sesban*.

In severely flood-stressed plants, N% was depressed. Although N% of *S. rostrata* was always lower than that of *S. sesban*, *S. rostrata* N yields were equivalent under good conditions and higher under flood-stressed conditions.

Cropping systems program

Preproduction testing and technology transfer

Training and Technology Transfer, Agricultural Engineering, and Agricultural Economics Departments

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TECHNOLOGY EVALUATION IN TWO RAINFED CROP PRODUCTION PROGRAMS

Training and Technology Transfer Department

A study initiated in 1982 continued to evaluate rice double cropping in two important rainfed rice production programs in the Philippines. In Iloilo and South Cotabato, double cropping is possible by

- direct dry-seeding the first rice crop at the beginning of WS,
- use of preemergence herbicides, and
- use of early-maturing varieties.

As in 1982, 1,000 m² cropping pattern production plots were located throughout the production program target areas of the two provinces. Superimposed trials were conducted to determine the importance of technology components, particularly variety and NPK fertilizer response. At four locations in Iloilo and at one in South Cotabato, researcher-managed trials studied the importance of N application timing at different rates and weed control levels.

Table 1. Yield from 1000-m² IR36 production plots at various locations in Iloilo Philippines, 1983.

Rainfall zone	Landscape	Yield (t/ha)		
		First crop	Second crop[a]	Total
Wet	Side slope	6.74 (n=6)	4.76 (n=6)	11.50
	Plain	6.39 (n=6)	4.10 (n=5)[b]	10.49
Intermediate	Plateau	7.84 (n=6)	4.35 (n=6)	12.19
	Plain	5.27 (n=6)	4.53 (n=6)	9.80
Dry	Plateau	5.80 (n=6)	–[c]	5.80
	Plain[d]	3.79 (n=6)	–[c]	3.79

[a]Herbicide toxicity from heavy rain and flooding after application reduced stands of many second crop plots. [b]One farmer withdrew from participation for the second crop for personal reasons. [c]Planted to mungbean using the rolling injection planter. [d]Affected by a dry spell during weeks 32 to 37.

Cropping patterns and crop yields. *Iloilo.* The study area was stratified according to rainfall pattern and landscape position which were hypothesized as the major influences on technology performance. In each of three rainfall zones (northern-wet, central-intermediate, and southern-dry), the two major landscape positions were identified (Table 1).

For each landscape in the rainfall zones, five to six cropping pattern production plots were planted with IR36 in farmers' fields. In the wet and intermediate zones, the cropping pattern was DSR - WSR. In the dry zones, the pattern was DSR - mungbean (Pag-asa 3). For each 1000-m² plot (except for some in the wet zone), a contiguous 100-m² area of IR58 was sown on the same date and received the same management for comparative purposes. Results show the high potential of IR36 when double-cropped under rainfed conditions (Table 1).

The double crop yields of IR36 in the wet and intermediate zones during 1983 were substantially higher than in 1982. In the wet and intermediate zones, rainfall from September to December was 26 to 99% higher during 1983 than in 1982 and partially accounts for the increase (Table 2).

In the dry zone, it was again considered too risky to sow a second rice crop so mungbean was established using the rolling injection planter. Although stand was good, subsequent heavy rains destroyed 9 out of 11 established crops by waterlogging. Surviving mungbean crops were severely affected by powdery mildew.

Table 2. Comparative yields and corresponding rainfall data for 1000-m² production plots, Iloilo, Philippines, 1982-83.

Rainfall zone	Landscape position	1983			1982		
		Yield[a] (t/ha)	Rainfall (mm)		Yield[a] (t/ha)	Rainfall (mm)	
			Apr-Dec	Sep-Dec		Apr-Dec	Sep-Dec
Wet	Side slope	11.50	1732	904	8.50	1370	628
	Plain	10.49	1984	951	8.06	1752	477
Intermediate	Plateau	12.19	1735	750	4.51	1271	474
	Plain	10.80	1609	909	6.37	1695	722
Dry	Plateau	5.80	1418	797	3.91	1751	415
	Plain	3.79	1544	752	3.49	876	363

[a]Total annual rice yield from the 1000-m² production plot.

Table 3. Yield from 1000-m² production plots in Norala and Surallah, South Cotabato, Philippines, 1983.

Location	Yield (t/ha)		
	First crop[a]	Second crop[b]	Total
	Partially irrigated		
Norala (n=6)	4.49	4.55	9.04
Surallah (n=6)	3.68	4.52	8.20
	Completely rainfed		
Norala (n=6)	2.74	3.57	6.31
Surallah (n=6)	3.63	4.23	7.86

[a]IR56. [b]IR60.

South Cotabato. Based on 1982 results, the South Cotabato environment was stratified by location (corresponding to soil type) and availability of partial irrigation. A significant number of area farmers obtained supplementary water from springs and creek diversions.

IR56 was planted as the first crop but was replaced in the second crop with IR60 which has better Bl and virus disease tolerance. Plot results from Norala showed that double-cropping with partial irrigation yielded 2.7 t/ha higher than two crops grown in completely rainfed conditions (Table 3). This difference was 1.7 t/ha for the first crop and 1.0 t/ha for the second.

In Surallah, the advantage from supplemental irrigation was substantially less (only 0.3 t/ha). One contributing factor may have been the 44% higher late season rains in Surallah, which may have negated the usually positive effect of irrigation. Another important factor was that the first crop of IR56 in Norala, which was completely rainfed, suffered more from Bl than Norala irrigated plots and Surallah rainfed plots. The yield advantage from supplemental irrigation in Norala may have been more related to the creation of less favorable conditions for Bl.

NPK fertilizer responses. *Iloilo.* NPK fertilizer trials continued to be superimposed on all rice crops grown in the production plots: 36 trials for the first crop and 22 for the second. For the second crop, trials were established only in the wet and intermediate zones. One farmer did not participate for the second crop and another's harvest was stolen.

In addition to standard NPK trials, treatment with Zn was added in the dry zone based on 1982 deficiency symptoms.

As in the previous year, N increased yields in all locations (Table 4). For both first and second crops in all locations, the 90-13-25 treatment yielded significantly higher than the 0-0-0 treatment. But in 3 of 6 locations, first crop yield did not significantly increase from increasing N from 30 to 90 kg/ha in the presence of P and K. For 1 of the remaining 3 locations, there was no significant increase in yield beyond 60 kg N/ha. For the remaining 2 dry zone locations, increasing N, from 60 to 90 kg N/ha in the presence of P and K, increased yield significantly.

In the second crop, 1 of 4 locations showed no significant yield increase above 30 kg N/ha in the presence of P and K. The other locations showed no significant yield increase beyond 60 kg N/ha.

Table 4. Effects of 8 fertilizer treatments on IR36 yields in 3 rainfall zones.[a] Iloilo, Philippines, 1983.

Rainfall zone	Landscape	Crop	Yield (t/ha) at given NPK rates (kg/ha)							
			0-0-0	30-13-25	60-13-25	90-0-0	90-0-25	90-13-0	90-13-25	90-13-25 +Zn
Wet	Side slope	First (n=6)	6.04 b	7.33 a	7.54 a	–	7.03 a	6.98 a	7.10 a	–
		Second (n=6)	3.96 c	4.62 b	5.03 ab	4.68 b	5.34 a	4.91 ab	5.16 a	–
	Plain	First (n=6)	5.07 c	7.03 a	7.01 a	–	5.81 b	6.27 b	6.36 ab	–
		Second (n=5)[b]	3.20 d	4.17 bc	4.81 a	4.00 c	4.49 ab	4.12 bc	4.77 a	–
Intermediate	Plateau	First (n=6)	4.93 c	7.48 b	8.19 ab	–	5.45 c	8.01 ab	8.67 a	–
		Second (n=5)[c]	3.37 d	4.45 abc	4.81 ab	4.16 c	4.27 bc	4.60 abc	4.96 a	–
	Plain	First (n=6)	4.04 b	5.13 a	5.71 a	–	5.32 a	5.84 a	5.74 a	–
		Second (n=6)	3.34 d	3.91 c	4.48 b	4.71 ab	4.84 ab	4.99 a	4.69 ab	–
Dry	Plateau	First (n=6)	3.98 c	4.84 b	4.96 b	–	5.72 a	5.85 a	5.93 a	5.70 a
	Plain	First (n=6)	1.30 d	2.20 c	3.28 b	–	3.16 b	3.73 ab	3.88 a	3.73 ab

[a]Superimposed trials conducted in production plots. [b]One farmer did not participate for the second crop. [c]One trial was harvested and removed without data collection.

Based on these and 1982 results, there is little to gain from applying more than 60 kg N/ha to rainfed rice crops in most parts of Iloilo. The optimum response in most locations appears to be between 30 and 60 kg N/ha. The average yield from 36 no-fertilizer plots for 1983 first crop was 4.2 t/ha; that from 35 no-fertilizer plots for 1982 first crop was 3.4 t/ha. In Iloilo, it appears that well-managed fields can produce moderate to high yields even at low fertilizer levels. Dawog (dry zone plain) was an exception, producing less than 2 t/ha from the zero-fertilizer plots in 1982 and 1983.

Both first and second crops responded significantly to P at the intermediate zone plateau locations, confirming 1982 findings. The P response in the second crop indicated an absence of significant residual P from the first crop.

The single rice crop grown in the plain locations in the dry zone also significantly responded to P. A similar but nonsignificant response was observed in 1982.

The only significant K response was for the second crop at the plain and side slope locations in the wet zone. The response was significant with or without P at the plain position, but was only significant without P at the side slopes. The DSR crops in the dry zone did not respond to Zn.

South Cotabato. Superimposed fertilizer trials in South Cotabato consisted of three trials (two replications each) on farmers' fields in each of the stratified areas. Production plots were classified by location and availability of partial irrigation (Table 5).

In the 1983 first crop, there was a small but significant response to the range 30 to 90 kg N/ha when P and K were present, except at completely rainfed locations in Surallah, where N depressed yield. IR56 was infected with neck and leaf Bl, which became severe when N was applied.

In Norala, IR56 showed a small but significant positive response to both P and K with partial irrigation. P and K responses were not observed in the rainfed locations in Norala nor at any Surallah locations.

In the second crop (wet seeded), there was no significant response to N in the range 30 to 90 kg N/ha in the presence of P and K. There was some nonsignificant evidence of P and K deficiency at the partially irrigated locations in Norala.

Considering the regular high incidence of Bl in South Cotabato and the fertilizer responses observed, there is no advantage in applying more than 30 kg N/ha in either rainfed or partially irrigated fields. The average yield of the 12 no-fertilizer plots was 3.0 t/ha for the 1983 first crop and 3.7 t/ha for the second crop.

Timing of N application to dry seeded rice at different N rates and weed control levels. Dry seeding of rice is advocated in rainfed crop production programs in Iloilo and South Cotabato. Extension workers recommend N rates from 70 to 90 kg N/ha; however, little advice has been offered on the optimum timing of N application. Recommended methods for WSR and TPR in puddled soils may not be relevant to dry seeded conditions. Farmers often delay their first fertilizer application

Table 5. Effect of 7 fertilizer treatments on IR56 (first crop) and IR60 (second crop) yields in South Cotabato, Philippines, 1983.[a]

Location	Crop[b]	Yield (t/ha) at given NPK rates (kg/ha)						
		0-0-0	30-13-25	60-13-25	90-0-0	90-0-25	90-13-0	90-13-25
				Partially irrigated				
Norala	First (n=3)	4.01 c	4.21 bc	4.30 bc	–	4.51 b	4.46 b	4.81 a
	Second (n=3)	3.89 b	4.40 ab	4.13 ab	4.22 ab	4.50 ab	4.53 ab	4.84 a
Surallah	First (n=3)	3.22 c	3.83 bc	4.00 ab	–	4.11 ab	4.18 ab	4.42 a
	Second (n=3)	4.33 b	4.73 ab	5.03 ab	5.02 ab	5.10 a	5.03 ab	5.21 a
				Completely rainfed				
Norala	First (n=3)	2.50 bc	2.43 c	2.50 bc	–	2.78 abc	2.89 ab	3.01 a
	Second (n=3)	3.23 c	3.30 bc	3.36 bc	3.40 abc	3.43 abc	3.61 a	3.53 ab
Surallah	First (n=3)	2.42 a	2.19 ab	2.19 ab	–	2.00 b	2.03 b	2.20 ab
	Second (n=3)	3.49 b	4.30 a	4.01 ab	4.40 a	4.42 a	4.31 a	4.53 a

[a]Superimposed trial conducted in production plots. [b]Results for each crop in each location represent average of 3 on-farm trials, each with 2 replications.

to DSR until after the first hand weeding.

A trial was established on four farms in Iloilo and one in South Cotabato to compare a researchers' split with farmers' split at different N and weed control levels. Researchers' split was 1/3 N basal, 1/3 25 DAS, and 1/3 at 40 DAS. Researchers' weed control method was to apply butachlor at 2.0 kg ai/ha and to hand weed 25 DAS. Farmers' weed control was a single hand weeding at 35 DAS, except at Surallah where farmers commonly use a reduced rate of butachlor.

One trial in Iloilo was abandoned because flooding negated all treatment effects.

Levels of weed infestation were high at Cabatuan and Miagao, moderate at Surallah, and low at New Lucena (Table 6).

The following are initial and tentative interpretations:

1. Researchers' split appears to have a yield advantage over farmers' delayed split at researchers' weed control level or at low weed populations. However, the results are inconclusive.
2. Researchers' split has little advantage over farmers' delayed split at farmers' weed control level, except with low weed populations as at New Lucena.
3. Researchers' weed control method produces substantially higher yields than farmers' weed control method at high weed infestation levels as at Cabatuan and Miagao.

Further verification is necessary before widespread recommendation. There is a need for more research on methods to improve N fertilizer use efficiency for DSR.

Table 6. Timing of N application for DSR at sites in Iloilo and South Cotabato, Philippines, 1983.

N rate (kg/ha)	Timing[a]	Yield (t/ha)		
		Farmers'[b] weed control	Researchers'[c] weed control	Difference
		Cabatuan, Iloilo[a]		
0	–	4.5	5.0	0.5*
45	FS	4.9	6.0	1.1**
	RS	5.4	6.4	1.0**
		0.5	0.4	
90	FS	5.3	5.8	0.5*
	RS	5.4	6.7	1.3**
		0.1	0.9**	
		New Lucena, Iloilo		
0	–	3.5	4.5	1.0
45	FS	4.4	4.4	0
	RS	5.2	4.8	-0.4
		0.8**	0.4	
90	FS	4.3	4.5	0.2
	RS	5.8	6.0	0.2
		1.5**	1.5**	
		Miagao, Iloilo		
0	–	0.6	1.6	1.0**
45	FS	2.0	3.0	1.0**
	RS	1.7	3.2	1.5**
		-0.3	0.2	
90	FS	2.8	4.4	1.6**
	RS	2.1	4.4	2.3**
		-0.7	0	
		Surallah, South Cotabato		
0	–	2.6	3.1	0.5
45	FS	3.0	3.2	0.2
	RS	3.5	3.8	0.3
		0.5	0.6*	
90	FS	3.7	3.8	0.1
	RS	4.0	4.1	0.1
		0.3	0.3	

[a]FS = farmers' split, RS = researchers' split. [b]Farmers' weed control = HW at 35 DAS at the Iloilo sites and butachlor 1 kg ai/ha fb HW at 35 DAS at Surallah. [c]Researchers' weed control = butachlor 2 kg ai/ha 1-3 DAS at all sites.

Evaluation of IR58 in Iloilo. In May 1983, the Philippine Seed Board approved the release of IR9752-71-3-2 under the name of IR58. Because of its early maturity, IR58 was compared with the currently recommended IR36 for rainfed lowlands in Iloilo. Trials on farmers' fields covered a wide range of rainfall, landscape, and soil conditions with both varieties dry-seeded at the beginning of the 1983 WS.

In 29 locations, IR58 averaged 4.6 t/ha and IR36 5.9 t/ha (Table 7). Double cropping is possible in the north and central locations, and 13 of the 17 cooperating farmers preferred to grow IR58 as a second crop despite the yield advantage of IR36. Farmers preferred the earliness of IR58. Depending on location, IR58 matured 86 DE, or 13 d earlier than IR36 for the first crop and 11 d earlier for the second crop (Table 8).

In favorable rainfed areas (such as Iloilo), there is considerable potential for very early-maturing varieties to increase cropping intensity or stabilize existing cropping patterns.

Table 7. Yield comparison of rainfed DSR IR58 and IR36 by location and landscape position, Iloilo, Philippines, 1983 first crop.

Location, landscape position	Farmers (no.)	Yield (t/ha)		
		IR58	IR36	Difference
Ajuy				
Side slope	2	5.90	7.01	1.11 ns
Plain	3	5.09	7.02	1.93**
Cabatuan				
Plateau	6	6.21	7.84	1.63**
New Lucena				
Plain	6	3.89	5.44	1.55**
Miagao				
Plateau	6	3.98	5.22	1.24**
Plain	6	3.46	4.10	0.64 ns
Total, av	29	4.56	5.88	1.32**

Table 8. Maturity of 2 WSR varieties under rainfed conditions (second crop) at various locations. Iloilo, Philippines, 1983.

Rainfall zone	Landscape	Variety	Maturity[a] (DAS)	
Wet	Side slope	IR36	100	(n=6)
		IR58	90	(n=6)
	Plain	IR36	97	(n=5)
		IR58	88	(n=5)
Intermediate	Plateau	IR36	91	(n=6)
		IR58	86	(n=6)
	Plain	IR36	96	(n=6)
		IR58	87	(n=6)

[a]From seeding to harvest.

MULTILOCATION TESTING OF NITROGEN PLACEMENT MACHINES

Training and Technology Transfer, Agricultural Engineering, and Agricultural Economics Departments

DS and WS trials during 1983 evaluated in farmers' fields N deep placement machines developed by the Agricultural Engineering Department.

The first set of trials continued from 1982 WS reported in the Annual Report for 1982. Two machines were tested: the curved spring auger for PU placement and the Rockwood plunger for USG placement. These machines were compared with hand placement of USG, researchers' best split of PU, and farmers' split of PU at seven sites (Table 9).

At all sites, yields from plunger-placed USG did not differ significantly from those of hand-placed USG. This confirmed 1982 WS results showing that the plunger was as effective as hand placement.

In six of seven sites, the curved spring auger had yields equivalent to those of researchers' split. At Ajuy, however, the curved spring auger had a statistically lower yield than researchers' split.

Although researchers' split outyielded farmers' split in five of seven trials, the difference was significant only in Gugo, Naic, Cavite.

Table 9. Summary of results of placement machine trials at various sites in the Philippines, 1983 DS.[a]

Site	Yield (t/ha)				
	PU			USG	
	Farmers' split	Researchers' split	Curved spring auger	Hand	Plunger
Luzon					
Buguey, Cagayan	6.5 a	6.2 a	6.9 a	5.8 a	6.2 a
Gugo, Naic, Cavite	4.2 c	4.7 ab	4.4 bc	4.8 ab	5.1 a
Molino, Naic, Cavite	5.5 a	5.7 a	5.4 a	6.3 a	5.9 a
Visayas					
Mina, Iloilo	4.4 b	4.2 b	4.6 ab	4.9 a	5.0 a
Ajuy, Iloilo	3.4 ab	4.0 a	2.8 ,b	3.9 a	3.8 a
Mindanao					
Koronadal, South Cotabato	4.8 b	5.8 ab	6.9 a	6.8 a	7.0 a
Tantangan, South Cotabato	5.3 a	5.8 a	5.7 a	5.7 a	5.8 a

[a]Rates were approximately 58 kg N/ha.

Table 10. Effect of timing and placement of N fertilizer on yield at 8 Philippine sites, 1983 WS.

Site	Yield[a] (t/ha)							
	Zero N	PU				USG		
		Farmers' split[b]	Researchers' split[c]	Oscillating plunger[d]	Spring auger[d]	Hand[e]	Plunger[d]	Press wedge[d]
Iloilo								
Oton #1	3.3 c	4.3 b	5.0 ab	4.4 b	4.9 ab	5.2 a	4.6 ab	4.3 b
Oton #2	3.2 d	3.9 c	4.9 a	3.9 c	4.3 bc	4.3 bc	3.8 c	4.6 ab
South Cotabato								
Koronadal	4.3 b	5.6 ab	6.0 a	5.6 ab	5.7 a	6.0 a	5.8 a	6.2 a
New Lambunao	3.1 b	3.8 ab	4.0 ab	3.9 ab	4.3 a	4.6 a	4.1 ab	4.8 a
Leyte								
Palo	4.8 ab	5.2 a	4.9 ab	4.9 ab	5.4 a	4.4 b	4.7 ab	4.8 ab
Dagami	4.5 b	5.3 a	4.9 ab	5.0 a	4.9 ab	4.9 ab	5.1 a	5.2 a
Cagayan								
Amulung	3.1 b	3.7 ab	4.0 a	3.7 ab	3.2 ab	4.0 a	4.0 a	3.3 ab
Gattaran	2.9 b	3.4 ab	3.7 a	3.6 a	3.7 a	3.7 a	4.0 a	3.8 a

[a]Means of 3 replications. [b]One-half 15 DT and the other half 5-7 DBPI. [c]Two-thirds basal and one-third 5-7 DBPI. [d]Double row type, fertilizer applied 5-7 DT. [e]Placed 10-12 cm deep by hand at 5-7 DT.

WS trials in 1983 tested two additional placement machines at eight sites: the press wedge for USG placement and the oscillating plunger for PU placement (Table 10). A zero-N plot was added for site characterization.

Placement of USG by the Rockwood plunger or the press wedge was as affective as hand placement, except for one site where yields were significantly higher for hand placement than for the press wedge.

At all but one site, yields with the oscillating plunger and spring auger were statistically equivalent to researchers' split.

Researchers' split averaged 0.3 t/ha higher than farmers' split across the 8 sites, but the difference was significant in only one.

In addition to the field trials, other farmer evaluations were undertaken during 1983 WS in Cagayan, Leyte, Iloilo, and South Cotabato. Farmers volunteered to test and evaluate machines on 500-m^2 plots with about half of them testing the spring auger and oscillating plunger for PU placement, and the other half, the press wedge and the deep plunger for USG placement.

Farmers said the spring auger was easier to operate than the oscillating plunger. The auger's main weakness was in metering accuracy. A more recent prototype has been tested and appears to have overcome this problem.

The press wedge was regarded as clearly superior to the deep plunger, which farmers thought was very tiring and time-consuming.

Suggested improvements have resulted in improved prototypes of the spring auger, oscillating plunger, and press wedge. These are currently under evaluation.

Placement machines are now reaching a stage of high operational efficiency; however, Training and Technology Transfer Department research in the Philippines does not show that deep placement is consistently more advantageous than researchers' best split.

Cropping systems program

Asian Rice Farming Systems Network

Rice Farming Systems Program

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In 1975, IRRI and national programs formed the Asian Cropping Systems Network which enabled them to jointly develop rice-based cropping systems for major rice environments in Asia. As some national programs expanded to include farming systems, the network unanimously agreed in April 1983 to change its name to Asian Rice Farming Systems Network (ARFSN). The network plans to generate technology by identifying more productive rice farming systems that are acceptable to small-scale farmers.

NATIONAL CROPPING AND FARMING SYSTEMS PROGRAMS

One of the network's major thrusts is to help national programs organize a coordinated cropping and farming systems program. The cropping systems research methodology for rice and upland crops was developed by IRRI and further refined in the network. It is being used by all participating countries. National programs in the Philippines, Indonesia, and Thailand have expanded their cropping systems program into farming systems which include livestock, fisheries, and forestry. The Philippines, Indonesia, Thailand, Sri Lanka, China, South Korea, Nepal, Malaysia, and Burma have organized nationally coordinated cropping and farming systems programs using the organizational structure promoted by the network.

Vietnam, Pakistan, and Bhutan plan to join the network. Pakistan is involved in rice - wheat cropping systems collaborative research and the Pakistan Agricultural Research Council plans to begin a 5-yr program on farming systems research. Presently IRRI is collaborating with Vietnamese scientists on varietal testing of upland crops before and after rice. Four scientists have trained on cropping systems. Bhutan is collaborating on the rice - wheat integrated trials and one of their scientists attended the 1983 cropping systems training. Malaysia joined the network after a 3-yr absence.

PREPRODUCTION PHASE

After more than 3 yr of site research, national programs implemented the preproduction phase of the cropping systems research methodology. In the Philippines, research site and multilocation tests in Iloilo resulted in a provincial cropping systems program covering about 17,000 ha of rainfed rice in 1982-83. At the same time, pilot production programs began in South Cotabato (1,720 ha), Pangasinan (870 ha), and North Cotabato (454 ha). Multilocation tests were conducted in three target areas in Agusan (Bukidnon) and Capiz.

Research teams in Indonesia identified a technology for two-rice-based crop systems which replaced the single-crop system in Barambai, South Kalimantan; Bantoa, South Sulawesi; and Blega, Madura. Production programs for hundreds of hectares are now operating in sites with similar environments.

Pilot production programs in Nepal have begun in or near the sites in Pumdi Bhumdi, Lele, Chauri, Jahari, Khandohari, Parsa, and Chitwan. A total of 6,425 ha wheat, 1,274 ha rice, 35 ha maize, and 12 ha daincha were in the program in 1982-83. The Bangladesh Rice Research Institute started multilocation testing in 1982 using data from the Bhogra rainfed lowland site. Yield levels of the rice (MV) - rice (MV) pattern were very encouraging in Sylhet (483-568% better than farmers' pattern), Feni (49-107% better), and Jamalpur (66-81% better).

VARIETAL TESTING

Varietal testing is conducted in collaboration with the Philippines Institute of Plant Breeding (IPB) and national programs. The IPB project on varietal improvement of upland crops for intensive cropping (mungbean, soybean, and peanut) develops and identifies varieties that fit the rice-based system. Promising materials are sent to IRRI for multiplication and testing in the network.

IRRI also collaborates with CIMMYT on maize and with ICRISAT on sorghum. Promising varieties from the CIMMYT program in Thailand are sent to IRRI for testing in the network. IRRI started to screen sorghum varieties after rice using 117 entries from ICRISAT and IPB.

In March 1983, IRRI and IITA began collaborative work to identify cowpea and soybean varieties for rice-based farming systems. One IITA senior staff member has been assigned to work at IRRI. Cowpea varieties and elite breeding lines

from the IITA breeding program are evaluated for early maturity, fresh and grain yield and tolerance to excessive moisture, drought, insects, and diseases.

IRRI multiplied seeds of 6 soybean varieties from IPB, 7 mungbean from IPB, 8 maize from CIMMYT and IPB, 4 sorghum from IPB, 10 cowpea from IITA, and 1 peanut from Burma for inclusion in the 1984-85 testing.

Promising varieties of mungbean, soybean, cowpea, peanut, maize, sorghum, and bush sitao were distributed in the network for testing in experiment stations or cropping and farming systems sites. Trials were not uniform. In 1982-83, seeds for 50 trials before rice (16 mungbean, 8 cowpea, 4 bush sitao, 7 soybean, 8 peanut, 2 sorghum, and 5 maize) and for 159 trials after rice (27 mungbean, 18 cowpea, 17 bush sitao, 25 soybean, 20 peanut, 20 sorghum, and 32 maize) were distributed. The most promising varieties, better than the local check or the highest yielding varieties for each country, are presented in Tables 1 and 2.

For crop year 1983-84, seeds for 107 trials before rice (23 mungbean, 20 cowpea, 13 bush sitao, 13 soybean, 13 peanut, 7 sorghum, and 18 maize) and 171 trials after rice (24 mungbean, 28 cowpea, 17 bush sitao, 33 soybean, 22 peanut, 27 maize, 20 sorghum) were distributed.

FARM IMPLEMENTS FOR INTENSIVE RICE-BASED CROPPING SYSTEMS

The Asian cropping systems working group collaborated on a simple seeding experiment. The study evaluated the effect of the rolling injection planter (RIP) (designed by IITA and modified by IRRI) on the establishment and performance of upland crops grown after rice in zero and optimum tillage conditions.

IRRI distributed 17 planters to 7 countries: Indonesia (9), Pakistan (1), Thailand (2), Bangladesh (2), Korea (1), Nepal (1), and Sri Lanka (1). In Korea, the RIP does not fit the cropping systems practices and the Korean seeder works better. In Burma, initial tests using soybean, sunflower, maize, and sorghum were successful in establishing upland crops after rice in a field recently harvested with a 1-m reaper. RIP worked well with wheat in Nepal. In Indonesia, it was as good as traditional planting in direct seeded rice, maize, and soybean, with about five times the labor efficiency. At the Bangladesh Rice Research Institute, the RIP has problems establishing plants because of heavy clay soil.

RICE - WHEAT COLLABORATIVE RESEARCH

National programs involved in ARFSN, CIMMYT, and IRRI cooperated to develop tech-

Table 1. Crop varieties better than the check or highest yielding across locations when planted before rice during crop year 1982-83.

Test site	Mungbean	Soybean	Peanut	Cowpea		Bush sitao	Sorghum	Maize
				Fresh	Grain			
Burma	CES N-GY	30290-11-11	CES101 F334-33 M-10	–	CP2-3-1 Vita 4	Los Baños	IS8965	Early DMR Comp. 2
Nepal	None	–	None	–	–	–	–	–
Thailand	EGMG 174-3 M350 CES55 Pag-asa 1	–	Acc. 12	All Season	–	–	–	–
Indonesia	CES3N-1 MB4	B3034 B3035	CES2-25				CS268 CS110	Phil. DMR Comp. #2 IPB Var 1
Vietnam	None	7207-1 Clark 63	– F334-33				CS226 CS182	Early DMR Comp.1 KUC #2 Arun 2
Philippines	IPB M79-13-60 IPB M79-13-70 IPB M79-17-79	UPL SY-2	–	TVx 4262-014D TVx 3236-01G	–	–	–	Glut. Syn. #41 Los Baños Lagkitan

Table 2. Crop varieties better than the check or highest yielding across locations when planted after rice during crop year 1982-83.

Test site	Mungbean	Soybean	Peanut	Cowpea		Bush sitao	Sorghum	Maize
				Fresh	Grain			
Nepal	–	–	–	–	All Season		–	–
Thailand	CES 3N-1 MG50-10A (Y)	–	F334-33 CES101 PI 118200 Acc. 12 Kidang CES102	TVx 1850-01E TVx 289-4G	TVx 7-5H TVx 2949-01D TVx 1850-01E	–	CS110	KUC #2 F_1
Sri Lanka	Pagasa 1 CES 3N-1 CES IT-2	–	–	–	TVx 1836-19E	BS1 (6-14R X AS) BS3 (6-14R X AS)	–	–
Indonesia	–	–	None	–	TVx 289-4G	BS1 (6-14R X AS)	–	Thai Comp. 1 Early DMR (S)C_4
Malaysia	–	–	M 10	–		–	–	–
Vietnam	CES 2F-1	None	–	–		–	IS2940 CS182	–
Bangladesh	–	–	CES2-25 UPL Pn-2 PI 118200 M10	–	TVx 7-5H	–		–

nology for rice - wheat systems for different rice environments. The first two projects were cropping pattern testing and integrated rice - wheat trials.

Cropping pattern testing. Collaboration on rice - wheat cropping pattern testing continues in Nepal. Bangladesh, Sri Lanka, and Korea. The cropping system sites in Nepal are in Ratna Nagar, Pumdi Bhumdi, Chauris, Lele, and Saichaina. In Ratna Nagar, improved rice - wheat -upland crops cropping patterns produced higher yields and income than the farmers' rice - wheat cropping pattern. Better management and new varieties further increased yield of the improved pattern by 50 to 116% and net income by 49 to 108% over farmers' practice. In Chauri Jahari, the rice - wheat pattern with improved management yielded 42% higher than the farmers' practice and net income was 29% better. With improved management, the rice - wheat - maize pattern at Pumdi Bhumdi produced 105% more income than the existing farmer management. In Saichaina, a rainfed lowland site, the cropping system is usually one rice crop. With the introduction of an early-maturing rice variety, farmers can also grow a wheat crop.

In a deepwater rice (DWR) site at Daudkandi, Bangladesh, the traditional pattern is rice - wheat and rice - potato. Experiments investigated three crop systems such as DWR - wheat - sesame, DWR - potato - sesame, DWR - mustard - mungbean, and DWR - mustard - sesame. Most promising were DWR - potato - sesame and DWR - mustard - mungbean. At an irrigated site in Salna, the team studied rice - rice, rice - rice - rice, and rice - rice - wheat cropping patterns. Although the difference is small, the net income of rice - rice - wheat is better than that for two or three crops of rice.

At Milyang and Iri in southern Korea, income from rice - wheat was a little higher than that for one rice crop although rice production was high.

In Bandarawela, Sri Lanka, the wheat variety Trigo 1 from the Philippines was introduced 3 yr ago for the highland wet zone. The cropping systems team identified an earlier-maturing rice variety with high yield, and is now able to stabilize a 3-crop system. The February first crop is rice; June second crops are potato, beans, cabbage, carrot, garlic, or tomato; and November third crops are wheat, soybean, carrot, or radish.

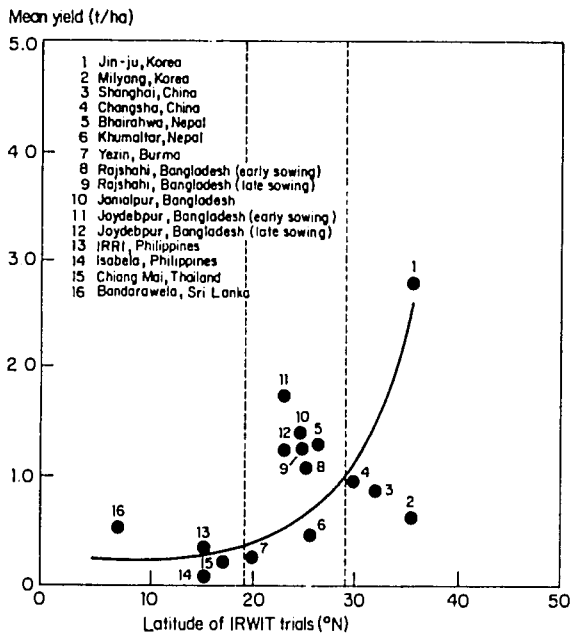
International Rice - Wheat Integrated Trials. To identify better varieties of rice and wheat which have multiple resistance to pests and diseases and will fit the rice - wheat system (rice - wheat, rice - rice - wheat, rice - wheat - upland crop, and rice - upland crop - wheat), 14 countries participated in

the International Rice - Wheat Integrated Trials (IRWIT).

CIMMYT provided 14 wheat varieties from their breeding program for 33 trials in 1982-83. The cooperators included a local check (the most popular recommended variety).

Results of 16 trials of the IRWIT project in 8 Asian countries showed that new, highly productive wheat varieties adaptive to rice - wheat cropping patterns are most needed. Yields ranged from 210 kg/ha in the Philippines to 5,400 kg/ha in Korea with a mean yield of 2 t/ha. An analysis of the 14 CIMMYT varieties revealed that yields were highly related to the latitude at which the trial was grown (Fig. 1). Trials grown within the 28°-35° latitude (Korea and China) had higher yields followed by sites within the 19°-27° latitude (Nepal and Bangladesh) and sites lower than 18° latitude (Burma, Thailand, Philippines, Sri Lanka). Lowest mean yields for each group of sites were 2.35, 1.47 and 0.47 t/ha. The higher yields obtained in Korea and China are expected since wheat is a temperate crop. Yield and number of days to maturity of the highest yielding variety and corresponding local checks are presented in Table 3.

In April 1983, the first rice trial began with one set of eight early-maturing varieties and another set



1. Relationship between country mean yields and latitudes at which the first (1982-83) IRWIT trials were grown.

Table 3. Yield and duration of the highest yielding wheat variety and local checks in 8 Asian countries, 1982-83.

Country	Variety[a]	Yield (t/ha)	Duration (d)
Korea	Genaro 81	6.6	232
	(Olmil)	5.8	239
China	Ures 81	3.3	184
	(Yang Mai No. 1)	2.0	187
Nepal	Abasolo 81	3.3	110
	(Lombini)	2.9	110
Bangladesh	BAW28	4.9	107
	(Balaka)	4.3	107
Burma	Abasolo 81	1.1	78
	(Monywa White)	0.5	90
Thailand	Ciano 79	0.9	105
	(Inia 66)	0.4	105
Philippines	Glennson 81	1.3	87
	(Trigo 1)	1.6	86
Sri Lanka	Celaya 81	1.3	95
	(Trigo 1)	1.1	115

[a]Local check varieties are in parentheses.

of eight early- and medium-maturing varieties from the IRTP international yield nurseries. Each cooperator included two local checks. Nine early-maturing sets were distributed to China, Egypt, Bangladesh, Nepal, Korea, Bhutan, and Pakistan, and 26 early- to medium-maturing sets to Malaysia, Bangladesh, Thailand, Philippines, Burma, Nepal, Indonesia, and Sri Lanka.

For the wheat trial in 1983-84, CIMMYT provided five varieties and national programs added five. For most tropical countries, the Philippines Institute of Plant Breeding added four to five varieties besides the five from CIMMYT. Of 42 trials, 22 investigated optimum planting time (about 15 Nov) and 20, late planting (about 15 Dec).

COLLABORATIVE RESEARCH ON LONG-TERM CROPPING PATTERN AND FERTILIZER STUDIES

In 1981, network scientists began to be concerned that more intensive crop production could result in rapid loss of soil fertility and productivity. Long-term cropping pattern and fertilizer studies were then initiated to determine the effects on the soil and crop performance of continuous cropping using different crop rotations and to determine residual effects of fertilization and other soil amendments on cropping pattern performance. Korea, Nepal, Indonesia, Burma, Thailand, and

China agreed to conduct studies on lowland irrigated rice; Indonesia and Nepal, on upland rice; and Bangladesh, Burma, and Indonesia, on rainfed lowland rice. At the 1982 rice conference and in the 13th working group meeting, collaborators were encouraged to conduct studies based on their environmental conditions. Long-term cropping pattern studies were initiated in 12 irrigated locations, 4 rainfed, and 1 upland. In cooperation with INSFFER, 18 long-term fertilizer studies were planned in 5 rainfed, 10 irrigated, and 12 upland rice locations.

SHARING OF RESEARCH INFORMATION

The network facilitates exchange of research information among scientists involved in cropping systems. In 1983, it organized the following activities:

1. Cropping Systems Working Group meeting, 25-29 Oct 1983, China
2. International Rice Research Conference, 18-22 Apr 1983, IRRI (Cropping Systems Network)
3. Crop Livestock Research Workshop, 25-28 Apr 1983, IRRI
4. Upland Crops Varietal Improvement Monitoring Tour, 14-21 Feb 1983
5. Multilocation Testing and Pilot Production Monitoring Tour, 13-24 Nov 1983.

The working group meeting in China and the multilocation testing and pilot production programs were funded by IDRC. The monitoring tour had 23 participants in Bangladesh and 27 in Sri Lanka. The group visited sites and reviewed progress of the pilot production and multilocation testing in Indonesia, Thailand, Nepal, and the Philippines.

Through national coordinators, IRRI and network publications on cropping and farming systems or related topics were distributed to scientists.

Machinery development and testing

Agricultural Engineering Department

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AXIAL-FLOW PUMP

A dimensional analysis determined the relationships of design parameters which affect the performance of the IRRI axial-flow pump. Results showed that it is possible to establish experimentally the relationship of dimensionless or Pi terms which express the capacity Q as a function of other design parameters (shape of inlet approach, impeller vane angle or pitch, clearance between the impeller and the stator casing, diffuser vane angle, and impeller diameter). A pump test determined the optimum flow condition of the pump by varying one Pi term at a time to establish the relationship between it and Q. All other variables were held constant.

Preliminary results showed that the diffuser vane angle affected Q. Other parameters (inlet guide vanes, pitch, and clearance between the impeller and stator casing) affected both Q and the brake horsepower (bhp) requirement of the pump. A change in the diffuser vane angle from 50° to 60° did not significantly affect pump performance. But a tremendous loss in Q and a drop in efficiency resulted from a straight or 90° vane angle although change in the bhp requirement was minimal. Pumps with inlet guide vanes yielded a higher Q and required less power at peak efficiency. At the same head at peak efficiency, Q increased at a greater rate as pitch increased from 15° to 25°, but the rate decreased at pitch greater than 25°. The bhp requirement increased as pitch increased. The maximum increase in efficiency was observed at 25° pitch. At ideal conditions, the clearance between the impeller and stator casing should have an inverse effect on efficiency. Preliminary results showed the optimum clearance to be 4 mm. A smaller clearance was less efficient because the impeller blade rubbed the stator casing when the long impeller shaft vibrated because of the rubber bushing supports at the middle portion and the hub of the diffuser vanes. Q decreased more than power when the clearance increased beyond 4 mm, resulting in less efficiency. At 10 mm clearance, loss in efficiency was significant.

Engineers compared the performance of the two-stage and the single-stage axial-flow pumps. After testing a two-stage unit, they determined the effects of the inlet guide vanes and the distance between stages.

At best efficiency point, the capacity of both pumps is 5,400 litres/min at 1,800 rpm. At the same capacity, the head increased from 2.05 m to 4.75 m or 132% while the bhp requirement increased from 4.22 kw to 8.70 kw or 106%. The greater percentage increase in Q than in bhp resulted from a slightly higher peak efficiency of the two-stage pump. The same observations were made at 1,500 rpm.

Research on the pump is continuing to determine the effect of shape of the inlet approach and the impeller size.

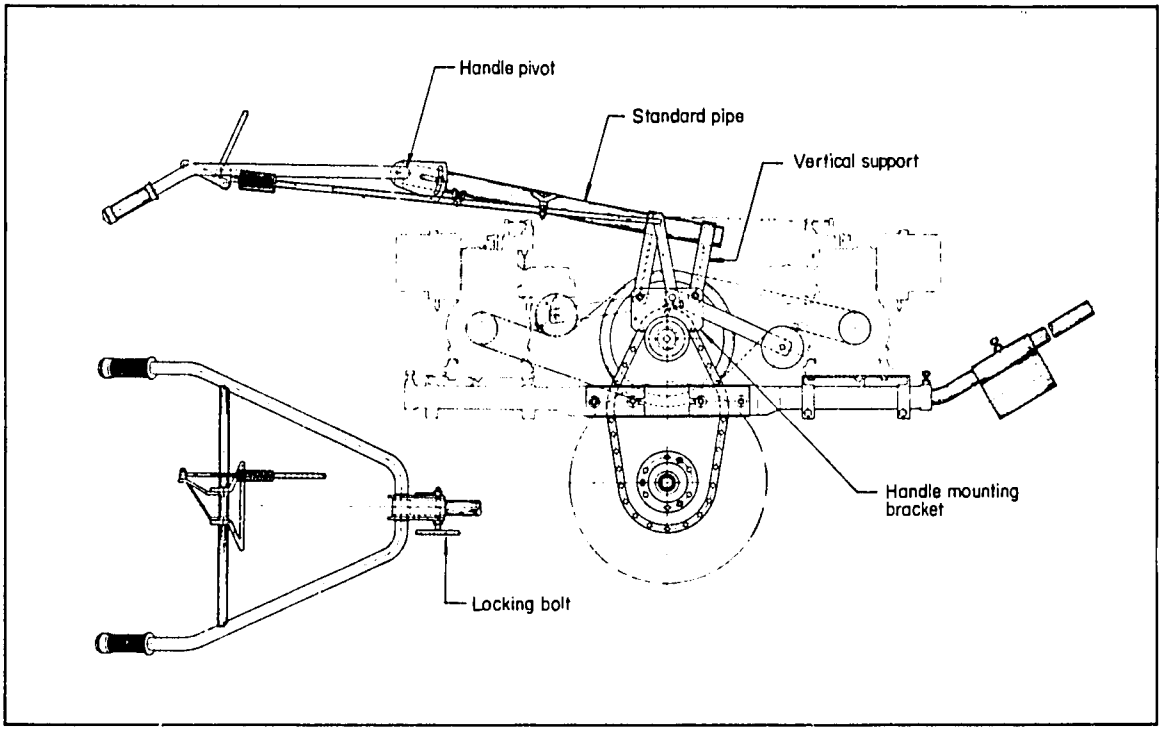
PT5 POWER TILLER

Since the 3- to 5-hp tiller was released to manufacturers in 1982, few design changes have been made and no serious complaints have been received from farmers or manufacturers. The design is simple, has few moving parts, and requires little maintenance.

The handlebar has been modified to make it more rigid. The new design helps counteract the added weight of the reaper header when the unit is used for harvesting. The pivot point, which provides adjustment for the handle height, was moved farther away from the mounting bracket. This reduced the bending movement acting on the pivot, which frequently loosened the friction joint in the previous design. The friction joint was replaced with a notched slot to lock the handle at different height positions. To adjust the height, the locking bolt is loosened by hand until the handle can be raised or lowered to the desired height. The mounting bracket, welded on top of the transmission casing, was changed to a pair of larger, thicker plates. A pair of vertical supports were bolted on two points of the mounting bracket where the handlebar was welded. The height difference of these vertical supports provides the necessary angle for the handlebar to clear the engine when it is mounted at the rear for a reaper header to be attached for harvesting. The design continues to use pipes for handlebars and the handle since pipes are cheaper and simple to work with. Figure 1 shows the improved handlebar of the PT5 power tiller.

THE 6-ROW TRANSPLANTER

Farmer feedback and field results on the 5-row manual transplanter guided development of the

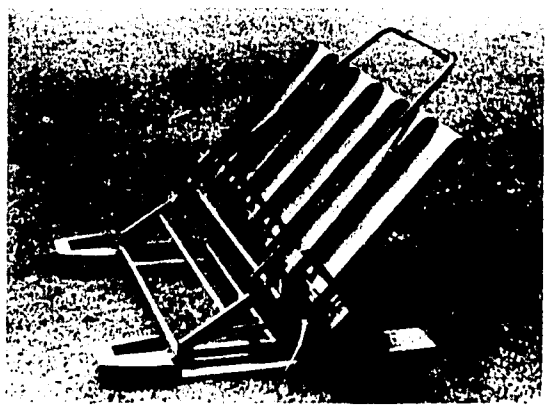


1. Modified handle for PT5. IRRI, 1983.

6-row manual rice seedling transplanter. The new design focused on increased field capacity, better operator comfort, and ease of manufacturing.

The 6-row transplanter increased field capacity for seedling transplanting and reduced the number of floating hills since transplanted seedlings will not fall at the operator's feet (Fig. 2). The seedling tray length was increased by 25%, which correspondingly reduced frequency of loading. A turnbuckle was used to adjust the position of the roller chain links at the end of the tray travel, which reduced the number of repetitive strokes at both ends. Two long, narrow wooden skids were used instead of the single wide skid of the 5-row design. This substantially reduced the weight of the machine and lessened the drag. Rubber grips were placed on the handle for operator comfort.

To make it easier to get parts and build the machine, specially in the rural areas, a bicycle free wheel was used for indexing the tray mechanism. The tray drive can be started with a seedling pusher link. A straight seedling tray replaced the 5-row curved tray. The rear support used the transplanter rear frame to guide its lateral movement. The transplanter drive mechanism was bolted as one unit to the skid, unlike the 5-row model which has some sub-assemblies independently bolted to the skid. A new pivot arm and picker assembly replaced the tension springs in the cam and the picker holder since the old tension springs easily lost resilience after 2 wk of operation. The new 6-row transplanter uses a different free wheel



2. The 6-row transplanter. IRRI, 1983.

sprocket to vary the tray displacement at different seedling densities. To make it easier for farmers to adopt the new transplanter, the farmer's wet-bed method of seedling preparation was modified (Fig. 3). Instead of using wooden frames as in the old IRRI method, an ordinary, sharp-edged bolo is used to cut seedling mats.

Table 1 summarizes comparative data on the 5- and 6-row transplanters. The new 6-row transplanter was introduced in Libmanan, Camarines Sur, and performed satisfactorily even on heavy and sticky clay soil. The new design was also demonstrated in other parts of Luzon and Mindanao.

Table 1. Comparison of the IRRI 5- and 6-row transplanters. 1983.

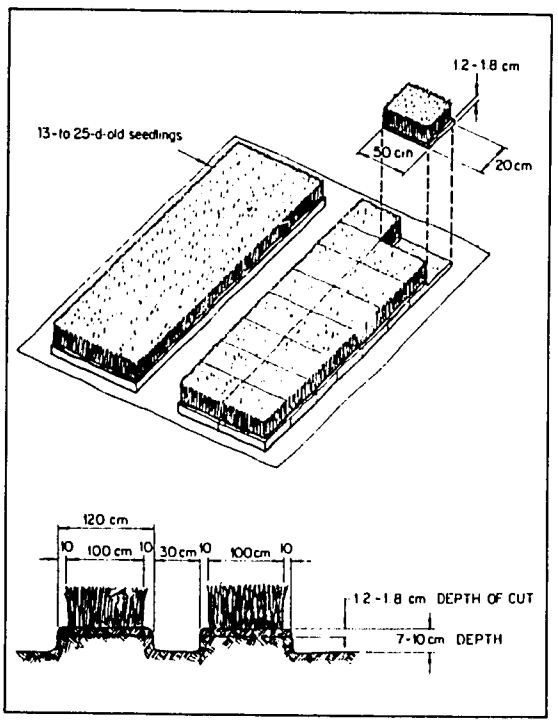
	5-row	6-row
Weight	25 kg	19 kg
Field capacity[a]	0.2 ha/d	0.37 ha/d
Mobility	Can be carried by 2 people	Can be carried by 1 person
Average pulling force	12 kg	10 kg
Maintenance	More wearing parts	Less wearing parts
Manufacture	Hard	Easier
Tray displacement per stroke	Fixed	Variable

[a]Data obtained from the records of the Philippine Packing Corporation Rice Garden Project in Musuan, Bukidnon, Philippines.

MACHINES FOR UPLAND CROPS

Planting shoe. The planting shoe is a sandal-type foot gear designed to plant seeds of maize, sorghum, mungbean, and other upland crops on untilled soil while a person is walking. The planting shoe could also be used to plant seeds in a national reforestation project.

The device has a wooden sole, shaped to fit an average adult foot, with a seed hopper attached at the back. A pair of sharp, pointed steel blades serve as the heel and are located directly beneath the hopper (Fig. 4). One of the blades is fixed while the other is hinged and welded to an opener lever, which extends down toward the toe. When the operator's foot is lowered into the soil, the lever is pushed up toward the sole. The hinged blade then moves away from the fixed blade, and a spring



3. Modified wet-bed seedling preparation. IRRI, 1983.

4. A prototype planting shoe. IRRI, 1983.

loaded toggle link, attached to the lever, moves a seed metering plate at the base of the hopper.

To operate the planting shoe, the user simply walks by pressing his heel first so that the digging blades penetrate the soil. As the foot moves down, the opener lever is pushed against the ground which causes the hinged blade to open a hole in the soil. The lever simultaneously moves the metering plate which discharges seeds into the hole. The user can cover the planted seed with a stick while planting the next row.

The first prototype performed well during initial tests with maize seed on uncultivated soil. However, the test was short and no attempt was made to cover the planted seed. An identical unit was made so that a planting shoe can be worn on each foot.

Metal lithao with seeder. The lithao is an animal-drawn native implement, similar to the animal-drawn comb harrow, commonly used by upland farmers in Batangas and Laguna. The lithao has wide wooden pegs, spread apart, and tapering to sharp points. It is used to open furrows on dry cultivated soil for broadcast planting.

A metal lithao was designed and built (Fig. 5). An individual seeding mechanism was added so that seeding can be done simultaneously (6 rows at 20 cm apart) when each furrow is opened. Each metering unit has a seed hopper and a grooved roller which rotates and discharges seed into a tube directly below the hopper. The metering rollers are mounted on a common shaft driven by a ground wheel controlled by a bicycle chain. The ground wheel (in front of the furrowers) doubles as a gauge wheel to regulate plant depth. The rigid steel pipe seed tubes guide the metered seeds into the furrows and form part of the frame that securely holds the furrower points.

5. A metal lithao with seeder. IRRI, 1983.

When the lithao was tested in the field, the metered seeds were placed at the bottom of the furrows and immediately covered by the displaced soil as it fell back into the furrows. The present design is lighter than the wooden lithao. Only one operator is needed compared to two for the native implement. More field tests are planned with the metal lithao to determine its effectiveness in establishing the crop and uniformity and density of the seeding.

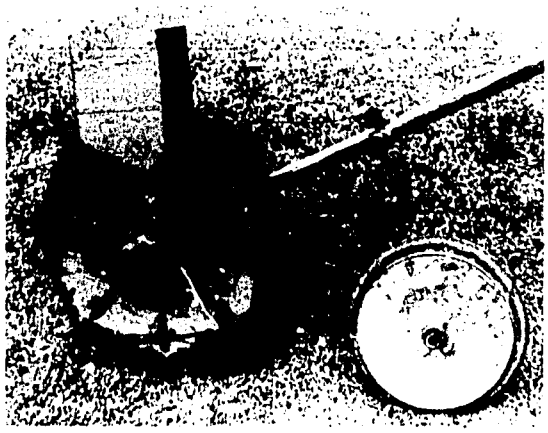
Modified rolling injection planter. Farmer acceptance of the rolling injection planter (RIP) was still hampered by a number of design drawbacks. The machine could not be used when the soil was sticky or wet since mud clogged the digging blades. Planting closer between hills is not possible unless the wheel diameter is considerably reduced. But a small-diameter wheel was difficult to push when tested on the IITA unit brought to IRRI for evaluation. The RIP was heavy. Since the weight was concentrated at the periphery of the wheel, the center of gravity was high; more effort was needed to keep it in correct operating position.

A machine that works quite differently from the existing RIP was developed. The new concept has a wheel with fixed digging blades that can be spaced closer. Seeds discharged by the metering system fall on the receiving pockets located at the periphery of the wheel. Each pocket has a spring-loaded shutter, opened by a trigger, enabling seeds to fall into the trench made by the rotating digging blade. Since there were only fixed blades, a stationary scraper was easily attached to wipe off dirt sticking to the blades.

A prototype was tested using the metering unit, presswheel, and handle of the existing RIP (Fig. 6). Results from initial tests were encouraging. The prototype is substantially lighter and more stable to operate than the existing RIP. More field tests are planned to evaluate its overall performance.

THE MODIFIED I-M REAPER

After testing the 1-m reaper in Bukidnon for about 1,000 h, equivalent to 4 yr of use, the unit was modified.



6. The modified rolling injection planter. IRRI, 1983.

Most changes concerned material specifications to improve durability of some parts. The upper and lower hitch brackets of the main frame were made from boxed angle iron to withstand vibration and impact of the header assembly during reaping and transportation. The gathering header was modified by the addition of a diagonal brace welded from the header point to the curved pipe and starwheel mounting bracket. Thicker sheet metal was used for the gathering header shield, the gather cover, and the front of the header. The starwheels, made from PVC materials, had their inner radii reduced. To eliminate the interlocking of the knife and the ledger plate, a knife guide was added to the guard assembly, mounted on the right part of the header. The knife bar was made from carbon steel. Knives and the knife bar brackets were secured to the knife assembly with flat head rivets instead of socket button head high-tension bolts.

The main drive shaft was also modified by reducing its diameter from 22 to 19 mm on both ends. More spacers were added to the shaft and crankplate hub during mounting. Self-aligning ball bearings were used in the pitman link rod assembly, increasing the bearings' service life. The chain-tightening pulley was redesigned for positive chain drive. Thicker material was used on the implement hitch frame bracket for reaper mounting to the power tiller. The modified reaper is now 25% heavier because of changes in material specifications.

The modified unit was mounted on one of the commercial power tiller prototypes made by co-operating manufacturers. IRRI tests showed good results. Applied research and durability tests in Central Luzon showed that, except for occasional clogging of the header point by heavy dry-leaf accumulation, the reaper performed satisfactorily. After the machine had worked for 53 h, its field capacity increased by about 0.32 ha/h. The modified reaper was also field tested in Bicol.

Testing will continue in farmers' fields. Some material specifications were already finalized and redesigned parts were incorporated in the production drawings of the reaper.

IMPROVED TH6 PORTABLE AXIAL-FLOW THRESHER

After a series of tests, the IRRI-designed TH6 portable axial-flow thresher was modified by adding a two-sectional threshing concave. The first half, near the feed side, was made of rasp bars. They were positioned to have a varying clearance between the threshing cylinder pegteeth and the rasp bars. The second half was made of round bar grill similar to that in the existing TH6 design.

Tests of the improved concave design showed a higher threshing efficiency and less broken straw. After testing, the clearance between the pegs and plate of the straw paddle was reduced to increase straw throwing capacity. A gusset was added to the straw paddle which was placed at an angle along the direction of the threshing cylinder rotation. The height of the last louver was increased to eliminate frequent straw clogging at the discharge outlet.

The 2 redesigned centrifugal blowers were moved upward by 5 cm. The inner side plates of the two blower spouts were curved inward to improve the uniformity of air distribution at the discharge spout. The grain chute at the feed side was inclined 34°, starting from the concave and extending to the upper tip of the blower discharge spout.

Performance and durability tests at IRRI and in Bicol showed that the improved TH6 had a higher capacity. The two centrifugal blowers performed efficiently, resulting in higher grain purity and less broken straw and leaves.

To reduce weight and improve portability, a second prototype thresher of the improved TH6 was developed. It can be easily taken apart and assembled into two major parts, each one light enough for two people to carry to the threshing area. One major section of the unit includes the

threshing cylinder, concave, cover, and feeding tray. This section can be easily connected to the second group of parts during threshing. The second section consists of the lower frame, two centrifugal blowers, and the engine with its base mounting frame. The second and lower assembly, with the blowers and set of pulleys for the drive system, can be used for separate grain cleaning.

Durability tests of the second prototype will be conducted at the Maligaya Research Station in Muñoz, Nueva Ecija.

HEATED FLOOR DRYER

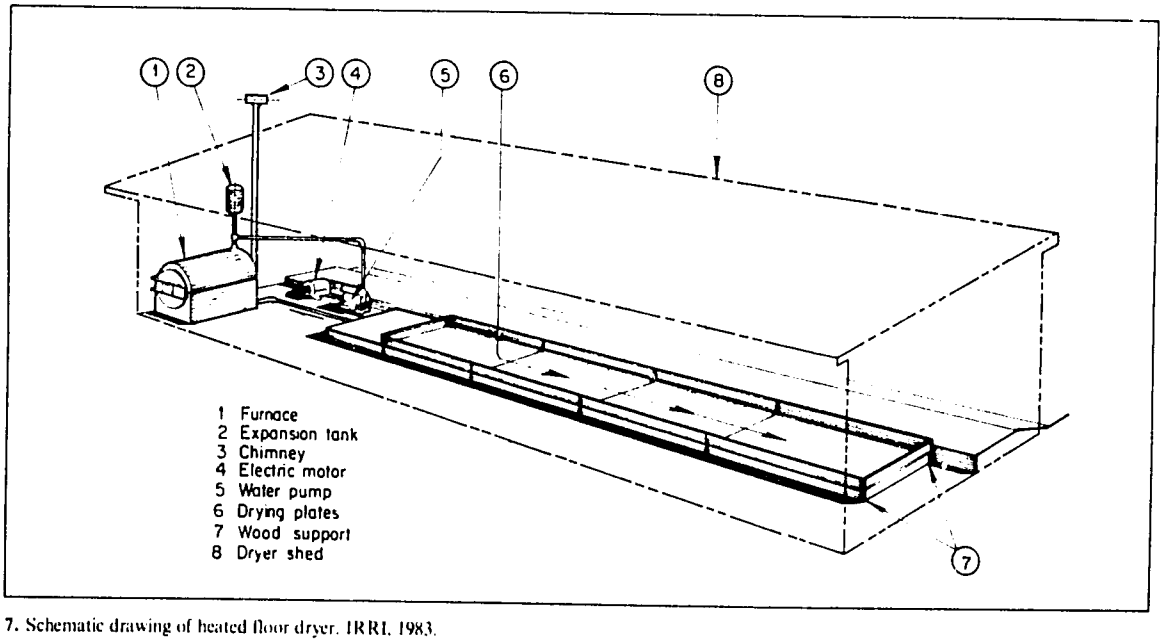
The heated floor dryer (HFD), a relatively inexpensive and simple technology for complementing sun-drying (SD), was developed, built, and tested. The HFD was built under a shed and installed adjacent to the existing SD floor. During cloudy and rainy periods, rice could easily be moved from the SD floor to the HFD.

The main function of the HFD is to predry the paddy by reducing the MC of newly harvested grains to about 18% (wet bulb). At this MC, grain can be safely stored for several days until fair weather allows SD to the desired MC.

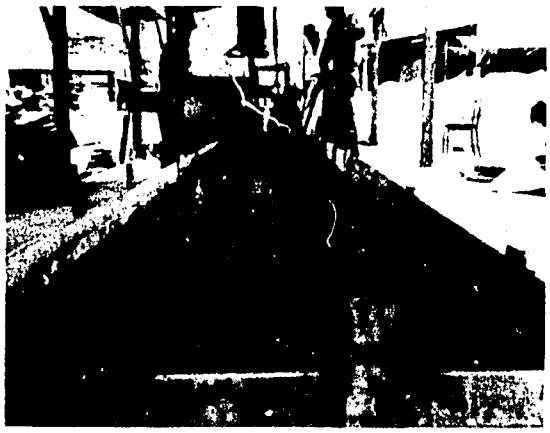
The basic components of the HFD are shown in Figure 7. The furnace, a Passat HO-45, uses fuels such as rice straw, rice hulls, corncobs, and firewood, which are fed manually through an access door. Heat from the steel wall of the cylindrical combustion chamber is transferred by conduction to a water jacket. Water temperature in the jacket is controlled by a simple thermomechanical draft regulator. A water pump, driven by a 1/2 hp motor, circulates hot water from the jacket to the heated dryer plates which serve as the floor The plates were made from 16 gauge, 1220 × 2240 mm iron and welded in a sandwich-like structure separated by 6-mm flat bars to provide a gap for the flow of 90° C water.

About 40 mm of paddy was placed on the heated floor and mixed or raked as in the traditional SD method (Fig. 8). Results showed that

- drying time increased in direct proportion to the thickness of the paddy layer for the range tested (20 to 60 mm);
- drying time was reduced by increasing frequency of mixing or raking;
- the drying process appears to be satisfactory in 66 to 99% RH;
- grain breakage was less than that in the traditional SD method;
- although the dryer was maintained at 90° C, no parboiling effect was observed; and
- the HFD was also suitable for drying wet paddy from the initial MC to 14% (wet bulb), in a single run even without SD.



7. Schematic drawing of heated floor dryer. IRRI, 1983.



8. Mixing of paddy on the heated floor dryer. IRRI, 1983.

THE WAREHOUSE DRYER

The warehouse dryer development in 1983 focused on improving system efficiency and selection and testing of alternative low-cost construction materials.

Soil brick furnace. Soil bricks, which were made from paddy soil and 4% rice hull ash (by weight), were used to construct the center-tube furnace. The bricks have an average compressive strength of 50 kg/cm^2 and a coefficient of thermal expansion of $4.8 \times 10^{-7}/°C$. These properties were satisfactory in durability and burning efficiency.

The furnace can generate temperatures of 800 to 1,000° C when fueled with rice hulls, corncobs, and coconut husks. Other materials such as sawdust, cornstalk, and rice straw also burned fairly well. The furnace can also be adapted to other purposes.

Soil-straw wall. Soil-straw blocks were used to construct the wall of the warehouse. Mechanical tests conducted on the blocks showed a compressive strength of 3.7 t and a bending strength of 1.6 t/15-× 15-cm area. Heat transfer through the wall was minimal at 1.19 kcal/m^2 per° C. The wall can be coated with a cement-lime-soap-water mixture for water proofing. Heat utilization efficiency with soil-straw walls increased because of reduced heat losses.

Material holding chamber. Drying bins in the chamber were mainly vertical trays with adjustable side louvers to hold a variety of grains. Test results showed that the drying rate, using the vertical trays, was about twice as fast as that of floor drying of the same capacity. Horizontal drying trays were also adapted for materials, such as fish and vegetables, that did not permit compressive forces during curing. Strip hangers to hold tobacco, abaca, etc. were also used during drying. Spaces around the warehouse could be used for drying and storing sacks.

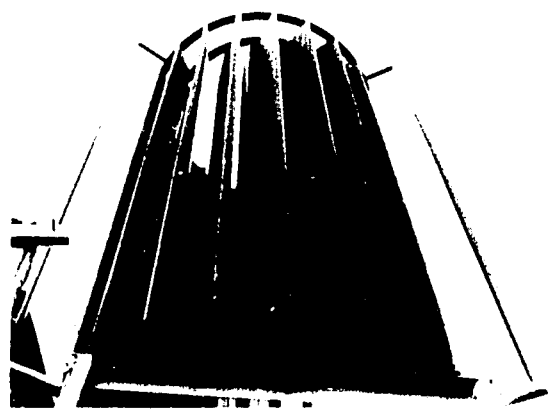
Vortex wind machine. The vortex wind machine was modified by changing the shape of the vane. The new model has the tail of the vane curved outward from the center of the vortex tower (Fig. 9). This design allows the wind entering the system to move in a streamlined path along the side of the tower wall, creating a more distinct and efficient low pressure zone at the center. Two prototypes, a single-blade vane and an airfoiled vane, were built. The single-blade vane is satisfactory for wind velocities lower than 5 m/s, while the airfoiled vane is good for wind velocities greater than 5 m/s. The modified vortex wind machine eliminates the use of the conical venturi structure.

Drying experiments on paddy, maize, coconut, and fish showed satisfactory results. The drying rate is greatly affected by prevailing winds, affecting critical temperature and airflow rate (Fig. 10). Drying time may vary from 6 to 14 h, depending on weather conditions.

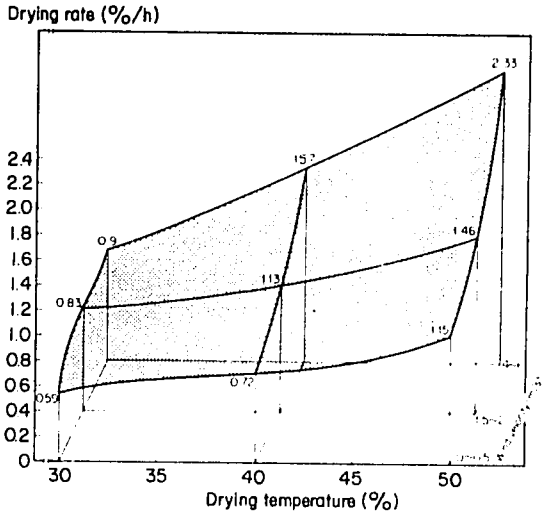
Cost analysis showed that the dryer can dry 1 t of paddy from 25% initial MC to 14% MC for about $1 at the foreign exchange rate of ₱14.00 to US$1, with a benefit-cost ratio of 1.8 and a payback period of 2.04 yr.

DEVELOPMENTS IN DEEP PLACEMENT FERTILIZER APPLICATORS

PU is the most popular fertilizer material for rice production in Asia. Over the last decade many



9. The vortex wind machine. IRRI, 1983.



10. The drying rate of paddy in the warehouse dryer is affected by temperature and air movement, with the airflow rate being more critical. IRRI, 1983.

deep placement applicators have been developed for PU in Japan, China, and at IRRI. Their erratic performance led to the belief that PU is not suitable for deep placement. Consequently, urea briquets and USG were developed. During 1983, the Agricultural Engineering Department concentrated on developing deep placement applicators for PU.

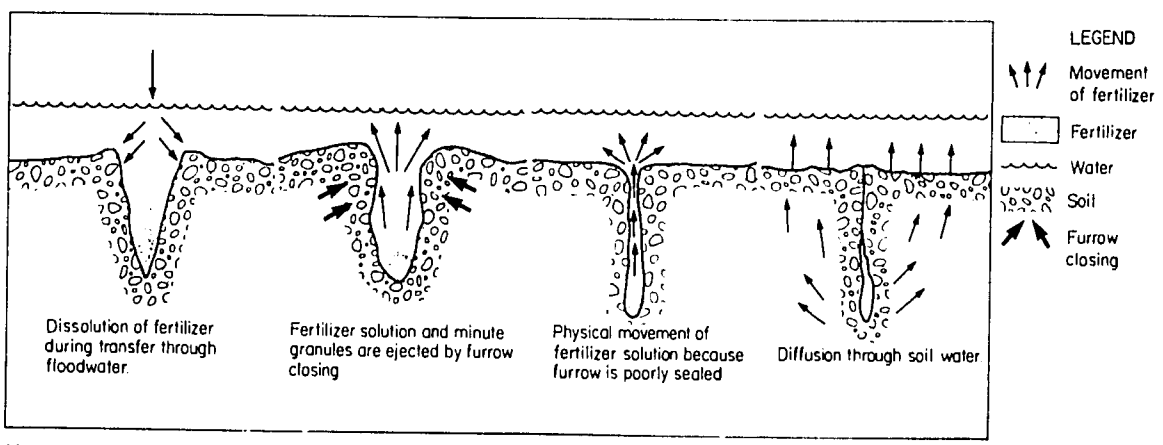
In 1982, the department reviewed the development of deep placement applicators throughout the world to better understand the problems. A set of criteria for technical and commercial acceptability of applicators was developed. Laboratory experiments during 1983 showed that conventional fertilizer placement methods result in a large transfer of N to floodwater. The three major applicator components (fertilizer metering, conveying, and furrow closing mechanisms) needed improvement.

Twenty new deep placement applicator concepts were proposed, and six were selected for intensive design and development efforts. Three new applicators were developed and showed good performance during 1983 WS. These applicators, two for PU and one for USG, were designed to minimize the transfer of N to floodwater.

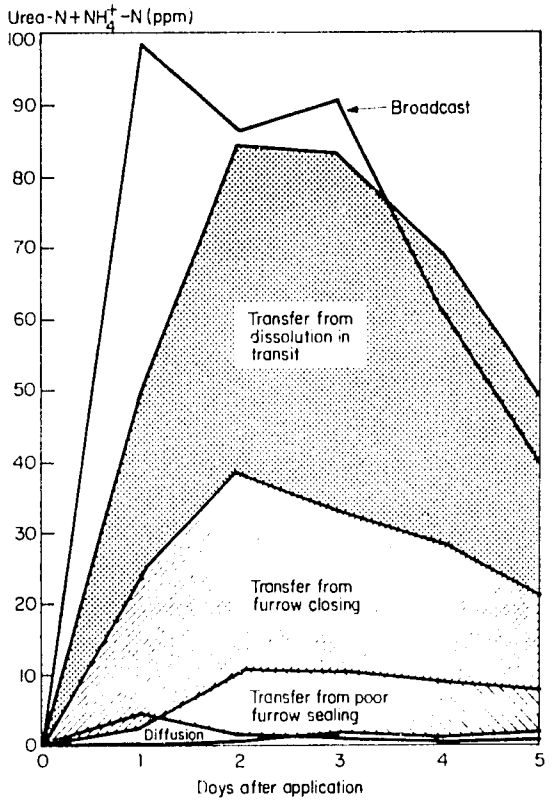
Mechanics of nitrogen transfer to floodwater. Fertilizer use efficiencies on upland farms are 50 to 60% while those in lowland areas are 30 to 50%. The reasons for this wide difference have not been well understood. Pakistan experiments reported a 60% recovery of applied N by rice when fertilizer incorporation in dry soil was followed by flooding. Since fertilizer use efficiency in upland conditions is quite high, perhaps low efficiency in lowlands is caused by the presence of water during fertilizer application.

In 1983, two laboratory studies in the Agricultural Engineering Department evaluated four different avenues (Fig. 11) of N transfer to floodwater during deep placement of fertilizer in flooded soils. PU was used in the first study as it was considered most susceptible to N transfer to floodwater because of its small granule size. Later experiments used both PU and USG.

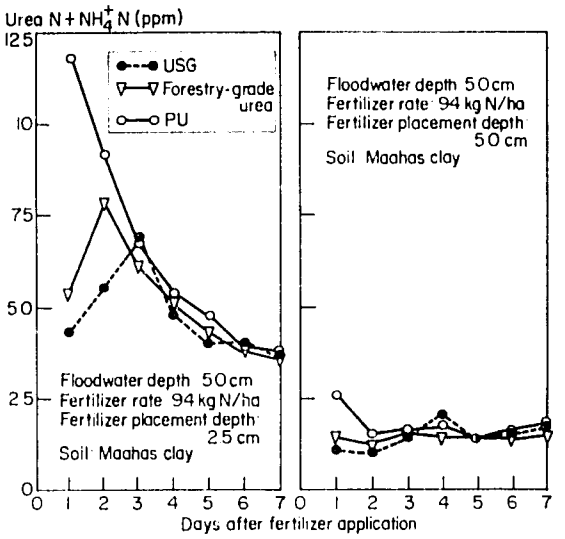
Results showed that deep placement of PU in flooded open furrows followed by closing was not a suitable approach since most fertilizer was transferred to floodwater (Fig. 12). About 43-75% of N transfer to floodwater during deep placement was from dissolution of PU during transit from the



11. Avenues for fertilizer transfer to floodwater during deep placement. IRRI, 1983.



12. Major avenues for N transfer to floodwater during PU placement at 5-cm depth in flooded furrows in Maahas clay. IRRI, 1983.



13. N transfer to floodwater when urea fertilizer is embedded at 2.5- and 5.0-cm depths in freshly puddled Maahas clay. IRRI, 1983.

water surface to the furrow bottom. Up to 20% of the transfer came from upward movement of fertilizer granules or solution to the floodwater during furrow closing. These two mechanisms were so significant that sometimes N transfer was almost as much as that of broadcast application. Transfer from poorly sealed furrows or diffusion through puddled soils was relatively small.

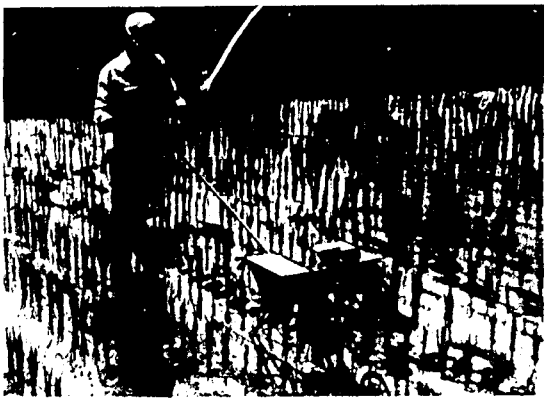
Experiments with fertilizer embedded at 2.5 cm- and 5-cm depths in Maahas clay (Fig. 13) indicated that placement at 3- to 5-cm depth minimized fertilizer transfer to floodwater. For improved fertilizer use efficiency, maintaining an adequate soil barrier between fertilizer and floodwater seems more important than deeper placement.

These studies showed that minimizing fertilizer-water contact during all three phases of fertilizer placement (transit, placement, and covering) and maintaining an adequate soil barrier between floodwater and fertilizer could be an effective approach for developing deep placement fertilizer applicators for flooded paddies. Three new applicators that were developed have demonstrated consistent performance during the 1983 WS:

- Spring auger applicator for PU (Fig. 14),
- Oscillating plunger applicator for PU (Fig. 15), and
- Press wedge applicator for USG (Fig. 16).

Comparative performance of applicators. During the design and development phase, machines undergo repeated design improvements and evaluation. In the past, the performance of deep placement applicators was evaluated at IRRI through yield experiments that required a 5- to 6-mo cycle between design improvement and its evaluation. This seriously hampered the development process. The urea and ammonium N concentration in floodwater, after fertilizer application, is usually related to volatilization loss. Therefore, floodwater

14. Spring auger applicator for PU. IRRI, 1983.



15. Oscillating plunger applicator for PU. IRRI, 1983.

16. Press wedge applicator for USG. IRRI, 1983.

N level was used to evaluate machine performance. This technique was successfully used for preliminary evaluation of applicator improvements, and it helped accelerate the applicator development process at IRRI.

The three machines can be manufactured and sold in most developing countries for about $40 to $60. They were extensively tested and improved during 1983 WS (Table 2) in cooperation with the following groups:

- the Agronomy Department at the IRRI Farm and at the Maligaya Rice Research and Training Center Station,
- the Training and Technology Transfer Departments at various research stations and farmers' fields in the Philippines, and
- nine progressive farmers in their fields in Laguna Province.

The two PU machines performed better than both manual and machine placement of USG (Table 2). The performance of all three machines was comparable to or better than researchers' and farmers' splits.

Results of farmer trials conducted by the IRRI Training and Technology Transfer Department in Cagayan are given in Table 3. The trials were conducted on 500-m² plots. Yields ranged from

Table 2. Effect on IR58 yields of N applied with different manual and machine placement techniques. IRRI, 1983 WS.

Urea source	Application method	N applied (kg N/ha)	Water depth (cm) during basal fertilizer application	Yield (t/ha)
No fertilizer N	–	–	–	2.9 c
PU	Band placement by spring auger	56	4.6	4.7 ab
PU	Band placement by oscillating plunger	58	4.8	5.1 a
USG	Point placement by deep plunger	58	4.9	4.4 ab
USG	Point placement by press wedge	46	5.1	4.3 b
USG	Point placement by hand	58	5.3	4.6 ab
PU	Researchers' split	58	5.0	4.2 b
PU	Farmers' split	58	5.0	4.3 b

Table 3. Effect on IR36 yields of N applied with 4 deep placement machines in farmers' field trials, Cagayan, Philippines, 1983 WS.

	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	Mean
	Farmer 1		*Farmer 2*		*Farmer 3*		*Farmer 4*		*Farmer 5*		
PU											
Spring auger	108	4.33	109	4.48	89	4.60	86	4.17	101	5.42	4.60 a
Oscillating plunger	59	4.85	85	4.33	68	4.34	82	4.56	74	5.65	4.75 a
	Farmer 6		*Farmer 7*		*Farmer 8*		*Farmer 9*		*Farmer 10*		
USG											
Press wedge	52	4.15	57	4.51	54	5.44	58	4.60	57	5.50	4.84 a
Deep plunger	71	4.64	66	4.09	69	5.12	73	5.54	65	5.78	5.03 a
CV (%)											7.9

4.17 to 5.78 t/ha. Trials at very high fertilizer rates usually did not produce as great an increase in yield as those at lower fertilizer rates. This suggests that deep placement may be more effective for increasing fertilizer use efficiency at low fertilizer levels rather than at excessively high levels.

The Agricultural Engineering Department conducted nine farmer trials (Table 4, 5). They showed that a single application by any of the three machines increased fertilizer use efficiency as compared to the farmers' traditional practice of split application. Since deep placement requires less

Table 4. Deep placement fertilizer trials[a] in farmers' fields. Calamba and Calauan, Laguna, Philippines, 1983 WS.

Farmer no.	Variety	Application method[b]	Fertilizer		Projected yield[c] (t/ha)	Fertilizer efficiency[d]	
			Material	Rate (kg N/ha)		kg paddy /kg N	% change over control
1	Sinandomeng (MV)	Farmer practice (no machine - control)	PU	90	4.87	54.11	–
		Spring auger	PU	47	4.42	94.04	+ 73.79
		Oscillating plunger	PU	48	3.95	68.10	+ 25.85
		Press wedge	USG	48	3.82	79.58	+ 47.07
2	Sinandomeng (MV)	Farmer practice (no machine - control)	PU	78	4.98	63.85	–
		Spring auger	PU	55	5.03	91.45	+ 43.22
		Oscillating plunger	PU	58	5.17	89.14	+ 39.61
		Press wedge	USG	48	5.03	109.79	+ 64.12
3	Sinandomeng (MV)	Farmer practice (no machine - control)	PU	78	6.87	88.08	–
		Spring auger	PU	42	5.46	130	+ 47.59
		Oscillating plunger	PU	41	5.01	122.20	+ 38.74
		Press wedge	USG	42	5.01	119.28	+ 35.42
4	IR42	Farmer practice (no machine - control)	PU	78	4.76	61.02	–
	C4	Spring auger	PU	52	3.42	65.77	+ 7.98
	IR42	Oscillating plunger	PU	39	4.42	113.33	+ 85.73
	IR42	Press wedge	USG	41	4.30	104.88	+ 71.88
5	IR42	Farmer practice (no machine - control)	PU	80	4.28	53.5	–
		Spring auger	PU	66	4.92	75.54	+ 39.33
		Oscillating plunger	PU	58	4.03	69.48	+ 29.87
		Press wedge	USG	45	4.06	90.22	+ 68.64
6	IR42	Farmer practice (no machine - control)	PU	78	4.66	59.74	–
		Spring auger	PU	47	4.27	91.06	+ 52.43
		Oscillating plunger	PU	50	4.20	84.00	+ 40.61
		Press wedge	USG	44	4.38	99.54	+ 66.62
7	IR42	Farmer practice (no machine - control)	PU	67	5.47	81.64	–
		Spring auger	PU	40	5.19	129.75	+ 58.93
		Oscillating plunger	PU	53	5.03	94.91	+ 16.25
		Press wedge	USG	51	4.58	89.80	+ 10.00
8	IR42	Farmer practice (no machine - control)	PU	78	5.74	73.59	–
		Spring auger	PU	40	5.25	131.25	+ 78.35
		Oscillating plunger.	PU	46	5.21	113.26	+ 53.91
		Press wedge	USG	47	5.37	114.26	+ 55.26
9	IR42	Farmer practice (no machine - control)	PU	68	5.71	69.26	–
		Spring auger	PU	45	4.58	101.78	+ 46.95
		Oscillating plunger	PU	47	5.53	117.66	+ 69.88
		Press wedge	USG	48	4.74	98.75	+ 42.58

[a]Each farmer applied his own traditional cultural practices on all 4 treatments. [b]With machine applications, all fertilizer was applied as a single dose at 10 to 18 DT. Farmer practice varied but generally included 2 to 3 split broadcast applications. [c]Based on 4 sampling sites (projected value at 14% MC). [d]For lack of better methods of assessment, fertilizer efficiencies at different fertilizer rates were compared.

fertilizer for comparable yields, lower fertilizer rates were used at the nine Laguna farm locations. The machines had these average increases in efficiency:

- spring auger applicator for PU, 49.8%;
- oscillating plunger applicator for PU, 44.49%; and
- press wedge applicator for USG, 51.29%.

By the end of 1984 DS, the machines will have been sufficiently tested and improved under different soil and water conditions and ready for limited commercial release in the Philippines.

A number of strategic steps led to the quick development of the deep placement applicators. They are the precise definition of the deep placement applicator problem, prioritization of the technical and market criteria for applicators, better understanding of N transfer to floodwater during deep placement, separate improvement of individual applicator components in the laboratory, shortening of the applicator evaluation process through floodwater N measurement, and development of a large number of applicator concepts which led to the designs of the three promising machines.

TESTING AND EVALUATION

Machines developed by the design section are tested before release to manufacturers by the Industrial Extension Section. Tests are also conducted on equipment submitted by outside agencies and on research projects.

In 1983 the following tests were conducted.

Test of HMC-urgent urea injector. An injector developed in the Netherlands injected PU into mud by hydraulic air pressure. It was effective and simple to operate but, being a one-row machine, is uneconomical compared with traditional methods of applying fertilizer.

Blower tests. Tests were conducted on blower fans made by local manufacturers for existing crop dryers. The fans are of poor quality and need improvement.

Comparative tests of standard moldboard plows and disk plows. The sale of disk plows has been increasing. Tests compared a two-disk plow with a single moldboard. Future tests will concentrate on the double moldboard. Both the moldboard and disk plows have a place in agriculture.

Table 5. Increases in fertilizer use efficiencies[a] with deep placement applicators on 9 cooperating farms in Laguna, Philippines, 1983 WS.

Farmer no.	Increase (%) over farmer split broadcast practice		
	Spring auger applicator for PU	Oscillating plunger applicator for PU	Press wedge applicator for USG
1	73.79[b]	25.85[b]	47.07[b]
2	43.22	39.61	64.12
3	47.59	38.74	35.42
4	7.98[c]	85.73	71.88
5	39.33[d]	29.87[d]	68.64
6	52.43[d]	40.61[d]	66.62[d]
7	59.93[d]	16.25	10.00
8	78.35	53.91	55.26
9	46.95	69.88	42.58
Av increase	49.82	44.49	51.29

[a]Due to lack of better methods for comparative assessment, efficiencies at different fertilizer rates were compared. [b]Plots were affected by SB infestation. [c]C4 variety was used with this machine only and the crop lodged. [d]Deep-placed plots recovered from field submergence 2-3 d during a typhoon.

Seedling raising experiment. The IRRI manual transplanter uses mat-type seedlings, but present methods of raising them are more costly than traditional methods. An experiment in progress is testing different methods of seedling preparation to reduce costs, simplify the procedure, and still provide seedlings that can be used by the IRRI transplanter.

Fertilizer applicators. The three most promising fertilizer applicators are being tested to determine the force required to operate them and to determine operating defects. During 1984 DS (Jan to Mar), applied nonreplicated trials in farmers' fields will be conducted in Laguna in cooperation with the design group.

Reaper. The reaper has been successfully redesigned and tested for 110 h to overcome operating difficulties.

Improved TH6. The portable thresher, the TH6, has been redesigned and tested, with latest results indicating reduced losses and improved threshing efficiency.

Other test activities. Other activities in 1983 consisted of the following:

- development of a new drawbar dynamometer for field-testing implements,
- comparative performance testing of gasoline engines,

- construction of an electric dynamometer to be used in the test program,
- assistance in the strip tillage experiment conducted by the Soil Chemistry/Physics Department,
- performance testing of a planocentric speed reducer for power tillers, and
- development of a testing method for measuring human energy expenditure.

INDUSTRIAL EXTENSION

Industrial Extension projects are active in the Philippines, Indonesia, Thailand, Burma, and Egypt. A 1983 project initiated in India is at Tamil Nadu University, Coimbatore.

Philippines. The 1.0-m reaper has been built by 30 manufacturers, and about 500 units were sold during 1982-83. The Ministry of Agriculture-IRRI staff are working together with manufacturers to overcome several deficiencies of the reaper.

In response to government interest in increasing upland crops production, the program has developed and tested an animal-drawn seeder and fertilizer applicator. On-farm testing will be initiated in 1984.

The improved transplanter was first introduced in Libmanan, Camarines Sur, where the desired cropping pattern is hampered by transplanting delays. Farmers are being trained to operate the transplanter, and the Economics Section is evaluating the machine in comparison with hand transplanting.

Indonesia. In West Sumatra, 450 threshers were produced by 14 manufacturers. Exports to other provinces have started.

Power tillers are used extensively in the Luwu district where a number of 4-wheel tractors have failed because of lack of service parts.

Axial-flow pumps are becoming popular in South Kalimantan where 3 manufacturers have produced 60 pumps.

Thailand. Although there is some interest in reapers, axial-flow pumps, and dryers, the principal IRRI-designed equipment produced in Thailand is the axial-flow thresher. About 40,000 units have been produced since they were introduced in 1970. Presently, 29 manufacturers are producing axial-flow threshers.

Increased efforts are directed to the northeast farming areas where mechanization is needed.

Burma. The most extensive mechanization has been in transplanting. The Agricultural Machinery Department staff has built more than 7,000 transplanters for farmers.

Associated training programs

IRRI's educational and training programs are designed to help developing countries create a nucleus of well-trained and highly motivated scientists working on rice and rice-based cropping systems programs. During the year, IRRI continued its commitment to provide high quality research-oriented and instruction-related training to scientists working in national rice programs.

RESEARCH-ORIENTED TRAINING PROGRAMS

Research-oriented training programs are of three types: the postdoctoral and senior research fellowship, degree (MS and Ph D), and nondegree. In 1983, 258 fellows and research scholars participated in the programs (Table 1). Table 2 shows the country distribution of the postdoctoral fellows.

Table 1. IRRI scholars and fellows who participated in research-oriented and nondegree training programs at IRRI, 1983.

Country	Research-oriented				Nondegree training										
	Post-doctoral	Ph D	MS	ND[a]	INSFFER	GEU	RPTP	URTC	IWMT	IPM	CSTP	Ag. Econ.	AEC I	AEC II	Total
Philippines	9	7	12	2	4	–	2	4	5	3	5	4	1	4	62
Bangladesh	3	10	23	1	–	1	2	1	6	1	5	–	–	2	54
China	11	1	16	7	5	4	–	–	–	2	2	2	–	2	52
India	22	2	1	1	2	–	1	5	2	2	4	1	3	2	48
Sri Lanka	1	1	13	–	–	2	6	2	3	1	6	2	2	2	41
Thailand	1	7	5	3	3	2	3	2	2	2	4	–	2	2	38
Indonesia	1	–	3	2	2	2	–	3	2	2	2	4	3	–	26
Burma	–	–	8	2	–	–	1	2	–	–	2	1	2	3	21
South Korea	3	9	1	3	–	–	–	–	–	1	1	–	–	–	18
Pakistan	2	3	7	–	–	–	–	–	–	–	1	1	1	1	16
Nepal	1	1	7	–	–	–	–	1	–	1	–	1	–	–	12
Vietnam	1	–	–	4	3	–	1	1	–	–	–	–	1	1	12
Japan	3	1	1	2	–	–	–	–	–	–	–	–	–	–	7
Germany	–	4	–	1	–	–	–	–	–	–	–	–	–	–	5
Malaysia	–	–	–	–	–	–	1	1	1	1	–	–	1	–	5
Nigeria	–	1	–	–	–	–	1	2	–	–	–	–	–	–	4
United Kingdom	1	–	–	3	–	–	–	–	–	–	–	–	–	–	4
United States	–	1	1	2	–	–	–	–	–	–	–	–	–	–	4
Bhutan	–	–	–	1	–	–	–	–	–	–	1	–	–	1	3
Egypt	1	1	–	–	–	1	–	–	–	–	–	–	–	–	3
Mexico	–	–	2	–	–	–	–	1	–	–	–	–	–	–	3
Senegal	–	–	–	2	–	–	–	–	–	–	–	–	1	–	3
Brazil	–	–	1	–	–	–	–	1	–	–	–	–	–	–	2
Colombia	–	1	1	–	–	–	–	–	–	–	–	–	–	–	2
Cuba	–	–	–	2	–	–	–	–	–	–	–	–	–	–	2
Madagascar	–	–	–	–	–	1	–	–	–	–	–	–	1	–	2
Peru	–	1	1	–	–	–	–	–	–	–	–	–	–	–	2
Belgium	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Chile	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Ecuador	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
France	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Gambia	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Iraq	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
Jamaica	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Liberia	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Netherlands	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Senegal	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Solomon Islands	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Sudan	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
Total	61	52	107	38	19	14	20	28	21	17	33	16	18	19	463

[a]Nondegree.

Table 2. Distribution of IRRI postdoctoral fellows by country, 1983.

Country	Visiting research fellows	Senior research fellows	Postdoctoral research fellows	Total
India	–	0	13	22
China	7	–	4	11
Philippines	–	4	5	9
Bangladesh	–	1	2	3
Japan	–	–	3	3
South Korea	–	–	3	3
Pakistan	–	1	1	2
Egypt	–	–	1	1
France	–	–	1	1
Indonesia	–	–	1	1
Nepal	–	1	–	1
Sri Lanka	–	1	–	1
Thailand	–	–	1	1
United Kingdom	–	–	1	1
Vietnam	–	–	1	1
Total	7	17	37	61

Among the degree candidates, 35 graduated from the University of the Philippines at Los Baños, 2 from Cornell University, and 1 each from Ohio State University, Colorado State University, Utah State University, Missouri State University, University of Reading, Kyoto University, Justus Liebig Universitat Giessen, Universitat Hamburg, the Post-Graduate Institute of Agriculture in Sri Lanka, Universiti Pertanian Malaysia, and Ateneo de Manila University.

INSTRUCTION-RELATED TRAINING

In 1983, the Upland Rice Training Course was instituted to provide training on the principles of rice production in rainfed uplands. It involves exposure to crop ecology and physiology; management principles of problem soils; crop management and protection of upland rice including weed control, soil and water conservation, harvesting, mechanization, pest management, and varietal improvement. Of these, Bl resistance, drought, and problem soils are emphasized.

In addition, nine regular nondegree courses were offered:

Course	*Date offered*
International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)	10 Jan-29 Apr
Genetic Evaluation and Utilization (GEU)	1 Feb-21 May
Rice Production Training Program (RPTP)	7 Mar-29 Jul
Upland Rice Training Course (URTC)	23 May-11 Sep
Irrigation Water Management Training (IWMT)	8 Aug-16 Sep
Integrated Pest Management (IPM)	15 Aug-25 Nov
Cropping Systems Training Program (CSTP)	26 Sep 1983-3 Feb 1984
Agroeconomic Research Methodology Training Course (Agricultural Economics)	17 Oct-9 Dec
Agricultural Engineering Course (AEC)	26 Jul-12 Aug 28 Nov-16 Dec
Rice Production Training Program (2-wk)	24 Jan-4 Feb 7-18 Feb 30 May-10 Jun 18-19 Aug 17-28 Oct 7-18 Nov

Table 1 shows the distribution by course and country of the 205 participants. The number excludes 176 trainees who participated in the 2-wk Rice Production Courses; 82 of those were also participants in the other regular courses.

ESTABLISHMENT OF THE TRAINING AND TECHNOLOGY TRANSFER DEPARTMENT

The responsibilities of the Rice Production Training and Research Department were expanded to include coordination of instruction-related training courses, preparation of training materials, and applied research activities. Under this arrangement, departments continue to be responsible for offering the courses, developing curricula, and providing technical expertise including research projects and overall supervision. The new Training and Technology Transfer Department (TTTD) coordinates and provides assistance in developing course schedules, selecting candidates, logistical support, methods, instructional resource development, course standardization, evaluation, and research feedback mechanisms associated with the learning process.

IRRI ACADEMIC COUNCIL

The IRRI Academic Council was created on 11 May 1983 to

- compare IRRI training programs with their initial objectives, existing training facilities,

and the needs of national research and development programs;

- review policies regarding existing and proposed training manuals and audiovisual modules;
- review courses that can be transferred to national programs and suggest procedures for assisting national programs in their training courses;
- recommend steps for promoting cooperation in graduate and postgraduate training programs between IRRI and leading agricultural or other universities in rice-growing countries; and
- recommend measures that can maintain relevance and excellence in IRRI's training programs.

The council members are the director general (chairman), the director of research and training (member-secretary), scientist directors, heads of research and global research services departments, two senior outreach scientists, the dean of the UP College of Agriculture, a nominee of the rector of the United Nations University, the president of the Association of Asian Agricultural Universities, the director general of the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, a nominee of the president of the Asian Development Bank, the resident representative of the United Nations Development Programme in Manila, and five other members nominated by the director general for their individual achievements in the field of agricultural education and training.

The council is assisted by four standing committees with the following functions:

Committee for	*Functions*
Visiting Scientist, Postdoctoral and Senior Research Fellowship Program	• Reviews and develops procedures for inviting and selecting candidates for positions of visiting scientists, and senior and postdoctoral research fellows; • Determines areas of specialization for selection priority; and • Selects the candidates for those positions.
MS and Ph D Research Fellowship Program	• Reviews the capacity of IRRI departments to accept MS and Ph D degree candidates, and pre- and post-masteral nondegree research fellows over a 3-yr period; • Reviews the needs of national research programs for degree training in various fields; • Establishes guidelines for selecting candidates; and • Selects candidates.
Nondegree Training	• Develops annual schedules of training programs and the distribution of country participation; • Reviews progress of the training programs; • Coordinates implementation of course material production; • Reviews resource requirements of courses, and plans field trips and invitations for outside lecturers; and • Reviews collaborative arrangements with national programs.
Scholars' Welfare and Cultural Programs	• Helps promote social and cultural activities that complement the academic and research activities of the scholars and fellows; and • Identifies problems affecting the welfare and well-being of scholars and fellows and recommends appropriate action to the director general.

The Academic Council met on 2 Aug 1983 and the other committees met several times during the year.

COLLABORATION WITH UNIVERSITIES ON MS AND PH D PROGRAMS

Because of the increasing need for MS and Ph D training for rice scientists in many countries, IRRI has continued to develop collaborative arrangements for graduate programs with universities around the world. Usually, students complete MS course requirements in their respective countries but come to IRRI to conduct their thesis research. For those working for the Ph D, arrangements are made for them to complete course work at universities in developed or developing countries which have a broader selection of courses; however, thesis research is done at IRRI under the guidance of IRRI scientists. In certain cases, thesis research is done at IRRI's outreach sites in the Philippines or in the student's home country to take advantage of the problems existing in those areas. The universities with which this program has been finalized are

Cairo University, Egypt; Institut Pertanian Bogor, Indonesia; Universiti Pertanian Malaysia; UPLB, Central Luzon State University, Philippines; Postgraduate Institute of Agriculture, Sri Lanka; Kasetsart University, Asian Institute of Technology, Thailand; and Cornell University, USA. Similar agreements are in progress with seven other universities.

SPECIAL TRAINING PROGRAM FOR SENIOR RESEARCH ADMINISTRATORS

IRRI organized a 1-mo (13 Jan-19 Feb 1983) study tour for 6 senior officials of the Agency for Agricultural Research and Development (AARD) of Indonesia to observe research management practices at IRRI and the Philippines, Taiwan, Malaysia, and India. A 1-wk (7-11 Mar 1983) rice production course was organized for senior officials of USAID in Thailand, Indonesia, Philippines, Burma, Sri Lanka, and India. It included an intensive orientation in rice production and opportunity for the participants to spend additional time with scientists and departments in their respective fields.

IRRI ALUMNI VIEWS OF TRAINING PROGRAMS

IRRI alumni and their supervisors were surveyed to obtain information on their current job responsibilities, post-IRRI training, academic and professional advancement, and their views on the relevance of IRRI training programs. The survey provided valuable information which has been summarized and published as *IRRI's Training and Professional Advancement Programs*.

TRAINING MANUAL

A training manual was published and distributed to assist scholars and fellows. It describes terms and conditions of scholarships and fellowships and contains general orientation material about IRRI.

ENGLISH COURSE

The English courses were continued to assist scholars improve their language proficiency. Two advanced scientific writing courses had 35 participants.

A beginners' course (Oct 1983-Mar 1984) for spouses of scholars and fellows had 27 participants.

SCHOLARS AND FELLOWS

The following sections list scholars and fellows who completed work in 1983. Their countries and research projects are included. An asterisk (*) indicates completion of the MS; two asterisks (**), completion of the Ph D. Absence of the symbol indicates that the work is in progress.

Another section lists the training courses offered and their participants.

RESEARCH SCHOLARS

Agricultural Economics

Mohammed Akhtar. Pakistan. Evaluating the impact of risk preferences on N-fertilizer in rice production.

Gaspar Bimbao.* Philippines. The economics of dry season irrigation management scheme: a case study of Central Luzon, Philippines.

Georgina Bordado.* Philippines. Analysis of the factors affecting the adoption of rice threshers in Laguna, Philippines.

J. A. T. P. Gunawardena.* Sri Lanka. Fertilizer demand and output supply elasticities for paddy in Sri Lanka.

Sarit K. Mohapatra.* India. Farm systems research on livestock enterprises to support rice-based cropping systems.

Roxane Nacario.* Philippines. Measuring income distribution in changing village economies.

Basilia Regalado.* Philippines. The distributional impacts of food policies on human nutrition in the less developed countries: the case of the Philippines.

P. A. Samaratunga. Sri Lanka. An aggregate economic analysis of the effects of the policy on rice production and distribution in Sri Lanka.

Agricultural Engineering

Eulito Bautista.* Philippines. Common metering mechanism for drilled, forestry grade, and supergranular urea applicators.

Yusuf Maamun.* Indonesia. The impact of the rice intensification loans on land productivity, input use, and income distribution: the West Java case, Indonesia.

Blanquita Reyes.* Philippines. The economic impact of mechanical land preparation on rice farmers in Nueva Ecija under conditions of weather uncertainty.

Yusuf Saefuddin.* Indonesia. The domestic resource cost of mechanization in West Java, Indonesia.

Felipe Santos.* Philippines. Performance of furrow closers, deep placement fertilizer applicators.

Mya Thein.* Burma. Influences of bedsoil upon use of soil-bearing seedling in the IRRI manual transplanter.

Agronomy

Nanda Senanayake.* Sri Lanka. External phosphorus requirement of wetland rice (*Oryza sativa* L.) based on phosphorus-sorption isotherms.

Nenita Seno. Philippines. Meteorological measurements, soil fertility, and varietal selection for rainfed lowland rice.

Chemistry

Md. Aslam Sagar. Pakistan. The physico-chemical characteristics of scented fine and coarse Pakistani rice varieties.

Communication and Publications

Quazi Mohammad Abu Daud Ibrahim. Bangladesh. Graphics training.

Sylvia Sunarno.* Indonesia. An assessment of the effectiveness of AARD publications among subject matter specialists in Indonesia.

Entomology

Lionel Nugaliyadde.* Sri Lanka. Resistance of *Oryza* spp. to rice thrips *Stenchaetothrips biformis*.

Ze ya. Burma. Rodent control research.

International Rice Germplasm Center

Alphonso Faye. Senegal. Management of rice genetic resources and computerized data processing of research results.

Ranjani Peiris.* Sri Lanka. Comparative studies of aus, bulu, and upland rices with emphasis on root characteristics and water uptake in research and drought resistance.

Chawevan Vutiyano. Thailand. Management of the rice germplasm bank.

Yong Bao Pan.* China. Electrophoretic analysis of genetic relationship among aus, bulu, and upland groups of rice.

Irrigation Water Management

Leticia Pua.* Philippines. Impact of informal training activities on farmers working with the Libmanan Cabusao Pump Irrigation System.

Abdus Sattar.* Bangladesh. A comprehensive study to improve water utilization in Thakurgaon tube well irrigation system.

Multiple Cropping

Akkas Uddin Ahmed.* Bangladesh. Agroeconomic evaluation of selected rainfed lowland rice cultivation practices in Cagayan Province, Philippines.

Kevin Bronson.* USA. The effect of flooding on the nitrogen contributions of a grass and two legume green manures to transplanted lowland rice.

M. A. H. Khan.* Bangladesh. Performance of maize (*Zea mays* L.) - soybean (*Glycine max* L.) intercrops as influenced by variety, population density, and canopy adjustment.

S. L. Shrestha.* Nepal. The effect of varietal type, plant population, and canopy adjustment of corn yields and agronomical characters in corn and soybean intercrop.

Plant Breeding

Wu Chun Fa.* China. Genetics of resistance to whitebacked planthopper in some rice varieties.

Anwarul Islam.* Bangladesh. Effect of heterozygosity on grain and nutritional quality of rice (*Oryza sativa* L.).

Le Thi Loan. Vietnam. Grain quality analysis of breeding lines.

Nguyen Thi Bay. Vietnam. Grain quality analysis of breeding lines.

S. Ponnuthurai.* Sri Lanka. Comparative studies on growth and grain yield of some F_1 rice hybrids and parents.

I. B. Sutaryo. Indonesia. Principles and practices of hybrid rice research.

Plant Pathology

Lu Shi-Hua.* China. Toxin production by *Cercospora oryzae* and its effect on rice plants.

Myo Khin. Burma. Screening for disease resistance and identification of races, strains, and pathotypes of different rice pathogens.

Amara Parejarearn.* Thailand. Identifying resistance of rice cultivars to ragged stunt virus and its vector *Nilaparvata lugens* (Stal).

Md. Montezar Rahman.* Bangladesh. Resistance mechanism of eight rice varieties to tungro virus complex and its vector *Nephotettix virescens*.

Plant Physiology

Sang Hyeon Nam. Korea. Seed derived callus culture and anther culture.

Esther Maria Arcia Ramirez. Cuba. Nitrosemethul urea-induced mutation on various plant traits.

Gopinath Sahu. India. Studies on cold tolerance, dormancy, and shading.

Rice Farming Systems

Thein Han.* Burma. Studies on the varietal performance of selected peanut cultivars under different cultural managements, following rainfed lowland rice.

Soil Chemistry/Physics

Mushidul Kabir.* Bangladesh. Effect of zinc treatment and soil drying on the growth and yield of wetland rice on eight soils.

Rojarae Netsanip. Thailand. Trace element analysis of soils and soil solution.

Soil Microbiology

Lin Chang.* China. Effect of inoculation on N_2-fixing bacteria in flooded soil-rice system.

Tran Quang Thuyet. Vietnam. Physiology of azolla.

Statistics

Maloy Kumar D. Amin. Bangladesh. Research methodology and statistical analysis for rice field experiments.

Manat Pithuncharurnlap.* Thailand. The use of principal component regression in fitting a production function with multicollinearity.

Training and Technology Transfer

Wangdi Wangdi. Bhutan. Adaptive research on rice-based cropping systems.

RESEARCH FELLOWS

Agricultural Economics

Chung Moo Nam.** Korea. Cost functions with respect to farm size in paddy rice and paddy rice - barley systems in South Korea.

Narendra Rustagi.** India. The determination of crop insurance premiums in India.

Agronomy

Sayeed Ahmad.** Bangladesh. Osmotic adjustment in several rice cultivars under field conditions.

Michael Dingkuhn.** Germany. Role of abscisic acid and solute accumulation in water stressed rices.

H. F. K. Schnier.** Germany. NH_4^+ dynamics in wetland rice soils.

Rashid Ahmad Shad.** Pakistan. Techniques to improve land preparation practices, methods of crop establishment, and fertilizer nitrogen efficiency in wetland rice (*Oryza sativa* L.).

Chemistry

Young Bae Kim. Korea. Studies on physicochemical properties of Korean milled rices.

Communication and Publications

Somasekharappa Gowdar.** India. Training needs of information services in agricultural research and educational organizations in Asia: a 9-country survey.

International Rice Germplasm Center

Songkran Chitrakon. Thailand. Management of the rice germplasm bank.

Irrigation Water Management

Carlos Garces.** Colombia. Irrigation system evaluation criteria: an analysis of performance indices.

Leonardo Lucero.** Philippines. A new systems management technique using crop growth curve.

Nenita Tapay.** Philippines. Comparison of management and performance characteristics of national and communal irrigation.

Alfredo Valera.** Philippines. Comparison of management and performance of three intensities of irrigation system management.

Multiple Cropping

Md. Abdur Rahman.** Bangladesh. An evapotranspiration model-derived index to account for the effects of weather, management, and soil factors on rainfed lowland rice yields.

Plant Breeding

Jiang Zhi Long. China. Multiplication of male sterile lines and production of F_1 rice hybrid seed.

Yuan Long Pin. China. Hybrid rice.

Plant Pathology

Young Hee Lee.** Korea. Activities of toxins produced by *Giberrella fujikuroi* on rice plant: varietal resistance screening techniques and mechanism of resistance to the fungus.

Plant Physiology

Philippe Koole.** Belgium. Use of calcium peroxide for better crop establishment.

Yoshiaki Shimada. Japan. Physiological mechanisms of varietal tolerance for iron toxicity.

John Thompson. United Kingdom. Rice protoplast for plant regeneration and genetic manipulation.

Soil Chemistry/Physics

Ursula Martin. Germany. Organic matter decomposition in flooded soils.

Muhammad Rashid.** Pakistan. Response of rice to five levels of salinity sodicity, zinc, and copper in a wetland soils.

Soil Microbiology

Yao Hui-quin. China. Ecology of N_2-fixing bacteria in root-zone of wetland rice.

Training

Violet Valdez. Philippines. 1) Preparation of IRRI Alumni Book; and 2) Post-training survey of IRRI training alumni.

A. S. Vivekanandan.** Sri Lanka.

POSTDOCTORAL SENIOR RESEARCH FELLOWS

Agricultural Economics

Choudhury S. Ahammed. Bangladesh. Employment and output implications of farm mechanization in developing countries: an input-output framework of analysis.

Entomology

Fahmy El Dakroury Abdallah. Egypt. Varietal resistance and chemical control of stemborers.

Shamsul Alam. Bangladesh. Varietal resistance to insects.

Fernando A. Cariño. Philippines. Sampling and insecticide management for rice hoppers and their predators.

N. Panda. India. Tolerance as a component in the resistance of rice varieties to the brown planthopper.

International Rice Testing Program

Tomas Masajo. Philippines. Management of International Rice Testing Program nurseries.

Multiple Cropping

Romeo C. Bruce. Philippines. Landform in the rice growing areas of the Cagayan Rice Basin.

Ram Kumar Pandey. India. 1) Drought response of grain legumes under irrigated gradients; and 2) Effect of leguminous green manuring on crop yields in rice-based cropping systems.

Plant Breeding

Bambang Suprihatno. Indonesia. 1) Effect of gibberellic acid (GA_3) on panicle exsertion of some cms lines; and 2) Effect of flag leaf clipping on outcrossing of some cms lines.

Plant Pathology

Delfin Lapis. Philippines. 1) Rate of infection (horizontal and vertical) of sheath blight on different rice cultivars; 2) Effect of plant age on symptom development of brown spot of rice; and 3) Integrated control of rice blast under upland conditions.

Eun Jong Lee. Korea. Shifting races of *Pyricularia oryzae* Cav.

V. Mariappan. India. Studies on rice tungro virus diseases.

Plant Physiology

Moo Sang Lim. Korea. Analysis of data on cold tolerance experiments in South Korea.

Mohammed S. Rahman. Bangladesh. Physiology of spikelet number and grain size in rice varieties.

M. Ogawa. Japan. Rice callus culture for increasing salt tolerance.

Statistics

Mariano B. de Ramos. Philippines. 1) Determination of the most suitable normalizing data transformation for data from entomological and weed control experiments; and 2) An empirical study on the accuracy of the Jacknife statistics in comparing two variances.

INTERNATIONAL NETWORK ON SOIL FERTILITY AND FERTILIZER EVALUATION FOR RICE (INSFFER)
(10 Jan-29 Apr)

China (5)

Chen Wan Hua, assistant researcher, Soil and Fertilizer Research Institute, Chinese Academy of Agricultural Sciences, Beijing

Li Hua Xing, research assistant, Guangdong Academy of Agricultural Sciences, Guangzhou

Luo Xiao Yan, assistant researcher, Zhejiang Academy of Agricultural Sciences, Hangzhou

Mi Jun Fu, assistant researcher, Soil and Fertilizer Institute, Academy of Sichuan Agricultural Sciences, Chengdu, Sichuan

Zhang Ming Chu, assistant researcher, Soil and Fertilizer Institute, Academy of Agricultural Science of Hubei Province

India (2)

R. M. Basavana Gowd, assistant agricultural officer, Department of Agriculture, Bangalore-1, Karnataka

Shivahari B. Kute, chief, Agricultural Services, 314-B Fertilizernagar Baroda, Gujarat

Indonesia (2)

Dedeh Hudaya Arief, head, Soil Microbiology Laboratory, Faculty of Agriculture, Padjadjaran University, Bandung

Azizar Abdullah, agricultural researcher, Sukarami Research Institute for Food Crops, Padang

Philippines (4)

Gibson M. Aguilar, senior soil technologist, Ministry of Agriculture, Davao City

Perlita N. Bruto, junior soil technologist, Soil Service Section, Ministry of Agriculture, Dagupan City

Redemcion B. Grifal, supervising soil technologist, Bureau of Soils, Manila

Imelda E. Santos, supervising soil technologist, Bureau of Soils, Ministry of Agriculture, Alabang

Thailand (3)

Chaiyan Satien, agricultural officer, Kuan Gut Rice Research Center, Phattalung

Somnak Luangsirorat, agronomist 5, Ratchaburi Rice Experiment Station, Department of Agriculture, Ratchaburi

Songchai Watanapayupkul, agricultural researcher, Soil Science Division, Department of Agriculture, Bangkok

Vietnam (3)

Nguyen Dinh Kiem, department head, Institute for Soils and Fertilizers, Hanoi

Tran Thi Tam, researcher, Institute for Soils and Fertilizers, Hanoi

Tran Than Vinh, teacher of agrochemistry, Agricultural College, Habac

GENETIC EVALUATION AND UTILIZATION (GEU)
(1 Feb-21 May)

Bangladesh (1)

A. K. M. Anwarul Haque, scientific officer in cereal chemistry, Rice Technology Division, Bangladesh Rice Research Institute, Joydebpur, Dhaka

China (4)

Huang He-qing, research assistant in genetics, Hunan Rice Research Institute, Changsha, Hunan

Luo Lin, research assistant in plant breeding, Guangdong Rice Research Institute, Shipai, Guangzhou City, Guangdong

Tan Yuan, research assistant in plant breeding, Grain Crops Institute, Hubei Academy of Agricultural Sciences, Wuhan

Wang Zhi-ming, research assistant in plant breeding, Jiangsu Academy of Agricultural Sciences, Nanjing

Egypt (1)

Abdelhamid I. Zahir, assistant researcher in plant breeding, Essirw Agricultural Research Station, Essirw, Gammaliya, Dakahliy

Indonesia (2)

Mugiono P. Suwarno, staff member in plant breeding, Center for the Application of Isotopes and Radiation, BATAN, P.O. Box 2, KBY. Lama, Jakarta, Selatan.

Yanfirwan Yanuar, research assistant in plant pathology, Sukarami Research Institute for Food Crops, Padang, West Sumatra

Liberia (1)

Wilfried E. Godderis, instructor in weed science, West Africa Rice Development Association, Monrovia

Madagascar (1)

Rahariniria Jeanine, officer in charge of the Rice Program, Plant Breeding Department, Department de Recherches Agronomiques, Antananarivo-M/Car Antananarivo

Sri Lanka (2)

S. Arumugam, agricultural experimental officer, Rice Research Station, Paranthan

J. M. P. Jayasundara, experiment officer, Regional Agricultural Research Station, Bandarawela

Thailand (2)

Boonrat Jongdee, research assistant in plant breeding, Ubol Rice Experimental Station, Ubolrachathanee

Panatda Bhekasut, research assistant in plant breeding, Prajinburi Rice Experiment Station, Bang Sang, Prajinburi

RICE PRODUCTION TRAINING PROGRAM
(7 Mar-29 Jul)

Bangladesh (2)

A. B. M. Saiful Islam, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dhaka

Abul Kashem, deputy director, Agricultural Extension, Ministry of Agriculture, Dhaka

Burma (1)

Khin Soe, deputy township manager, Agriculture Corporation, Rangoon

India (1)

Sudhindra Acharyya Chaudhuri, training associate, Agricultural Extension, Swami Buddhananda; chairman, Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, 24-Parganas, West Bengal

Jamaica (1)

Owen Windell Gilpin, land reform officer, Ministry of Agriculture, St. James Land Authority, Catherine Hall, Montego Bay

Malaysia (1)

Khalid B. Saad, senior assistant research officer, MARDI, Serdang, Selangor

Nigeria (1)

Julius Nwachukwu Arinze, training officer, c/o General Manager, World Bank Project, Ministry of Food Production, Enugu

Philippines (2)

Imelda C. Atabay, research assistant, Maligaya Rice Research and Training Center, Maligaya, Muñoz, Nueva Ecija

Dante V. Fidel, agronomist I, Bureau of Plant Industry, San Andres, Manila

Solomon Is. (1)

Adah Taro, research assistant (varietal coordinator), Brewers Solomon Agriculture, Ltd., P.O. Box 5, Honiara

Sri Lanka (6)

Attanayake M. K. Banda, technician, University of Peradeniya, Peradeniya

M. K. B. Dissanayake, agriculture instructor, Department of Agriculture, Peradeniya
Adikari M. Seneviratne, research assistant, Department of Agriculture, Peradeniya
Wellawatta M. Ubeysena, farm manager, Department of Agriculture, Peradeniya
Winal J. Walgampaya, agriculture instructor, Department of Agriculture, Peradeniya
Wijayaratna B. Yatiwella, agriculture instructor, Department of Agriculture, Peradeniya

Thailand (3)
Sarinna Charopasratana, agriculture technician, Koksamrong Rice Experiment Station, Amphur Koksamrong, Lopburi
Padejpong Chantaro, subject matter specialist 6 (head, Field Crops Section), Southern Regional Agricultural Extension Office, Songkhla
Chongkol Kunnalaca, subject matter specialist 5, Regional Office of Agricultural Extension, Khon Kaen

Vietnam (1)
Tran Huu Du, researcher, Central Seed Agency, Hanoi

UPLAND RICE TRAINING COURSE
(23 May-11 Sep)

Bangladesh (1)
Ashutosh Barai, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dhaka

Brazil (1)
Octavio B. de Almeida, researcher (IAC), Research and Breeder Rice, Agronomic Institute, São Paulo

Burma (2)
Kyaw Way, township manager, 753 Bogyoke Road, Minbaing Twante, Rangoon
Aung Kyi Thein, deputy township manager, Loikaw, Kayah State

India (5)
V. S. Chauhan, scientist I, V. P. K. A. S. Almora, Uttar Pradesh
S. K. Gupta, scientist S-2, ICAR Research Complex, Tripura Centre, Lebucherra-799210, Agartala
G. N. Mishra, scientist S-1, Central Rainfed Rice Research Station, P.O. Box 48, Hazaribagh, Bihar
N. C. B. Raychudhuri, assistant botanist, Rice Research Station, P.O. and Dist. Bankura, West Bengal
M. P. Singh, senior rice breeder, Birsa Agricultural University, P.O. Kanke Dist., Ranchi, Bihar

Indonesia (3)
Ardan Ahmadin, head of Phytopathology Division, Bandar Buat, P.O. Box 34, Padang
Len Bahri, junior agronomist, Balittan Sukarami, P.O. Box 34, Padang, West Sumatra
Agusli Taher, program leader of Upland Rice, Sukarami Research Institute, Padang, West Sumatra

Iraq (1)
Adnan Humed Abd. Al Naby, research assistant, Najaf, Muthena Street

Malaysia (1)
Raja A. S. bin Raja Sulaiman, senior research assistant, 1673 Jalan Pengkalan, Machang, Sungai, Dua, Butterworth

Mexico (1)
Eduardo Ayon Ramos, research assistant, CAECOT, Apartado Postal 429, Veracruz, Ver

Nepal (1)
K. L. Shrestha, assistant agronomist, Agronomy Division, Programme Cropping Section, P. Chaimphair

Nigeria (2)
Olutayo A. Fademi, research officer, National Cereals Research Institute, Rice Research Programme, PMB 5042, Moor Plantation, Ibadan
J. K. Kehinde, senior research officer, National Cereals Research Institute, Rice Research Programme, PMB 5042, Moor Plantation, Ibadan

Philippines (4)

Cresencio Aquino, agronomist III, Bureau of Plant Industry, San Andres, Manila

Shirley Duhaylungsod, production technician, Ministry of Agriculture, Pagadian City, Zamboanga del Sur

Sofio Iligan, agronomist I, Bureau of Plant Industry, San Andres, Manila

Charlie Mangogtong, area supervisor, Ministry of Agriculture, Pagadian City, Zamboanga del Sur

Sri Lanka (2)

Godakanda Jinadasa, experimental officer, Paddy Research Station, Ambalantota

R. M. Ranaweera Banda, experimental officer, Agricultural Research Station, Maha Illuppallama

Sudan (1)

Mohammed Abd. El Mohmoud Sheikh, agricultural engineer, Ministry of Agriculture, Irrigation Engineering Affair Administration, Khartoum

Thailand (2)

Wicharn Witayasiri, agricultural technician IV, Phrae Rice Research Center, Phrae

Vitoon Rattana, agricultural technician V, Samoeng Upland Rice Station, Chaing Mai

Vietnam (1)

Nguyen Huu Hong, lecturer, Agricultural Institute, #3 Bacthai

IRRIGATION WATER MANAGEMENT TRAINING COURSE
(8 Aug-16 Sep)

Bangladesh (6)

Md. Abdul Baten, executive engineer, Water Development Division (West), G. K. Project, Kushtia

Md. Abdul Matin Bhuiyan, sub-divisional engineer, Water Development Division, G. K. Project, Kushtia

Abdus Salam, executive engineer, Bangladesh Water Development Board, Chuadanga, G. K. Project

Md. Nazrul Islam, scientific officer (agricultural engineer), SO Agr. Engineering Division, Bangladesh Rice Research Institute, Joydebpur, Dhaka

Md. Nurul Alam Akhand, senior scientific officer, Bangladesh Agricultural Research Council, New Airport Road, Farmgate, Dhaka

Abul Khair, assistant professor, Department of Irrigation Water Management, BAU, Mymensingh

India (2)

Krishna Murari, Water Technology Centre, Indian Agricultural Research Institute, New Delhi

Ram Kumar Rajput, project coordinator, Central Soil Salinity Research Institute, Karnal-13200 , Haryana

Indonesia (2)

Irwan Amin, construction supervisor, Bureau of Maintenance, Sub-Directorate O&M, Jatiluhur

Iis Syamsiah, staff member, Water Management Section, Agronomy Department, Sukamandi Research Institute for Food Crops, Jln. Raya No. 9, Sukamandi-Subang, West Java

Malaysia (1)

Lai Cho Sim, executive engineer, Drainage and Irrigation Department, Jln. Badruddin, Kuching

Philippines (5)

Wilfredo C. Papaya, soil technologist, National Irrigation Administration Regional Office No. 5, Naga City

William P. Ragodon, engineer A, National Irrigation Administration, Regional Office No. 5, Naga City

Armando I. Marcelo, engineer B, NIA-AMRIS, Tambubong, San Rafael, Bulacan

Javier B. Ramos, engineer B, NIA-UPRIIS, CLSU, Muñoz, Nueva Ecija

Proceso T. Domingo, engineer B, NIA-UPRIIS, Cabanatuan City

Sri Lanka (3)

H. A. Boyagoda, agriculture officer, Soil Conservation Division, Peradeniya

M. A. Ariyasinghe, lecturer, Sri Lanka School of Agriculture, Pelwehera, Dambulla

Ramanayake Pathirannahelage-Mahindapala, agricultural officer, Department of Agriculture, Farm Mechanization Training Centre, Anuradhapura

Thailand (2)

Kuerpan Neanchaleay, irrigation engineer, Royal Irrigation Department, Samsen Road, Bangkok

Songyos Sirisuvanna, irrigation engineer, Royal Irrigation Department, Samsen Road, Bangkok

INTEGRATED PEST MANAGEMENT COURSE
(15 Aug-25 Nov)

Bangladesh (1)

Md. Daud Mia, senior scientific officer, BARI, Regional Agricultural Research Station, Jamalpur, Dhaka

China (2)

Ma Miao Xian, research assistant, Shanghai Academy of Agricultural Sciences, Shanghai

Wang Zhi-Yong, research assistant, Institute of Plant Protection, Guangdong Academy of Agricultural Sciences, Guangzhou

India (2)

N. V. Krishnaiah, scientist, AICRIP, R'Nagar, Hyderabad 500030, Andhra Pradesh

S. Uthamasamy, associate professor of entomology, Department of Entomology, Tamil Nadu Rice Research Institute, Aduthurai 612101, Tamil Nadu

Indonesia (2)

Mahrita Willis Azidin, Banjarmasin Research Institute for Food Crops, Jalan Sutoyos, No. 1143 A, P.O. Box 1, Bajarmasin

Cahyaniati, Directorate of Food Crop Protection, Jl. Ragunan-Pasarminggu, P.O. Box 36, Jakarta Selatan

Korea, South (1)

Hen-Je Cho, Entomology Department, Institute of Agricultural Sciences, Office of Rural Development, Suweon 170

Malaysia (1)

Abdul Razak Nik Yahaya, Crop Protection Unit, Pusat Pertanian, Lundang, Kota Bharu, Kelantan

Nepal (1)

Dilip Chandra Paudel, assistant plant pathologist, HMG Department of Agriculture, NWDP Bhairahawa Agricultural Farm, Rupandehi

Pakistan (1)

Saleem Khan, weed scientist, Pakistan Agricultural Research Council, Pest Management Project, F. Station, Nisatta Road, Mardan, NWFP

Philippines (3)

Leonardo Salazar Dirige, provincial surveillance officer, Ministry of Agriculture, Pagadian City, Zamboanga del Sur

Priscilla Cudal Jover, plant pathologist, Betinan Rice Research Station, Ministry of Agriculture, Zamboanga del Sur Development Project, Zamboanga del Sur

Emma Mituda, plant entomologist, Multiple Cropping System Project Program, Zamboanga del Sur Development Project, Ministry of Agriculture, Pagadian City

Sri Lanka (1)

M. S. B. W. T. M. Bandara Menike Tennakoon, experimental officer, Entomology Division, Central Agricultural Research Institute, Gannoruwa, Peradeniya

Thailand (2)

Somboon Tongsakul, entomologist, Pesticide Application Research Section, Entomology and Zoology Division, Department of Agriculture, Bangkhen, Bangkok

Orawan Wuthijindaroj, zoologist, Plant Protection Service Division, Department of Agricultural Extension, Bangkok

CROPPING SYSTEMS TRAINING PROGRAM
(26 Sep-3 Feb)

Bangladesh (5)

Mukhlesur Rahman Ahmed, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dhaka

Md. Hazrat Ali, assistant extension officer, Bangladesh Water Development Board, Dhaka

Md. Usman Ghani, extension officer, Deep Tube Well Project, Bangladesh Water Development Board, Thakurgaon, Dinajpur

A. B. M. Nurul Imam, scientific officer, Bangladesh Agricultural Research Institute, Dhaka

Md. Badirul Islam, scientific officer, Bangladesh Agricultural Research Institute, Dhaka

Bhutan (1)

Pirthiman Pradhan, in-charge, Center for Agricultural Research and Development, Wangdiphodrang

Burma (2)

Kyaw Sein, inspector, Agricultural Research Institute, Yezin, Pyinmana

Mauk Nyunt, deputy township manager, Agriculture Corporation, Amarapura Township, Mandalay

China (2)

Lu Zheng Qing, assistant scientist, Shanghai Academy of Agricultural Sciences, Shanghai

Jin Qing Zhu, assistant scientist, Agricultural Academy of Zhejiang, Hangchow

India (4)

Rajib Lochan Nayak, research agronomist, Bidhan Ch. Kirshi Viswa-vidyalaya Agriculture Faculty, Kalyani, Nadia, West Bengal PIN 741235

Abdul Rafey, associate professor, Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi-6, Bihar

Mohinder Singh Sidhu, assistant agronomist, Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab

K. K. Subbiah, professor of agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu

Indonesia (2)

Gunardi, assistant agrometeorologist, Directorate of Food Crop Protection, P.O. Box 36, Pasar Minggu, Jakarta Selatan

Haryanto Hardiwikarta, research staff, Centre for the Application of Isotopes and Radiation, Pasar Jumat, P.O. Box 10, Kebayoran Lama, Jakarta Selatan

Korea, South (1)

Si Chool Noh, extension worker, Nou Poong Pak, Jeonbuk Provincial Office of Rural Development

Pakistan (1)

Nazir Ahmad Sidhu, assistant agronomist, Ayub Agricultural Research Institute, Faisalabad

Philippines (5)

Adelaida L. Aguinaldo, senior economic researcher, Regional Integrated Agricultural Research System, Ministry of Agriculture, Region XII, Amas, Kidapawan, North Cotabato

Marlene C. Cubero, core staff, Regional Integrated Agricultural Research System, Ministry of Agriculture, Region VII, Bohol Experiment Station, Ubay, Bohol

Flora D. Gagni, core staff, socioeconomics, Regional Integrated Agricultural Research System, Ministry of Agriculture, Region I, Bacnotan, La Union

Danilo C. Rodriguez, researcher-agronomist I, Zamboanga del Sur Development Project, Ministry of Agriculture, Pagadian City

Artemio P. Sagun, farm management technician II, Ministry of Agriculture, Region IV, Bansud, Oriental Mindoro

Sri Lanka (6)

W. D. Atukorala, experimental officer, Department of Agriculture, Rahangala, Boralanda

G. D. S. W. Gamini, research assistant, Regional Agricultural Research Station, Bombuwella, Kalutara South

A. M. H. Pathma Piyasena, subject matter officer, Agricultural Segment Office, Vidyala Marata, Kuliyapitiya

Saravanamuttu Sinnathurai, agricultural officer, District Training Center, Department of Agriculture, Kilinochchi

Nallathamby Sivayogarajah, experimental officer, Regional Research Centre, Department of Agriculture, Karadiyan-Aru

P. G. Thurairatnam, agricultural instructor, Agricultural Research Station, Department of Agriculture, Murunkan

Thailand (4)

Husachai Pramote, subject matter specialist, Provincial Agricultural Extension Office, Buriram

Manat Leechawengwongs, agriculturist 5, Farming Systems Research Institute, Department of Agriculture, Bangkhen, Bangkok

Pannee Poramarapornkard, agriculturist 5, Farming Systems Research Institute, Department of Agriculture, Bangkhen, Bangkok

Yongyut Suvanarerk, subject matter specialist, Southern Regional Agricultural Extension Office, Songkla Province

AGROECONOMIC RESEARCH METHODOLOGY TRAINING COURSE
(17 Oct-9 Dec)

Burma (1)

Soe Pe, junior planning officer, Agriculture Corporation, 72/74 Shwedagon, Pagoda Road, Rangoon

China (2)

Zhang Linxiu, assistant researcher, Chinese Academy of Agricultural Sciences, 30 Bai Shi Qiao Lu, Beijing

Tian Weiming, assistant researcher, Chinese Academy of Agricultural Sciences, 30 Bai Shi Qiao Lu, Beijing

India (1)

Benudhar Bhuyan, reader in agricultural economics, Department of Agricultural Economics, Orissa University of Agriculture and Technology, Bhubaneswar

Indonesia (4)

Yanti Rina Darsani, researcher in agroeconomics, Banjarmasin Research Institute for Food Crops, Jl. Mayjen Sutoyo S, No. 1134 A, Banjarmasin

Maria Theresia Anitawati Kusuma, researcher, Center for Agroeconomic Research, 20 Juanda Str, Bogor

Supadi, researcher, Agroeconomic Department, Bogor Research Institute for Food Crops, Climanggu, Kecil 2, Bogor

Eddy M. Yusnardi, researcher, Agroeconomic Department, SARIF, P.O. Box 34, Padang, West Sumatra

Nepal (1)

Prem Lal Chitrakar, senior agriculture officer, Regional Agricultural Directorate, Central Development Region, Kathmandu

Pakistan (1)

Maqbool Hussain Sial, scientific officer, Pakistan Agricultural Research Council, P.O. Box 1031, Islamabad

Philippines (4)

Benjamin D. Cariaga, agricultural economist, Bago Oshiro Soil Research Station, Ministry of Agriculture, Davao City

Joselito O. Garcia, core staff, socioeconomics, Regional Integrated Agricultural Research System, Ministry of Agriculture, Ilagan Experiment Station, Ilagan, Isabela

Maria Teresa M. Javier, senior project planning specialist/research supervisor, Bicol River Basin Development Program, San Jose, Pili, Camarines Sur

Bienvenido M. Reyes, Jr., statistician III, Bicol River Basin Development Program, San Jose, Pili, Camarines Sur

Sri Lanka (2)

Herath Mudiyanselage Dissanayake, economic assistant, Agriculture Research Station, Maha Illuppallama

Gamage Don Siripala, economic assistant, Agriculture Research Station, Maha Illuppallama

AGRICULTURAL ENGINEERING COURSE
(25 Jul-12 Aug)

Burma (2)

Sann Maung, head of branch (Repair), Agricultural Mechanization Department, No. 1, Base Workshop, Rangoon

Than Tun, head of branch (Repair), Agricultural Mechanization Department, No. 2, Base Workshop, Kyaukse

India (3)

Prabhakar Datt, scientist, Farm Machinery and Power, Central Institute of Agricultural Engineering, G. T. B. Complex, T. T. Nagar, Bhopal

Surender Kumar Makhija, area manager, Messrs. Premier Irrigation Equipment, Ltd., 26 Shamla Road, Bhopal

Sudhanwa Chandra Patra, scientist S-1, Engineering Division, Central Rice Research Institute, Cuttack

Indonesia (3)

Asparmin Junus, manager, Tembok Jaya Workshop, Sumatra, Barat

Soetomo, Staff of Subdirectorate of Agricultural Mechanization, Ministry of Agriculture, Pasarminggu, Jakarta

Suhardi, Mechanization Section, Agricultural Extension Service, South Kalimantan

Madagascar (1)

Rakotovaovahy R. Mahazo, agricultural engineer, Service du Machinisme Agricole-Nanisana, P.O. Box 1061, Antananarivo

Malaysia (1)

Muhamad Isa bin Otiman, research officer, Agricultural Engineering Branch, MARDI, Serdang, Selangor

Pakistan (1)

Mohammad Afzal, senior engineer, Farm Machinery Institute, Pakistan Agricultural Research Council, P.O. NIH, Islamabad

Philippines (1)

Noel L. Oguis, market analyst, Marsson Industrial Corporation, Diamond Motors Building, Greenhills, San Juan, Metro Manila

Senegal (1)

Alioune Fall, researcher, ISRA (Institut Senegalaise de Recherche Agricole), B.P. 3120, Dakar

Sri Lanka (2)

Kulasogaram Subramanian, agricultural instructor, Farm Mechanization Research Centre, Maha Illuppallama

Herath M. Tilakaratna, mechanical engineer, Farm Mechanization Research Centre, Maha Illuppallama

Thailand (2)

Chalermsak Bamrungthai, administrative staff, Lim Chieng Seng Part., Ltd., 92-94 Sawanwithee Road, Amphur Muang, Nakornsawan

Winit Chinsuwan, assistant professor and department head, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen

Vietnam (1)

Dao Trong Loi, manager, Mechanical Workshop, Institute of Agricultural Engineering, Hanoi

AGRICULTURAL ENGINEERING COURSE
(28 Nov-16 Dec)

Bangladesh (2)

Md. Maminul Huq, assistant professor, Farm Power and Machinery Department, Bangladesh Agricultural University, Mymensingh

Saifullah Md. Hossain Saif, principal scientific officer, Agricultural Engineering, Bangladesh Agricultural Research Council, Dhaka

Bhutan (1)

Shamba Tshering, extension officer, Department of Agriculture, Ministry of Development, Thimphu

Burma (3)

Hla Kyin, head of branch, Training Centre, Meiktila

Kyaw Tun, head of branch, No. 1, Base Workshop, Agricultural Mechanization Department, Rangoon

Than Tun, head of branch, No. 459, Prome Road, Agricultural Mechanization Department, Rangoon

China (2)

Wang Yue, engineer, Chinese Academy of Agricultural and Mechanical Sciences, Beijing

Xia Xiaodong, engineer, Chinese Academy of Agricultural and Mechanical Sciences, Beijing

India (2)

D. M. Bhandarkar, scientist S-1 (W & SE), Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh

Jaswinder Singh Atwal, scientist S-1 (Farm Machinery & Power), All India Coordinated Research Project for Dryland Agriculture, Saidabad, Hyderabad

Philippines (4)

Rolando Ansale, farm management technologist, Ministry of Agriculture, Cagayan de Oro City

Arthur Benedicto, Design and Production in-charge, Grain Master Metalcraft, Davao del Norte

Bibiano Buenacosa, manager, F. Buenacosa Repair Shop, Sultan Kudarat

Balbino Geronimo, research assistant, AMDP/CEAT, University of the Philippines at Los Baños, College, Laguna

Sri Lanka (2)

Dissanayake M. Ariyaratne, agricultural instructor, Farm Mechanization Research Centre, Maha Illuppallama

Manfred Guntz, consultant, Farm Mechanization Research Centre, Maha Illuppallama

Thailand (2)

Surasak Bamrungwong, lecturer, Faculty of Engineering, Chiang Mai University

Maitree Preecha, agricultural engineer, Subdivision of Farm Mechanization, Department of Agricultural Extension, Bangkok

Vietnam (1)

Pham Duc Long, mechanical engineer, Ministry of Agriculture

International activities

COLLABORATIVE RESEARCH

In IRRI's plan for the third decade, it "will seek to develop annual collaborative work plans with those countries where there is need for greater rice production. These plans will cover research, training, information, and extension services."

During 1983, collaboration with many national programs became much more comprehensive and realistic in number of joint projects. Regular meetings were held with appropriate administrators and scientists from national programs. Some meetings were at IRRI; others were in the country concerned so that administrators could visit experiment stations to see research in progress and identify challenges for future attention. Collaborative efforts continue with China, Cuba, India, Indonesia, Japan, and South Korea.

INTERNATIONAL PROGRAMS

In 1983, IRRI maintained cooperative national projects in Indonesia, Bangladesh, Thailand, the Philippines, Burma, and Egypt.

Indonesia. Agricultural development was difficult in 1983. The worldwide recession caused priorities to be reordered, administrative changes made, and new directions implemented. Drought was serious and BPH infestation severe in North Sumatra. Despite those difficulties, about 24 million t of milled rice was produced, slightly more than in 1982. Upon request, about 20 t of IR56 was airlifted to Indonesia to suppress the spread of BPH. A modest hybrid rice program initiated in 1982 progressed during 1983 with IRRI consultants assisting in programming.

After 10 yr of extensive collaboration, in-country IRRI activities took on a lower profile in 1983. A consultant continued work in farming systems and another in agricultural engineering. The program liaison scientist retired after 6 yr and was succeeded by a new representative.

Bangladesh. The cooperative research and training programs with the Bangladesh Rice Research Institute (BRRI) continues to be funded by the Ford Foundation and the Governments of Australia, Canada, and the United States.

Bangladesh had a series of good rice harvests. Farmers continued to increase acreage of MVs during aus seasons, with BR10 and BR11 quite common during transplanted aman. Fertilizer use continued to increase despite a subsidy reduction, but average use is only a fraction of recommended levels. BRRI released four new varieties for boro and aus: BR12, 14, 15, and 16.

Donors approved continuation of the IRRI deepwater rice breeder position through 1985, a recommendation of the 1982 external review. Since the government did not approve purchase of certain properties and equipment, some phases of the project were behind goals set for the year.

Four IRRI scientists are in Bangladesh: a research systems specialist and IRRI representative, a rice production specialist, a rice breeder (deepwater rice), and an agricultural economist. The current project funding is scheduled to end in 1985. Near the end of 1983, preparations were made to propose a possible extension of the program from 1986 through 1990 to an anticipated external review group in late 1984.

Burma. The second phase of the Canadian-funded IRRI-Burma Cooperative Project was initiated. It consisted of three projects similar to the first: plant breeding, cropping systems, and agricultural engineering. The agricultural engineering project will be different since it is primarily based in Yezin. The plant breeding and cropping systems programs continued, following the format in phase I.

A comprehensive progress report about the cropping systems program was prepared. From the breeding program, six WS lowland selections, four DS lowland, and four low-elevation upland were recommended to the National Seed Committee for release. Three IRRI scientists (rice breeder, cropping systems agronomist, and agricultural engineer) are assigned to the project.

Thailand. IRRI research on deepwater rice is conducted collaboratively with the Ministry of Agriculture of Thailand. An IRRI agronomist and an entomologist work at the Huntra Research Station with a Thai deepwater rice research scientist. During 1983, the program was intensified

and more regional activities were assumed. Thailand is one of the sites for the small farm machinery industrial extension project similar to that in 1982. A Rockefeller Foundation staff member, who had been a rice breeder for 14 yr and also the coordinator of IRRI's rice program, was reassigned during the year.

Philippines. An IRRI scientist works with the Ministry of Agriculture (MA) on a cooperative project which emphasizes technology transfer. Significant progress was made in 1983. Technology transfer workshops were held on 11-13 Mar and 5-6 Oct, both involving input and interaction from IRRI senior scientists. An agricultural engineer also works with MA personnel in an industrial extension project similar to that in Thailand.

Egypt. IRRI's working relationship with Egypt continued under the 1982 format, with a program review during the year. The Third National Institute Conference was held in Cairo 21-24 Feb. The "Mabrouk 4" program now has about 25,000 feddans as centralized demonstration fields distributed over 48 sites in 6 northern delta communities.

REGIONAL PROGRAMS

The programs of liaison scientists at IITA (Ibadan, Nigeria) and CIAT (Cali, Colombia) continue as described in the 1982 annual report. The program in Africa followed up on recommendations from the October 1982 upland rice workshop at Bouaké, Ivory Coast. In Latin America, the Fifth Conference of the IRTP for Latin America was held 9-14 Aug. It focused on exchange of information about varietal improvement, regional IRTP activities, and recent studies of hoja blanca and its vector.

The liaison office in Indonesia intensified its activities in Malaysia and Brunei. The deepwater rice research group in Thailand consulted with colleagues working on deepwater rice in Bangladesh, India, and Indonesia.

Traditionally, graduate training has primarily been a collaborative effort with UPLB. In recent years, with the increase in graduate students, it has become more difficult to handle the additional students specializing in rice. Therefore, IRRI has developed several similar relationships with other agricultural colleges of national universities in countries with which the Institute has a long history of cooperative research.

Collaborative agreements were developed with Kasetsart University in Thailand, the Agricultural University of Malaysia in Serdang, and the Agriculture University at Bogor, Indonesia. These arrangements were patterned after the UPLB program which worked effectively for 25 yr.

Table 1. International networks coordinated by IRRI, 1983.

Network	Cooperating countries (no.)	Region	Cooperating scientists (no.)
International Rice Testing Program (IRTP)	69	Worldwide	785
Cropping Systems Network	10	Asia	10
INSFFER	17	Asia, Africa, Latin America	60
Agricultural Machinery Network	7	Asia, Latin America	22

GLOBAL RESEARCH SERVICES AND INTERNATIONAL RESEARCH NETWORKS

The administrative organization of IRRI was restructured to meet a growing need for expanded service to national programs. Certain activities and departments were established as Global Research Services. They are the

- International Rice Testing Program,
- International Rice Germplasm Center,
- Communication and Publications Department,
- Rice Farming Systems Program, and
- Training and Technology Transfer Department.

The INSFFER continues to expand and intensify its activities from the Department of Agronomy. The Agricultural Machinery Network operates within the framework of the Industrial Extension Project. IRRI continues to serve as a catalyst in the planning and implementation of national research activities and transfer of technology (Table 1).

Table 2. IRRI-sponsored or cosponsored workshops, conferences, reviews, and meetings held at IRRI in 1983.

Event	Date	Participants
Annual program review	25-28 Jan	18
FAO-IRRI insecticide selectivity/specificity	21-23 Feb	39
ORD-IRRI collaborative research planning meeting	28 Feb-2 Mar	26
Workshop on food and development	1-4 Mar	38
MA-IRRI technology transfer workshop	11-12 Mar	62
International rice research conference	18-22 Apr	226
Rice genetic conservation workshop	25-26 Apr	63
Crop livestock workshop	25-28 Apr	32
Interagency joint committee meeting on Masagana 99	29 Apr	36
Crop Science Society of the Philippines 14th annual meeting	2-4 May	428
Biological nitrogen fixation advisory committee meeting	9-13 May	32
Rice crop modeling workshop	16-18 May	16
IRRI academic council meeting	2 Aug	35
Women in rice farming systems conference	26-30 Sep	76
MA-IRRI technology transfer workshop	5-6 Oct	67
Semidwarf mutant for rice improvement workshop	24-28 Oct	26
Copublication: strategies for multilanguage publication in agriculture	28 Nov-1 Dec	64
		1284

IRRI CONFERENCES

Conferences and workshops continued to bring together international participants (Table 2). Traditionally the International Rice Research Conference (IRRC) has been held annually in April. After the 1983 IRRC, a comprehensive review was made of its nature and role. It was decided to vary the IRRC site beginning in 1984.

Information resources, experimental farm, and service laboratories

LIBRARY AND DOCUMENTATION CENTER

Bibliographies. The 1982 Supplement to the *International Bibliography of Rice Research* was published in 1983. It is the third computerized supplement jointly produced by the Library and Statistics Department. It contains 6,081 references to scientific rice literature, most of which appeared in journals in 1982. Its coverage is worldwide and the items of reference are classified according to subject matter. The supplement includes literature written in 24 languages and a list of 102 rice literature translations, mostly from Chinese to English. It has an author index and a keyword index. Bibliography supplements for 1971-83 have already been fed into the computer system. Computer retrieval of rice information will begin soon.

The 5-yr cumulative index covering the 1976-80 supplements was also published in 1983. It was computer produced and is divided into author and keyword indexes. It is the fourth cumulated index; the first covered 1961-65; the second, 1966-70; the third, 1971-75.

The 1983 supplement to *Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute* lists 132 titles, bringing the overall collection to 1,375.

The *International Directory of Rice Workers,* a listing of scientists, administrators, and extension specialists of the rice world, was also published in 1983. It gives the name, date of birth, marital status, children, nationality, field of specialization, education, membership in professional organizations, awards, professional experience, and address of people listed. Workers are first listed alphabetically with their biographic information, then by country, and finally by field of specialization. The directory was compiled to facilitate contacts and enhance information exchange among rice workers.

All new bibliographies and the directory were sent to agricultural libraries and documentation centers of rice-producing regions. All citations in the bibliographies are available at IRRI.

Reference and circulation. Within IRRI, the number of books, journals, and other library materials borrowed during 1983 increased markedly. As in previous years, requests for copies of Japanese literature on genetics and breeding exceeded those for literature on all other aspects of rice culture. Requests for photocopies of papers on water management and irrigation and for short specific-subject bibliographies were also received. IRRI assistance in library organization and management, and in the selection and acquisition of agricultural materials was also sought. The greatest number of requests came from India and Bangladesh, followed closely by those from Malaysia and the United States. A substantial number was also received from the Latin American countries and Africa.

Library holdings. An additional 4,106 books, pamphlets, and reprints increased the monograph collection to 66,528. Also added were maps, translations, microfilms, and 196 serial titles from subscriptions, exchanges, and donations.

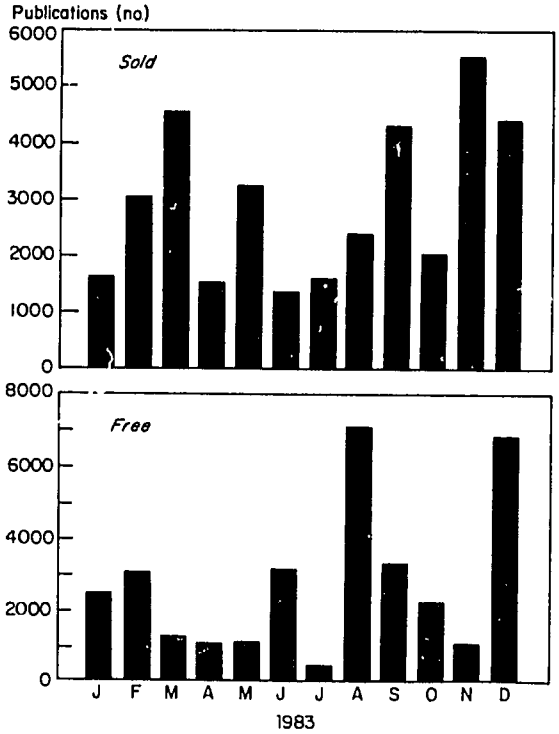
Other library activities. To inform scientists of the latest rice publications, tables of contents of newly received journals continued to be routed within IRRI, and to the Bangladesh Rice Research Institute; Central Research Institute for Food Crops, Indonesia; and the West Africa Rice Development Association, Liberia.

The library continued to purchase and distribute books to IRRI research scholars and other training participants.

COMMUNICATION AND PUBLICATIONS DEPARTMENT

In Mar 1983, the Information Services Department became part of the newly established Global Research Services and was renamed Communication and Publications Department (CPD).

CPD distributed 69,792 copies of major publications during the year. About 53% were free, mostly to key third world libraries, and the remainder were sold (Fig. 1).



1. Distribution of publications by the Communication and Publications Department, IRRI, 1983.

Major publications. Fifteen publications were released in 1983:

- *Cell and Tissue Culture Techniques for Cereal Crop Improvement*
- *1983 Rice Germplasm Conservation Workshop*
- *Field Problems of Tropical Rice (rev. ed.)*
- *Weed Control in Rice*
- *Adoption, Spread, and Production Impact of Modern Rice Varieties in Asia*
- *Symposium on Potential Productivity of Field Crops Under Different Environments*
- *Technical Handbook for the Paddy Rice Postharvest Industry in Developing Countries*
- *Consequences of Small-Farm Mechanization*
- *Copublication: IRRI Design, Procedures, and Policies for Multilanguage Publication in Agriculture*
- *Publications on International Agricultural Research and Development (Catalog of Publications of International Agricultural Research Centers)*
- *Annual Report for 1982*
- *Research Highlights for 1982*
- *International Bibliography of Rice Research for 1982*
- *Upland Rice: An International Bibliography, 1965-1982*
- *International Directory of Rice Workers*

Serial publications. Four issues of the *IRRI Reporter* were published and distributed to about 14,000 rice workers. Six issues of the *International Rice Research Newsletter* and *Subject Index for 1982* were published. Thirteen issues of the IRRI Research Paper Series were put out:

No. 86 New rice technology, intrarural migration, and institutional innovation in the Philippines

No. 87 RICEMOD: A physiologically based rice growth and yield model

No. 88 Sensitivity tests of the environmental variables in RICEMOD

No. 89 Sensitivity tests of the crop variables in RICEMOD

No. 90 New rice technology and labor absorption: comparative histories of two Philippine rice villages

No. 91 Calculating the private benefits of farm machinery: a microcomputer application

No. 92 Cropping systems research in the Pangasinan project

No. 93 Estimating risk of fertilizer use in rainfed rice production

No. 94 Sensitivity tests of the environmental variables in IRRIMOD

No. 95 Sensitivity tests of the crop and management variable in RICEMOD

No. 96 Fertilizer transfer to floodwater during deep placement

No. 97 Interaction between fertilizer and weed control methods in Philippine upland rice: estimates from farmers' fields

No. 98 Training needs of information services in agricultural research and educational organizations in Asia: a 9-country survey

Book exhibits. IRRI and the German Agency for Technical Cooperation (GTZ) cosponsored an exhibit of books from the international agricultural research centers (IARCs) at the 1983 Frankfurt Book Fair 12-18 Oct. Seventeen IARCs displayed about 1,000 titles of books, periodicals, slide sets, and films. The fair brought together center information officers and international publishers interested in joint publishing arrangements and

exposed center publications to the world's book distributors and librarians. IRRI exhibited about 200 major books, audiotutorial modules, and periodicals at the Fair. GTZ also hosted the CGIAR communication workshop, which was held in Eschborn immediately after the fair.

IRRI coordinated the exhibition of center publications in the World Agricultural Book Fair — 4 10-d exhibits in Beijing, Wuhan, Guangzhou, and Sian, China, in October 1983. This was a follow-up of the first IARC Book Exhibit in China, sponsored by IRRI and the China National Publications Import and Export Corporation in 1982.

CPD also arranged for IRRI exhibits at fairs in Singapore, Manila, Bangkok, Jakarta, Honolulu, and Kuala Lumpur.

Copublication workshop. An international workshop — Copublication: Strategies for Multilanguage Publication in Agriculture — was held 28 Nov-1 Dec 1983 at IRRI. It was the first to focus on strategies to alleviate the language barrier in agricultural development. IRRI and Canada's International Development Research Centre (IDRC) were cosponsors.

The meeting attracted 62 publishers, communicators, and administrators from national programs, and development groups in Asia, Africa, and Latin America. Sessions focused on design techniques, policies, and strategies to encourage copublication. The establishment of a multilanguage communication network for agriculture was recommended, and several donor agencies expressed interest in supporting a 1-yr pilot project to test its feasibility.

Copublication. *A farmer's primer on growing rice* has been published in 13 languages, and at least 15 other editions are in preparation. The revised edition of *Field problems of tropical rice* is being translated into about 20 languages.

EXPERIMENTAL FARM

On the upland farm, more than one-half ha of block UL was converted into a lowland rice field for the Multiple Cropping Department.

A drainage pipe line leading to Boot Creek was constructed at the low portion at the end of block G to convert the area into a deepwater field for floating rice experiments.

UPLB gave plots 27-28 in block B to IRRI in exchange for the same number of plots in block C. The Experimental Farm has planted some of the plots for seed production. When the crop is harvested, the Plant Breeding Department will be in charge of the whole area.

Plots 51-56 and 60 in A series, which had been previously assigned to the Training and Technology Transfer Department, were used for seed increase by the Experimental Farm.

Preliminary planting of rainfed and irrigated rice varieties was done on blocks R and S for the "Demonstration Cum-Training Program on Improving the Efficiency of Production and Utilization of Rice Biomass."

The new 4-wheel drive Iseki tractors will reduce land preparation cost on the lowland farm in 1984.

Plans were made to divert the Mabacan irrigation canal to a new location to increase the rice field area by more than 1 ha in blocks 700 and 1000.

The coconut area near the greenhouse in block A was cleared and construction of new greenhouses began.

About 190 ha (a 6.9% decrease) was planted on the lowland rice farm during 1983 WS and DS and about 116 ha on the upland farm. Multiple Cropping planted the largest area, followed by Agronomy, Experimental Farm, Plant Breeding, Training and Technology Transfer, Entomology, Plant Pathology, and IRTP.

About 25 ha was used for multiplication of seeds of IR29, IR36, IR42, IR43, IR45, IR48, IR50, IR52, IR56, IR58, IR60, IR841, IR13429-299-2-1-3, IR9752-71-3-2, IR13525-43-2-3, IR1972-155-1-1-3, SS169, IR19672-140-2-3-2-2 SS159, IR19672-140-2-3-2-2 SS159, and IR2973-143-3-2-1. About 61.5 t of rice was produced for seed and 42.6 t for milling.

About 171.8 t of fertilizer valued at $34,009 were used on the experimental farm. This is 5.78 t higher than that of last year. AS accounted for 48.4% of the total consumption, followed by 14-14-14 complete, 18.86%; urea, 15.08%; solophos, 13.15%; muriate of potash, 4.25%; zinc sulfate, 0.23%; and zinc oxide, 0.03%.

The expenditure for insecticides and sticker was

Table 1. Summary of analysis done by the Chemical Analysis Laboratory. IRRI, 1983.

Property analyzed	Determinations (no.) on samples		
	Soil	Plant	Water
Total elements (S, Ca, Al, Fe, Mn, K, Na, Mg, P, Cu, Zn, B)	–	29,525	4,736
Total N	5,156	37,820	–
EC	717	–	66
CEC	2,672	–	–
Available P, K, Zn, Cu, B	7,723	–	–
Organic C	3,314	–	–
Special Si	–	40	–
Perchloric acid P, K, Mg, Zn, Fe, Mn, Cu, Ca, Al	942	–	–
Exchangeable Na, K, Mg, Ca	8,955	–	–
pH	2,655	–	1
Ammonia and urea	–	–	34,105
Particle size analysis	1,583	–	–
Total	33,717	67,385	38,908
Samples (no.)	5,948	39,861	21,023
Sample preparation done	4,168	16,780	

$64,821.60, $15,412.50 higher than last year, partly because of price increases. There was a serious outbreak of RTV in 1983.

The herbicides for weed control on production plots, levees, ditches, and roadways was $15,094.50, an increase of $2,267.30 or 17.67%. Contract labor cost $219,281.60, up by 11.9%.

The farm income for 1983 ($32,889.20) increased by $8,540. It was derived from the sale of rice for seed, rice for milling, milled rice, milled glutinous rice, green supersweet maize, flint maize, soybean, and rice bran.

ANALYTICAL SERVICE LABORATORIES

Chemical Analysis Laboratory. The Chemical Analysis Laboratory ran 140,010 determinations on 66,832 soil, plant, and solution samples (Table 1). To improve efficiency in preparing laboratory results, a North Star Horizon System was purchased for data acquisition and processing.

Mass Spectrometer Laboratory. The Mass Spectrometer Laboratory analyzed the ^{15}N-to-^{14}N ratio in 5,391 samples of floodwater (160), soil (3,880), and plant extracts (1,351).

Radioisotope Laboratory. The laboratory measured 2,390 samples for ^{14}C activity using the HP Liquid Scintillation Counter and the Varian Vibrating Reed Electrometer.

PESTICIDE RESIDUE LABORATORY

The Pesticide Residue Laboratory received 478 samples for complete analysis in 1983. Two hundred eighty-eight samples were formulations of carbofuran, diazinon, isoprocarb, and monocrotophos analyzed for the Entomology Department. The Agricultural Engineering Department submitted 144 samples of paddy water and 18 samples of tilapia for analysis of carbofuran and Ciba-Geigy 73102 pesticides. The remainder of the samples were submitted by the Cereal Chemistry Department for analysis of carbofuran and BPMC in rice straw.

The Cereal Chemistry Department also submitted 316 samples for injection into the PRL gas liquid chromatographs. Sixteen samples were aldononitrile derivatives of cell wall sugars, and 300 were extracts from rice plants for determination of insect resistance factors.

PHYTOTRON

Forty research projects from 10 IRRI departments and UPLB used the phytotron in 1983. The

glasshouse room had the highest occupancy (93%) followed by the naturally lighted cabinets (87%). Occupancy of other environmental rooms and cabinets ranged from 34 to 78%. The screenhouse was used at full capacity throughout the year. About 50% of the cold room space was used to store RGA bulk rice seeds. The drying oven intended for phytotron users accommodated 114 requests from other departments and was used heavily throughout 1983.

A 1-h course in Apr 1983 familiarized 31 participants in the use of phytotron facilities.

Publications and seminars

PUBLICATIONS

Administration

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SEMINARS

The seminars held at IRRI during 1983 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

Enemies of biological nitrogen fixation from molecular to ecological level. Dr. I. Watanabe.

Adaptation of germinating rice to submergence. Dr. H. Greenway, plant physiologist, School of Biological Sciences, University of Sussex, UK.

A method for classifying and evaluating environments for selection. Dr. K. Brown, deepwater rice breeder, Research Management International, Kalimantan, Indonesia.

Improvement of postharvest facilities and systems and progress in grain protection. Mr. N. Teter, Technical Team Member, SEARCA Post-Harvest Research and Development Program, Los Baños, Laguna, Philippines.

Degradation of pesticides in flooded soils. Dr. S. Kuwatsuka, professor of soil science, Nagoya University, Chikusa, Nagoya, Japan.

Training needs of information services in agricultural research and educational organization in Asia: a 9-country survey. Dr. G. Somasekharappa, postdoctoral fellow, Communication and Publications Department.

This is CIMMYT. Ms. L. Ainsworth, head, Visitors and Conference Service, CIMMYT.

Returning (pest) control to villagers: the FAO intercountry IPC (rice) programme. Mr. P. Kenmore, liaison-training officer, FAO, Philippines.

Slide wars: my slide is better than yours. Mr. E. P. Hettel (visiting editor) and Mr. W. H. Smith, Communication and Publications Department.

Radar as an aid to the study of insect flight. Dr. J. R. Riley, head, COPR Radar Unit.

Analysis of the genetic structure of *Oryza sativa* L. by isozymes study. Dr. J. C. Glaszmann, postdoctoral fellow, Plant Breeding Department.

Breeding for salinity resistance in rice — a physiologist's view. Dr. T. J. Flowers, Agronomy Department, University of Western Australia, Australia.

Integrated organic farming. Dr. G. D. Para, Iloilo City.

Do's and don't in rat control. Mr. O. G. Santos.

The physiological responses and agronomic importance of leaf expansion to water deficits in sunflower. Dr. N. C. Turner, visiting scientist, Agronomy Department.

What can sunflower teach rice about withstanding water stress. Dr. N. C. Turner, visiting scientist, Agronomy Department.

Response of four leafhoppers and planthoppers to three volumes and rates of monocrotophos. Dr. S. Alam, senior research fellow, Entomology Department.

Plant chemicals and insect resistance. Dr. D. Dale, senior research fellow, Cereal Chemistry Department.

New deep placement applicators for minimum N transfer to floodwater. Dr. A. U. Khan.

Mechanization of agriculture in RNAM countries. Prof. A. C. Pandya, project manager, RNAM, Los Baños, Philippines.

Fun with fungi: *Peronosclerospora sorghi* and the three S's of Thai culture. Dr. J. M. Bonman.

Monitoring and simulation of Asian corn borer populations. Dr. J. A. Jackman, pest forecasting specialist, NCPC, UPLB, Laguna.

Plant protoplast culture: its applications in agriculture. Dr. F. J. Zapata.

Pest management on the IRRI farm. Mr. T. J. Perfect, visiting scientist, Entomology-COPR.

IRRI's physics activity. Dr. T. Woodhead.

The Himalayas from Vedic to present time and its influences on life. Dr. B. S. Shahu, senior research fellow, Plant Breeding Department.

Management of fishponds in acid sulfate soils. Dr. V. P. Singh, Fisheries Department, UP in the Visayas, Iloilo, Philippines.

How to manage your time. Ms. G. Rivera, director, In Touch Foundation, Makati, Metro Manila.

Risk and technology: is econometrics relevant to biological scientists? Dr. J. Smith, postdoctoral fellow, Agricultural Economics Department.

The long-range dispersal of plant viruses by arthropod vectors. Dr. J. M. Thresh, deputy head, Plant Pathology Department, East Malling Research Station, Maidstone, Kent, England.

Ecological model of malnutrition. Dr. M. Nube, programme officer and visiting associate professor in human nutrition and foods, UPLB-FNP, College, Laguna.

Rice nematode diseases. Dr. J. Bridge, CAB Tropical Plant Nematology Adviser, Commonwealth Institute of Parasitology, St. Albans, Herts, UK.

Factors affecting agricultural growth in Asia — experience of the last decade. Dr. V. S. Vyas, IDRC senior research fellow, Asian Development Bank, Manila.

A cultural anthropological approach to agricultural decision making by farmers. Dr. A. Polak, visiting anthropologist, Agricultural Economics Department.

Computers: who needs them? An introduction to computer basics. Ms. J. B. Wood, consultant, IRTP and Computer Center.

Los Baños: the special university zone. Mr. A. O. Nocon, municipal mayor, Los Baños, Laguna.

Consumer demand for grain quality. Dr. L. J. Unnevehr, research associate, Agricultural Economics Department.

Genetic evaluation for insect resistance in rice. Dr. E. A. Heinrichs.

Advances in dryland crop improvement work at the Institute of Plant Breeding. Dr. R. M. Lantican, director, Institute of Plant Breeding, College, Laguna.

Agroclimatology, typhoon, and food production. Dr. L. R. Oldeman, visiting scientist, Multiple Cropping Department.

The effect of plant spacing on the response to plant selection. Dr. T. Kramer, Institute of Plant Breeding, Wageningen Agricultural University, The Netherlands.

Mimosine: biocidal properties and mechanisms of toxicity. Dr. E. M. T. Mendoza, research biochemist, Institute of Plant Breeding, UPLB.

Technology transfer — the Philippine outreach program. Dr. D. M. Wood.

Crop protection in the Philippines. Dr. F. F. Sanchez, director, National Crop Protection Center, UPLB.

Agricultural equipment for the Philippines: dryers, fertilizer applicators, reduced tillage equipment, and other priorities. Dr. R. E. Stickney.

Maximal utilization of rice straw for food and feeds through mushroom cultivation. Dr. T. H. Quimio, associate professor, Plant Pathology Department, UPLB.

Saturday seminars

Inheritance of and breeding strategies for blast resistance. Dr. Hak-Soo Suh, postdoctoral fellow, Plant Breeding Department.

Inoculation of N_2-fixing bacteria to lowland rice. Dr. Lin Chang, research scholar, Soil Microbiology Department.

Cytogenetical and electrophoretic study on the relationship among aus, bulu, and upland rices (*Oryza sativa* L.). Mr. Chu-Chi Ren and Mr. Pan Yong-Bao (research scholars) and Dr. T. T. Chang, Plant Breeding Department.

The role of analytical service laboratories in rice research. Ms. R. Castro.

Preliminary tests of a low-cost paddy dryer utilizing rice hulls. Dr. B. Shukla, postdoctoral fellow, Agricultural Engineering Department.

Problems and solutions in the analysis of survey data: a Philippine case study. Ms. P. Lim.

Performance of a common metering device for prilled, forestry-grade, and supergranular urea fertilizer. Mr. E. Bautista, research scholar, Agricultural Engineering Department.

Status of chemistry-entomology cooperative study on the chemical basis of rice plant resistance to stem borer and brown planthopper. Dr. B. O. Juliano.

Problems and potentials of rice straw utilization as animal feed. Dr. D. B. Roxas, assistant professor, Institute of Animal Science, UPLBCA.

Inheritance of resistance to planthoppers and leafhoppers in rice. Mr. E. R. Angeles, Ms. E. H. Bacalangco, and Dr. G. S. Khush.

Current status of hybrid rice research at IRRI. Dr. S. S. Virmani.

Movement and distribution of deep-placed nitrogen in wetland rice. Ms. W. N. Obcemea and Dr. S. K. De Datta, IRRI, and Dr. F. E. Broadbent, professor of soil microbiology, Department of Land, Air, and Water Resources, University of California, Davis, California.

Adaptation of food legumes to water stress using the line source sprinkler system. Dr. R. K. Pandey, senior research fellow, Multiple Cropping Department.

Influence of bed soil upon the use of soil-bearing seedlings in the IRRI manual transplanter. U Mya Thein, research scholar, Agricultural Engineering Department.

Comparisons of rice simulation models RICEMOD and IRRIMOD. Dr. F. D. Whisler, visiting scientist, Multiple Cropping Department.

Tropical wheat cultivation technology for the post-rice crop. Mr. S. P. Liboon.

Collaborative research on rice-based cropping systems in Asia. Dr. V. R. Carangal.

Utilization of hydrogen by N_2-fixing bacteria associated with wetland rice. Dr. T. K. Gowda, postdoctoral fellow, Soil Microbiology Department.

Methods of studying blue-green algae in the paddy field. Dr. P. A. Roger, visiting scientist, Soil Microbiology Department.

Dual culture of rice and azolla. Mr. R. Oliveros.

Green leafhopper resistance in rice. Ms. H. Rapusas.

Sampling and insecticide management for rice hoppers and their predators. Dr. F. O. Cariño, Dr. V. A. Dyck, Dr. O. Mochida, Dr. S. Alam (senior research fellow), Mr. T. J. Perfect (visiting scientist), and Mr. S. de Sagun, Entomology Department.

Mass screening of rices for drought resistance at flowering stage. Mr. R. P. Novero, Dr. J. C. O'Toole, Mr. R. T. Cruz, and Dr. D. P. Garrity.

Neem oil and neem extracts as potential insecticides for control of hemipterous rice pests. J. von der Heyde, research fellow, Entomology Department.

Factors affecting population development in the brown planthopper. Dr. A. G. Cook, visiting scientist, Entomology Department.

Rice seed health tests. Mr. S. D. Merca.

Rice tungro disease as influenced by fertilizer nutrition and the effect of seed oils on insect vector transmission. Dr. V. Mariappan, postdoctoral fellow, Plant Pathology Department.

RGSV 2 — a strain of rice grassy stunt virus. Mr. P. Q. Cabauatan.

Experiment with sheath rot of rice. Mr. Ken-Chang Chuke, research fellow, Plant Pathology Department.

A comparative assessment of three irrigation subsystems at Central Luzon: a progress report. Mr. A. Valera, Mr. D. M. Cablayan, Mr. M. M. Alagcan, and Dr. A. C. Early.

Farmer cooperation for efficient allocation-distribution of water in irrigation systems. Mr. G. Dozina.

Economic impact of irrigation on rice production in Camarines Sur: the case of the LCPIS. Ms. P. Moya, Ms. M. A. Lantican, and Dr. S. I. Bhuiyan.

Rainfed rice production in Tarlac, Philippines. Mr. P. B. Masicat, Mr. V. P. Marciano, and Dr. J. C. Flinn.

Cropping patterns farmers grow and why they choose them. Mr. R. F. Rañola, Ms. A. L. Frio, and Dr. E. C. Price.

Risk aversion and the fertilizer gap. Ms. G. Umali.

Effect of zinc fertilization on the mineral nutrition of rices differing in tolerance to zinc deficiency. Mr. M. T. Cayton, Dr. E. D. Reyes (director for research, UPLB), and Dr. H. U. Neue.

Risk and fertilizer use on rainfed rice in Bicol, Philippines. Dr. J. Smith, Ms. G. Umali, Dr. M. Rosegrant, and Mr. A. M. Mandac.

A study of some characteristics of five coastal saline soils in relation to their suitability for rice production. Mr. R. Y. Reyes, Mr. G. M. Panaullah (research fellow), and Dr. H. U. Neue, Soil Chemistry/Physics Department.

Influence of salinity of water regime on the chemical changes and growth of rice in a coastal peat soil. Mr. G. R. Jayaweera (research scholar) and Dr. H. U. Neue, Soil Chemistry/Physics Department.

Update on ammonia volatilization and the role of urease inhibition in increasing N use efficiency. Ms. E. V. Flordeliz, Mr. E. G. Castillo, Ms. M. del Rosario, Dr. I. R. Fillery, and Dr. S. K. De Datta.

Rice ratooning. Dr. J. S. Chauhan (postdoctoral fellow) and Dr. B. S. Vergara, Plant Physiology Department.

Progress of rice anther culture at IRRI. Dr. F. J. Zapata.

Constraints to rice yields in farmers' fields. Mr. F. Garcia, Mr. W. Abilay, Jr., and Mr. J. Alcantara.

Physiological analysis of heterosis in rice. Dr. M. Yamauchi (postdoctoral fellow) and Dr. S. Yoshida, Plant Physiology Department.

Special seminars

Human dimensions of irrigation water delivery systems for small farmers in the Philippines. Dr. F. T. Rivera, dean, Graduate Studies, Central Luzon State University, Muñoz, Nueva Ecija.

Progress and problems in the use of tissue culture to obtain stress-tolerant cereals. Prof. M. W. Nabors, Tissue Culture for Crops Project, Department of Botany and Plant Pathology, Colorado State University.

Breaking the yield barrier in rice. Dr. M. S. Rahman, postdoctoral fellow, Plant Physiology Department.

Science and religion at IRRI. Dr. R. W. Herdt.

Tissue culture studies on rice and other crops. Prof. G. M. Reddy, professor and head, Department of Genetics, Osmania University, Hyderabad, India.

Biotechnology's impacts in agriculture: a socioeconomic perspective. Dr. M. Kenney, research associate, Cornell University, Ithaca, New York, USA.

The new agriculture: a view from the 21st century. Dr. S. G. Wittwer, director, Agricultural Experiment Station, and associate dean and professor of horticulture, College of Agriculture and Natural Resources, Michigan State University, East Lansing, Michigan.

Nitrogen and water stress interactions in simulated rainfed wetland rice. Mr. J. L. Padilla, Dr. J. C. O'Toole, Dr. I. R. Fillery, and Dr. S. K. De Datta.

The International Rice Research Institute — a progress report. Dr. M. S. Swaminathan.

Terrace planning criteria for various slopes and soils. Mr. P. Jacobson, consulting engineer (formerly conservation engineer, Soil Conservation Service, USDA).

China review. Dr. H. Hanson, former director general, CIMMYT, Mexico.

IR varieties in India. Dr. S. S. Nagarajan, chief agricultural economist, Tractors and Farm Equipment Limited, Madras, India.

Tourist spots in the Philippines. Mrs. B. Montfort, chief, Circulation Department, Ministry of Tourism; and PAL representative.

Status of mycology. Prof. C. V. Subramanian, Centre for Advanced Study in Botany, University of Madras, India.

Some reflections of a liaison scientist. Dr. J. Ritchie Cowan, IRRI liaison scientist for Indonesia and Malaysia.

Agricultural development and human fertility. Prof. S. Stokes, rural sociologist, Pennsylvania State University.

Genetic resources — an overview. Dr. J. G. Hawkes, emeritus professor of botany, the University of Birmingham, Department of Geological Sciences.

Acid sulphate soils in Thailand. Mr. J. F. Osborne, soil chemist, ODA, Acid Sulphate Soils Improvement Project, c/o Soil Analysis Division, Department of Land Development, Bangkhen, Bangkok, Thailand.

Somaclonal variation in celery: selection for resistance to *Fusarium oxysporum* f. sp. *apii*. Dr. L. Rappaport, chairman, Department of Vegetable Crops, University of California, Davis, California, USA.

Biology of insects and their evolution, with special reference to seasonal activities of field crickets, Dr. S. Masaki, entomologist, Hirosaki University, Aomori Prefecture, Japan.

Precision spaced planter for exact numeric planting of all kinds of seeds. Mr. W. Betzwar, export manager, F. Walter & H. Wintersteiger KG, Exportburo, A-1037 Wien, Austria.

Applications of plant tissue culture in agricultural research. Dr. M. R. Sondahl, manager, Tropical Plant Genetics, DNA Plant Technology Corporation, New Jersey.

Gene organization and regulation in the quinic acid (QA) gene cluster of *Neurospora crassa*. Prof. N. H. Giles, Callaway professor of genetics, Department of Molecular and Population Genetics, University of Georgia, Athens, Georgia.

Application of plastics for agriculture. Mr. M. Parthasarathy, member, Indian National Committee for Plastics in Agriculture, Madras, India.

Green revolution in Punjab, India. Dr. K. S. Gill, director of research, Punjab Agricultural University, Ludhiana, India.

Global view of agricultural research. Dr. W. T. Mashler, senior director, Division for Global and Interregional Projects, UNDP.

Effect of straw incorporation on growth and yield of rice in three soils. Dr. M. W. Thenabadu (senior research fellow), Ms. M. C. Robielos, and Dr. H. U. Neue, Soil Chemistry/Physics Department.

Source, time, and placement of fertilizer N and P for rice. Dr. R. B. Diamond, visiting scientist, Agronomy Department.

Finances

Summary of financial support to IRRI core and special projects received in 1983.[a]

	Core			
	Unrestricted	Restricted	Special Projects[b]	Total
U.S. Agency for International Development	$ 5,520,278.00	$ —	$1,891,133.69	$ 7,411,411.69
Japanese Government	—	3,331,292.10	300,511.51	3,631,803.61
Canadian International Development Agency	1,242,722.50	—	1,756,492.82	2,999,215.32
United Nations Development Programme	—	1,490,700.00	289,143.00	1,779,843.00
International Fund for Agricultural Development	—	1,700,000.00	—	1,700,000.00
Ministry of Overseas Development, UK	975,810.00	—	—	975,810.00
Australian Government	635,448.00	—	—	635,448.00
Federal Republic of Germany	533,728.59	—	7,528.00	541,256.59
International Bank for Reconstruction & Development	420,000.00	—	—	420,000.00
Government of Sweden	370,605.82	—	—	370,605.82
Asian Development Bank	—	—	326,500.00	326,500.00
Government of Saudi Arabia	300,000.00	—	—	300,000.00
International Development Research Centre	—	186,400.00[c]	110,385.36	296,785.36
International Centre of Insect Physiology & Ecology	—	61,906.00[c]	205,707.66	267,613.66
Ford Foundation	150,000.00	—	70,800.00	220,800.00
Government of Belgium	142,558.45	—	—	142,558.45
Government of Denmark	129,282.48	—	—	129,282.48
Government of India	122,748.00	—	—	122,748.00
Swiss Federal Council	—	120,510.97[c]	—	120,510.97
Government of the Philippines	105,396.63	—	—	105,396.63
Rockefeller Foundation	100,000.00	—	—	100,000.00
Government of the Netherlands	—	75,000.00	—	75,000.00
International Food Policy Research Institute	—	—	68,733.19	68,733.19
International Fertilizer Development Center	—	—	65,201.19	65,201.19
Government of Spain	25,000.00	—	—	25,000.00
Government of New Zealand	16,387.50	—	—	16,387.50
Others	—	—	—	305,590.87[d]
Total	$10,789,965.97	$6,965,809.07	$5,092,136.42	$23,153,502.33

[a]Receipts are accounted for on a cash basis. [b]Includes funds received from the International Centre of Insect Physiology and Ecology, International Food Policy Research Institute, and International Fertilizer Development Center in support of collaborative research arrangements. [c]Transferred Projects starting 1983. [d]Other donors were the Third World Foundation, 1982 Third World Prize to IRRI, $100,000.00; Office of Rural Development, Korea, $70,000.00; International Board for Plant Genetic Resources, $55,418.20; National Food and Agriculture Council, $29,204.23; Philippine Council for Agriculture and Resources Research and Development, $11,591.64; United Nations Environment Programme, $8,876.80, International Potash Institute and Potash and Phosphate Institute, $8,000.00; Ciba-Geigy, $5,000.00; Monsanto, $3,500.00; Stauffer Chemical Company, $3,000.00; SKTrostberg Aktiengesellschaft, $3,000.00; FMC International, $3,000.00; American Cyanamid Overseas Corporation, $2,000.00; Walt Disney Production Scholarship Fund, $2,000.00; KenoGard, $1,000.00. IRRI also received the following donations in kind. IBM Philippines provided IRRI the exclusive use of an IBM 4331 computer system for 4 yr beginning 1983. USAID donated excess property of an indeterminable value. Honda Philippines, Inc. donated 8 Honda engines and Marsson Industrial Corp. donated 5 Briggs and Stratton engines. In 1983, the governments of France (ORSTOM) and the Netherlands provided the Institute with visiting scientists; the value of their service cannot be quantified.

Staff changes

January

Dr. Felix N. Ponnamperuma, principal soil chemist, began a 9-1/2 mo sabbatic leave to work on a monograph, "Soil Health and Rice Growth."

Dr. Terence Woodhead, former head, Physics Department, Rothamsted Experimental Station, joined the IRRI staff as physicist.

Dr. Dennis M. Wood, former senior scientific officer, National Academy of Sciences, joined the IRRI staff as crop production specialist.

Dr. Ian F. Grant, of Boyce Thompson Institute, began a 1-yr assignment as visiting associate soil microbiologist, Soil Microbiology Department.

Prof. Harold C. Conklin, anthropologist, Yale University, joined IRRI as honorary visiting research associate.

Dr. Elvis A. Heinrichs, entomologist, completed a 6-mo sabbatic leave at the University of Nebraska.

Dr. Leonard R. Oldeman of the Soil Survey Institute at Wageningen was granted a 2-yr extension of his assignment as visiting scientist at the Multiple Cropping Department.

March

Dr. Robert E. Huke, professor of geography, Dartmouth College, completed a 3-mo assignment as visiting scientist, Agricultural Economics Department.

Dr. Albert A. Polak, senior scientist, Agricultural University of Wageningen, joined IRRI as visiting scientist, Agricultural Economics Department.

Mr. Malcolm M. Hammond, agricultural engineer, USAID/Indonesia, joined IRRI as agricultural engineer with the Cooperative IRRI/Burma Project.

Dr. Masao Kikuchi, associate agricultural economist, resigned.

Mr. Marvin L. Nafziger, associate agricultural engineer, resigned.

Ms. Posalind M. Wilson, magazine editor of Target, Living Media India Limited, worked as consultant with the Communication and Publications Department.

April

Dr. Seung-Chan Lee, head of the Plant Pathology Department, Office of Rural Development, Korea, began a 2-yr assignment as visiting plant pathologist with the Plant Pathology Department.

Dr. John A. Wicks, associate agricultural economist, Agricultural Engineering Department, resigned.

Dr. Gun Sik Chung, rice breeder, Office of Rural Development, Korea, completed his assignment as visiting scientist with the Plant Breeding Department.

Dr. Bienvenido O. Juliano, chemist, began a 1-yr sabbatic leave partly at the University of California, Berkeley, and at SEARCA.

Ms. Rebecca C. Pascual, manager, Food and Housing Services, began a 6-mo sabbatic leave at the International Management Institute in Geneva and at the Food Services Department, Virginia Polytechnic Institute and State University, USA.

May

Dr. Keith Moody, agronomist, completed his 1-yr sabbatic leave at the Weed Research Organization, England.

June

Dr. Marlin G. Van Der Veen, formerly with IADS, Nepal, joined the IRRI staff as network economist, Agricultural Economics Department.

Dr. Alan C. Early, associate agricultural engineer, Irrigation Water Management, resigned.

Mr. Michel Arraudeau, IRAT plant breeder, joined the Institute staff as visiting scientist, Plant Breeding Department.

Dr. Neil C. Turner, principal research scientist, CSIRO, completed his assignment as visiting scientist, Agronomy Department.

Dr. Frank D. Whisler, professor of soil physics, Mississippi State University, completed his assignment as visiting scientist, Multiple Cropping Department.

Dr. Jerry Maranville, professor of agriculture and natural resources, University of Nebraska-Lincoln, completed his assignment as visiting scientist under the IPB/IRRI collaboration.

July

Dr. Iwao Watanabe, soil microbiologist, began a 6-mo sabbatic leave at the University of Sussex, England.

Dr. Robert W. Herdt, agricultural economist, resigned and joined the CGIAR Secretariat.

Dr. V. Seshu Durvasula, plant breeder, began a 1-yr sabbatic leave at Cornell University.

Dr. Howard H. Hagerman, of Lyman Briggs College, Michigan State University, completed his assignment as visiting communication specialist.

Dr. Mark Rosegrant, IFPRI, arrived to work on the ADB/IFPRI/IRRI collaborative project.

August

Mr. Walter C. Tappan, formerly with USAID/Indonesia, joined IRRI as liaison scientist for Indonesia and Malaysia.

Dr. Billy J. Cochran, formerly with Louisiana State University, joined IRRI as agricultural engineer in the IRRI Cooperative Projects with the Ministry of Agriculture and Cooperatives, Thailand.

September

Dr. Don Roberts of Boyce Thompson Institute completed his assignment to the collaborative IRRI/BTI Project, Entomology Department.

Dr. Mark Rosegrant, IFPRI, completed his work on the ADB/IFPRI/IRRI collaborative project.

Dr. E A. Siddiq, formerly with ICAR, joined the Institute as plant breeder with the Cooperative Project in the Arab Republic of Egypt.

Dr. Dioscoro L. Umali, former assistant director general of FAO, joined IRRI as consultant to serve as IRRI's liaison scientist in China.

Dr. J. Ritchie Cowan, liaison scientist for Indonesia and Malaysia, resigned.

Dr. Ram K. Pandey, IITA agronomist/breeder, joined IRRI as visiting scientist.

Ms. Rebecca C. Pascual, manager, Food and Housing Services, completed a 6-mo sabbatic leave at the International Management Institute in Geneva and at the Food Services Department, Virginia Polytechnic Institute and State University, USA.

Atty. Zosimo Q. Pizarro, senior administrative associate, left for a 6-mo study leave in the USA to develop a patent policy for the Institute.

October

Dr. Foster Cady, adjunct professor, Cornell University, joined IRRI as visiting scientist, International Rice Testing Program.

Dr. Cristina C. David, formerly with the Philippine Institute of Development Studies, joined IRRI as agricultural economist, Agricultural Economics Department.

Dr. Felix N. Ponnamperuma, principal soil chemist, was granted a 2-1/2 mo extension of his sabbatic leave.

November

Dr. Gerhild Boje-Klein, University of Bonn, Federal Republic of Germany, joined IRRI as visiting associate soil chemist, Soil Chemistry Department, under the IRRI/GTZ Special Project Collaboration.

Dr. Leo Dale Haws, formerly with Boston University, Center for the Management of Agricultural Development, rejoined IRRI as rice production training specialist with the IRRI/Egypt Collaborative Project.

December

Dr. Ray B. Diamond, IFDC, completed his 1-1/2 yr assignment as visiting scientist, Agronomy Department.

Mr. Eugene P. Hettel of Iowa State University completed a 1-yr assignment as visiting associate editor, Communication and Publications Department.

Dr. Robert E. Huke, professor of geography, Dartmouth College, returned as visiting scientist, Agricultural Economics Department.

Crop weather

Total 1983 rainfall was 1,695 mm, almost 300 mm below normal for Los Baños. The rainy season lasted from June to October compared to the normal May to December. July was exceptionally wet with 651 mm of rain, 339 mm of which was received within 48 h from a severe typhoon. DS lasted from 25 Jan to 29 May, during which only 1 d had more than 3 mm rain.

Maximum temperatures at the upland site ranged from 35.6° C in May to 28.5° C in December. Those at the lowland site averaged about 1.5° C lower. The highest temperature was on 28 May (37.3° C) at the upland farm. Minimum temperatures at the upland site ranged from 19.8° C in February to 24.6° C in June; those at the lowland farm averaged about 0.5° C higher. The lowest temperature was 15.2° C on 8 Feb at the upland site.

Total radiation reached peak values in April and May (about 600 mWh/cm^2 per d) and gradually dropped below 300 mWh/cm^2 per d in December. Sunshine averaged 9 h/d from February to May and decreased to only 3 h/d in December.

Mean RH was lowest in Apr-May (65%, upland; 72%, lowland) and was about 80% during the rainy season. Vapor pressure deficit increased to 35 mbars in May in the upland farm at midday (29 mbars, lowland) and dropped to about 15 mbars in the rainy season at both sites.

Wind speed was higher in DS, averaging 1.8 m/s, compared to 1.25 m/s during WS and was higher in the upland farm than in the lowland.

Because of higher temperatures, vapor pressure deficit, and wind speeds in the upland farm during DS, its evaporation was higher from February to May than in the lowland farm. The highest monthly total value was 251 mm in the upland farm and 215 mm in the lowland in May. During WS, monthly values dropped to about 110 mm at both sites. Annual evaporation in the upland farm was 1,961 mm compared to 1,783 mm in the lowland.

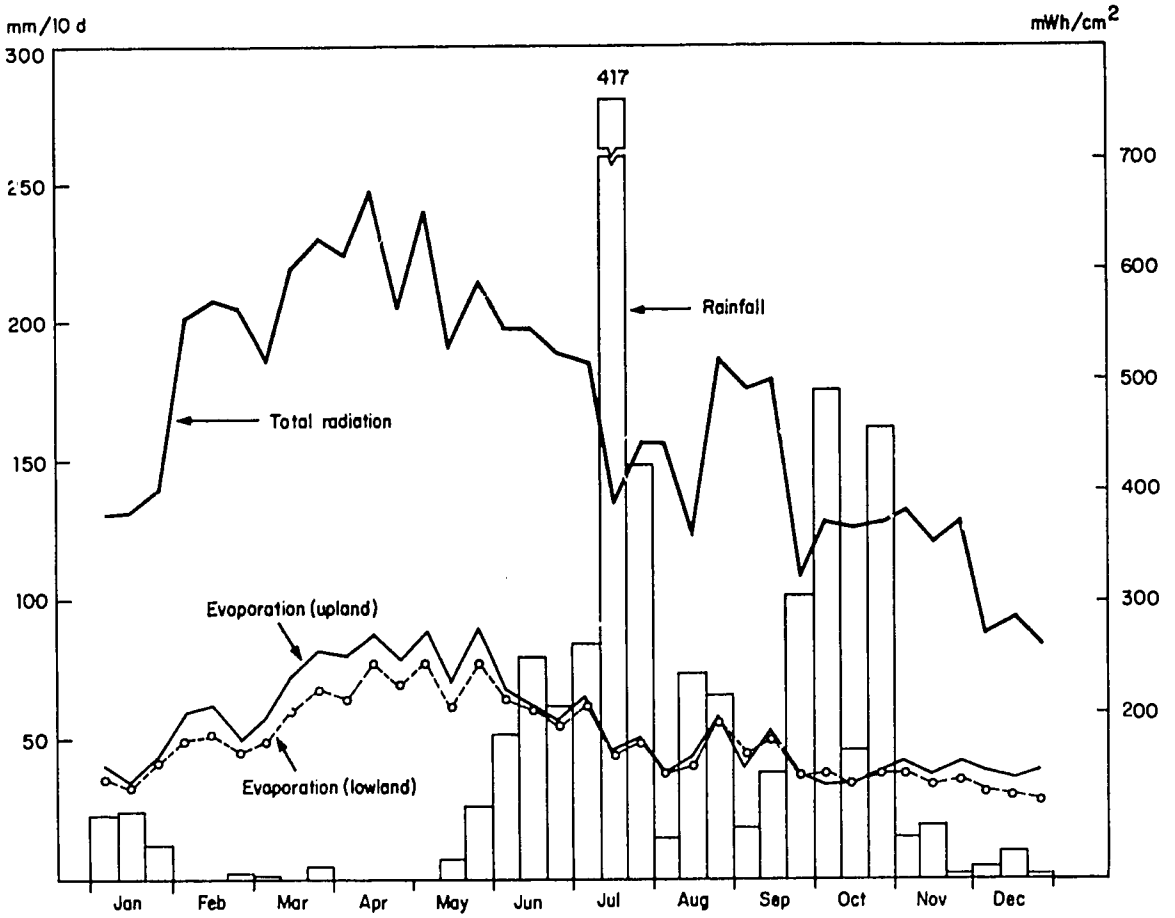
Although 17 tropical disturbances entered the Philippines' area of responsibility, only one typhoon (code-named Bebeng) directly affected the IRRI farm. Maximum rainfall was 55 mm in 1 h and wind speed averaged 10 m/s over a 6-h period. Individual wind gusts were considerably higher. Serious damage to buildings, infrastructure, and crops resulted.

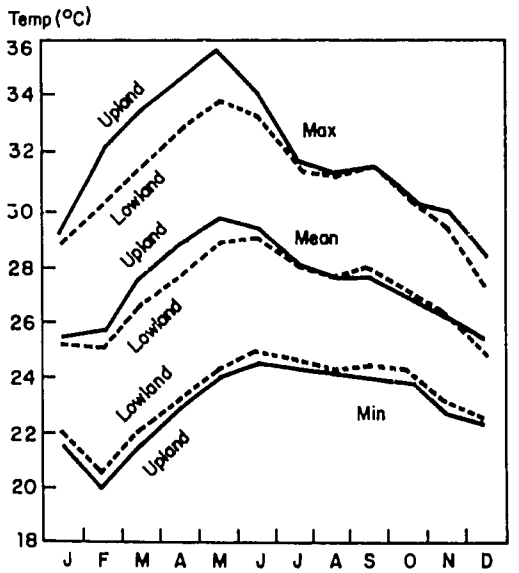
Table 1 shows the monthly summary of the major parameters. Figure 1 shows the highlights of the data.

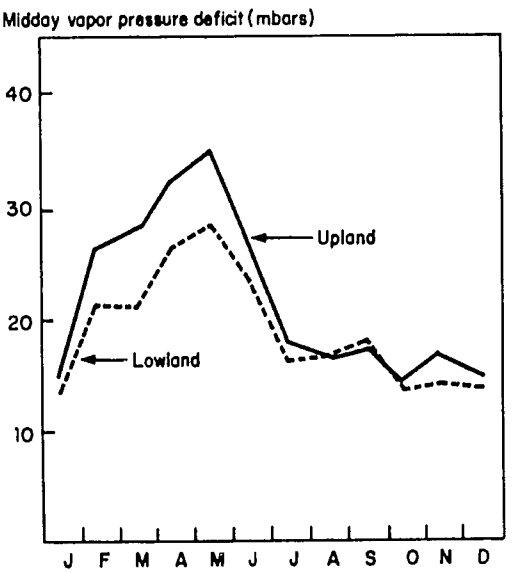
Table 1. Monthly weather data at IRRI, Los Baños (14°30'N, 121°15'E), Laguna, Philippines, 1983.[a]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm/mo)	62	2	5	*b*	32	194	651	155	158	384	36	16	1695
Normal rainfall (mm/mo)	41	18	28	32	180	237	282	255	264	238	257	160	1991
Total radiation (mWh/cm^2 per d)	395	540	545	570	570	520	475	435	435	360	365	290	460
Bright sunshine (h/d)	5.2	9.3	8.6	9.4	8.9	7.4	5.3	5.0	4.5	3.5	4.4	2.8	6.2
Upland farm													
Max temp (°C)	29.3	32.0	33.5	34.4	35.6	34.1	31.9	31.3	31.6	30.3	30.0	28.5	31.9
Min temp (°C)	21.7	19.8	21.6	23.0	24.1	24.6	24.2	24.1	24.0	23.9	22.9	22.3	23.0
Lowest RH (%)	63	44	45	40	39	49	60	62	60	65	59	59	54
Highest vapor pressure deficit (mbars)	15.1	26.6	28.5	32.6	35.5	27.3	18.9	17.4	18.6	15.1	17.4	15.9	22.4
Wind speed (m/s)	1.7	1.8	1.8	2.1	2.0	1.8	1.4	1.5	1.2	1.2	1.5	2.2	1.7
Total evaporation (mm/mo)	118	174	213	246	251	188	158	139	132	107	120	115	1961
Lowland farm													
Max temp (°C)	28.8	30.2	31.6	32.8	33.9	33.4	31.5	31.4	31.6	30.4	29.4	27.3	31.0
Min temp (°C)	22.0	20.5	22.0	23.1	24.0	24.9	24.5	24.2	24.4	24.1	23.2	22.4	23.3
Lowest RH (%)	64	49	53	46	46	53	63	62	61	67	64	60	57
Highest vapor pressure deficit (mbars)	14.3	21.9	21.9	26.9	28.6	24.2	17.1	17.5	18.1	14.3	14.8	14.5	19.5
Wind speed (m/s)	1.6	1.6	1.5	1.7	1.5	1.4	1.3	1.1	1.0	1.1	1.5	1.9	1.4
Total evaporation (mm/mo)	115	149	177	211	215	181	158	136	132	110	108	91	1783

[a]Agrometeorological Station "Upland" is always surrounded by upland crops. Agrometeorological Station "Lowland" is always surrounded by lowland rice. [b]Trace.







1. Highlights of 1983 weather at IRRI, Los Baños, Philippines.

END