INTERNATIONAL RICE RESEARCH INSTITUTE

ANNUAL REPORT FOR 1982



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

About this report

This 21st annual report includes research reported during 1982. The department or departments that performed the research are identified in italics below the topic heading. For example:

DISEASE CONTROL

Plant Pathology 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 Plant Physiology Departments cooperate in the project ROOT STUDIES. Because the Plant Breeding Department bears responsibility for one phase of that work, its name follows the heading:

Correlation of root characteristics in F_2 populations *(Plant Breeding).*

This report makes reference to three fundamental types of rice culture. Dryland (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 *dryland* (instead of upland) and *wetland* (instead of 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. The International System of Units (SI) is not, however, completely adopted for 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 by is 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. See the list of abbreviations.

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 annual report

A line = cytoplasmic male-sterile line
AC = amylose content
ACSN = Asian Cropping Systems Network
AGM = Angoumois grain moth
ai = active ingredient
AMS = aman season
AN = ammoniacal nitrogen
ARA = acetylene reduction activity
AS = ammonium sulfate
AVRDC = Asian Vegetable Research Development Center
AWMT = assistant water management technician
AWS = available water supply

B line = maintainer line
B&I = broadcast and incorporated
B:C = benefit-cost ratio
BA = Batangas ecotype of *Echinochloa colona*
BGA = blue-green algae
BLB = bacterial leaf blight
BPH = brown planthopper
BPI = Bureau of Plant Industry (Philippines)
BRBDP = Bicol River Basin Development Program
BRP = brown-rice protein
BS = boro season
BU = Bukidnon ecotype of *Echinochloa colona*

C:N = carbon-nitrogen ratio
CAAMS = Chinese Academy of Agricultural Mechanization Sciences
cbar = centibar
CEC = cation exchange capacity
CFU = colony-forming units
CIMMYT = International Maize and Wheat Improvement Center
cLr = lodging resistance factor
cms = cytoplasmic male sterile
cps = centipoise
CRB = Cagayan River Basin
CS = Camarines Sur ecotype of *Echinochloa colona*
CSR = completely stained round
CT = canopy temperature
CV = coefficient of variation

d = day
DAH = days after harvest
DAI = days after inoculation
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
DCD = dicyandiamide
DE = days after emergence
DEI = distribution equity index
DI = days after infection, infestation
DS = dry season
dS = decisiemens (electrical conductivity)
DSC = differential scanning calorimetry
DSR = dry-seeded rice
DT = days after transplanting

ECe = electrical conductivity of the saturation extract
EE = ethyl ester
ELISA = enzyme-linked immonuosorbent assay
E_{pan} = pan evaporation
ET = evapotranspiration

FA = fluorescent antibody
fb = followed by
FGU = forestry-grade urea
FPLI = functional plant loss index

g = gram
GC = gel consistency
GEU = genetic evaluation and utilization
GLH = green leafhopper
GMA = good market access
GT = gelatinization temperature

h = hour
ha = hectare
HAI = hours after inoculation
HC = hours after caging
HI = harvest index
HLS = helminthosporium leaf spot
hp = horsepower
HS = highly susceptible
HT = hours after treatment
HW = hand weeding

ICRISAT = International Crops Research Institute for the Semi-Arid Tropics
IITA = International Institute of Tropical Agriculture
IL = Iloilo ecotype of *Echinochloa colona*
INSFFER = International Network on Soil Fertility and Fertilizer Evaluation for Rice
IPB = Institute of Plant Breeding (UPLB)
IPE = isopropyl ester
IPM = integrated pest management
IPVR = Institute for Plant Virus Research (Japan)
IRAT = Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres
IRCTN = International Rice Cold Tolerance Nursery
IRTP = International Rice Testing Program

J = joule

kg = kilogram
kgf = kilogram-force
km = kilometer
Krw = relative crowding coefficient of rice with respect to *Echinochloa colona*
kW = kilowatt
Kwr = relative crowding coefficient of *Echinochloa colona* with respect to rice

LCPIS = Libmanan-Cabusao Pump Irrigation System
LD = lethal dose
LE = Leyte ecotype of *Echinochloa colona*
LER = leaf elongation rate
LGB = lesser grain borer
LSD = least significant difference
LSS = line source sprinkler
LTRIS = Lower Talavera River Irrigation System
LU = landform unit
LV = local (traditional) variety
LWP = leaf water potential

m = meter
MC = moisture content
MEANT = mean temperature
meq = one thousandth of an equivalent of a chemical element or compound
min = minute
MINT = minimum temperature
mo = month
mol = mole
MPa = megapascal
MPN = most probable number
MR = moderately resistant
MRRTC = Maligaya Rice Research and Training Center (Philippines)
MS = moderately susceptible
MT = months after transplanting
MV = modern variety

N·m = newton-meter
NA = naphthalic anhydride
NBLS = narrow brown leaf spot
NIA = National Irrigation Administration (Philippines)
NPU = net protein utilization

OM = organic manure
OMR = land preparation on the onset of monsoon rains
OP = owned parcel
OYT = observational yield trial

PA = Pangasinan ecotype of *Echinochloa colona*
PAGE = polyacrylamide gel electrophoresis
PE = preemergence
PI = panicle initiation
PMA = poor market access
PMC = pollen mother cell
PPD = phenylphosphorodiamidate
PR = phosphate rock
PRG = plastic rain gauge
PRIS = Pampanga River Irrigation System
PTVT = provincial technology verification team (Philippines)
PU = prilled urea
PW = panicle weight
PWP = land preparation as soon as there is water for puddling

Q = diverted flow

R = resistant
R line = restorer line
R:S = root-shoot ratio
RAD = solar radiation
RCPC = Regional Crop Protection Center (Philippines)
RCW = rice caseworm
Rf = retardation factor
RGA = rapid generation advance
RGS = rice green semilooper
RGSV = rice grassy stunt virus
RH = relative humidity
RIP = rolling injector planter
RN = rainfall
RRSV = rice ragged stunt virus
RTBV = rice tungro bacilliform virus
RTSV = rice tungro spherical virus
RTV = rice tungro virus
RWL = rice white leafhopper
RWM = rice whorl maggot
RWS = relative water supply

S = susceptible
s = second
S&P = seepage and percolation
SC = South Cotabato ecotype of *Echinochloa colona*
SCU = sulfur-coated urea
SDS = sodium dodecyl sulfate
SES = standard evaluation system for rice
SMT = soil moisture tension
SRP = share-rented parcel
SSB = striped stem borer
SSP = single superphosphate
STD = standard nonrecording rain gauge

t = ton
TAT = turnaround time
TDR = target discharge requirement
TPR = transplanted rice
TRIS = Talavera River Irrigation System

UOP = unit price of paddy
UPLB = University of the Philippines at Los Baños
UPRIIS = Upper Pampanga River Integrated Irrigation System
USG = urea supergranules

W = watt
WAI = weeks after inoculation
WAS = weeks after seeding, sowing
WE = weeks after emergence
WFT = weed-free with tillage during the dry season
wk = week
WMT = water management technician
WP = wettable powder
WS = wet season
WSR = wet-seeded rice
WT = weeks after transplanting
WUE = water utilization efficiency

yr = year
YSB = yellow stem borer

ZPH = zigzag planthopper

Research highlights

ONE STEP AHEAD

Growth with production stability is a major aim of IRRI's research strategy for the 80s. We will accomplish this only through close alliance with rice scientists in national programs. Within the International Rice Testing Program, we work with approximately 800 researchers in more than 70 countries through a worldwide grid of cooperative experiments.

The experiences of farmers are also important to our efforts. When an old rice farmer in a production brigade in the Hanzhou Province of China was complimented for his excellent hybrid rice crop, he said that we must not diminish our attention to maintaining plant and soil health. He was emphasizing that a productive, stable agriculture needs ceaseless vigilance.

Much of IRRI's work illustrates the wisdom of vigilance in the never-ending battle to stay one step ahead of pests' ability to counter varietal resistance. One example is our work on breeding for resistance to brown planthopper (BPH), a serious insect pest of rice. During the last few years, the IRRI variety IR36 has become very popular with farmers in Southeast Asia because it matures early and has high yield potential and insect and disease resistance. More than 10 million hectares of IR36 were grown in 1982.

However, reports have come from Mindanao in the southern Philippines and North Sumatra in Indonesia that IR36 is being damaged by BPH, indicating a new shift in the biotype population (Fig. 1). A biotype shift is to be expected when resistance of a widely grown variety is specific to particular biotypes, and so our plant breeders had varieties ready that are resistant to the new biotype population. IR56, named by the Philippine Seed Board in 1982, is one such variety.

Several tons of IR56 seed were sent to areas in Mindanao where the new BPH biotype was attacking IR36 (Fig. 2).



1. Differential reactions of rice varieties TN1, IR36, and IR56 to brown planthoppers collected from Mindanao, Philippines. IR56 showed no feeding damage 12 days after infestation.

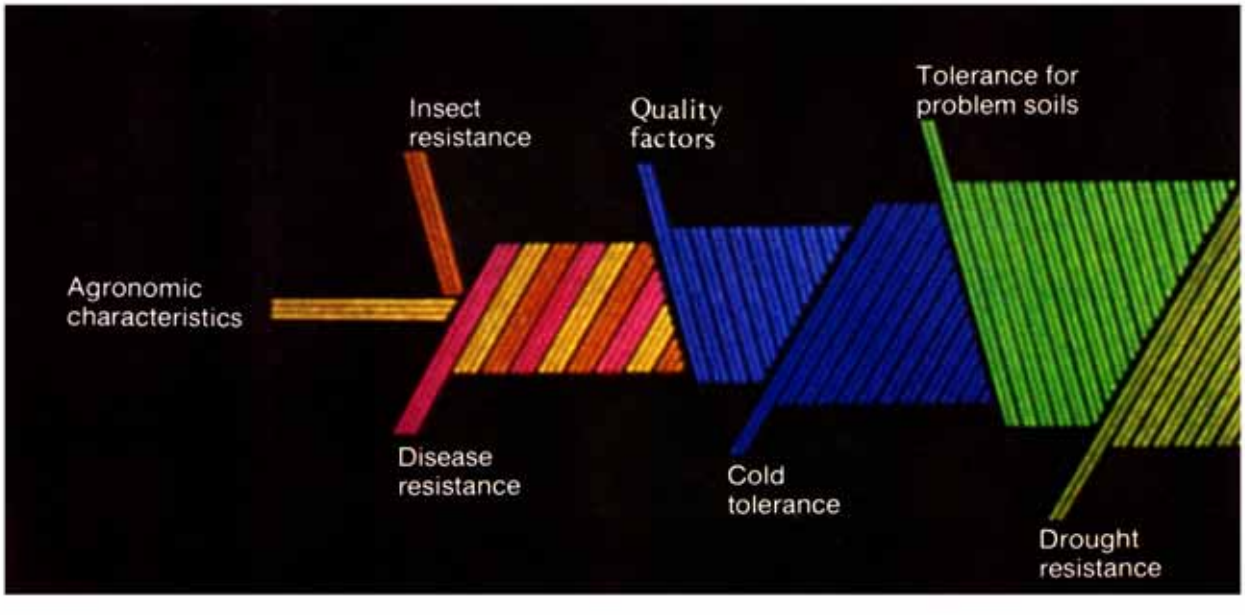
2. In Mindanao, about 150 farmers were each given 1.5 kg of IR56 seed to multiply.

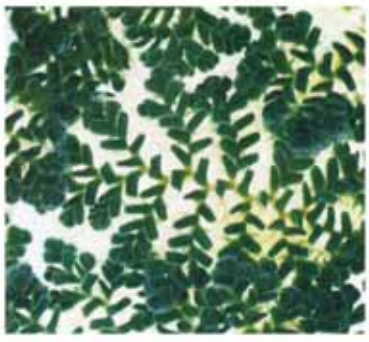


4. Disease and insect resistance and superior agronomic characteristics are the core of IRRI's Genetic Evaluation and Utilization (GEU) program. Plant breeders and problem area scientists work to incorporate into a desired plant type the genetic ability to withstand other production constraints, without sacrificing its desired agronomic characteristics. IRRI works closely with scientists in national programs to focus breeding strategies on rice varieties for less favored environments.

Indonesian scientists also found that IR56 is resistant to the new biotype occurring in North Sumatra. In response to an urgent call, we airlifted more than 20 tons of IR56 seed for distribution and multiplication to the stricken areas of North Sumatra.

BPH is not the only enemy of rice that we must stay one step ahead of. That was made poignantly clear when a new strain of grassy stunt virus tentatively called RGSV 2 appeared in 1982. BPH is the vector for that virus. We are now searching for genes that will provide RGSV 2 resistance.





3. In areas where the soil has an adequate amount of phosphorus, the water fern azolla has the potential to help reduce the need for purchased nitrogen fertilizer. Blue-green algae associated with the fern actually do the nitrogen fixing.

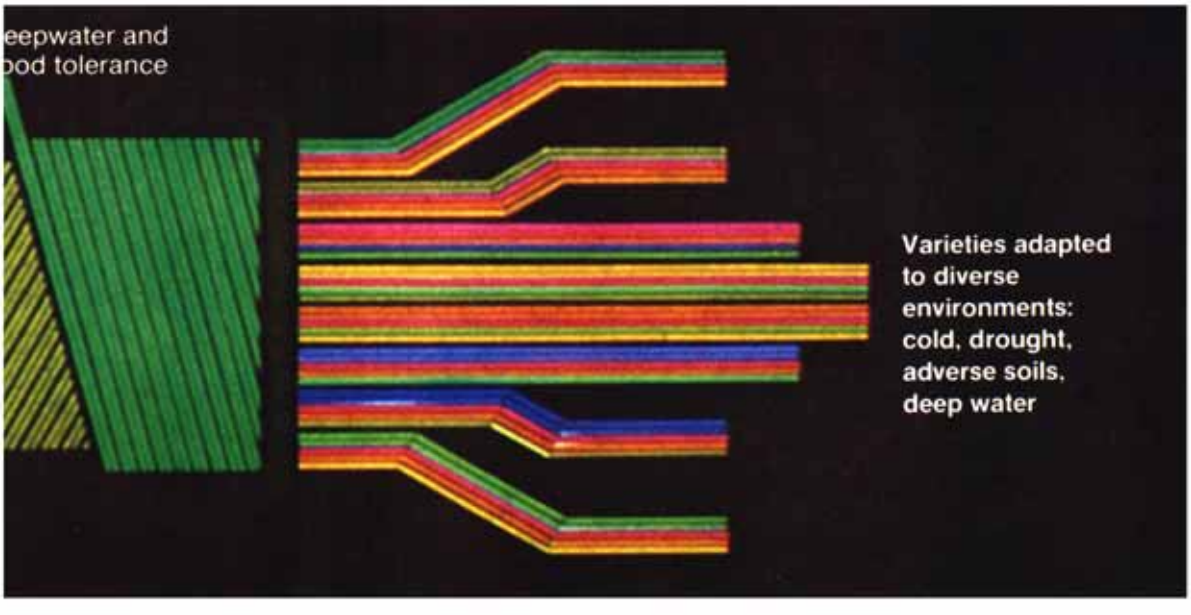
To reduce occurrence of such shifts of insect biotypes and virus strains, varietal diversification must be encouraged. In October 1982, we jointly conducted a Technology Transfer Workshop with the Philippine Ministry of Agriculture to recommend varieties with general as well as specific adaptation to various rice environments. Steps were taken to intensify regional testing of varieties and for prerelease multiplication of the most promising strains on the plant breeders' assembly line.

The Chinese farmer in Hanzhou Province wisely advised greater attention to soil health. IRRI is strengthening soil management work, particularly in the area of biological nitrogen fixation.

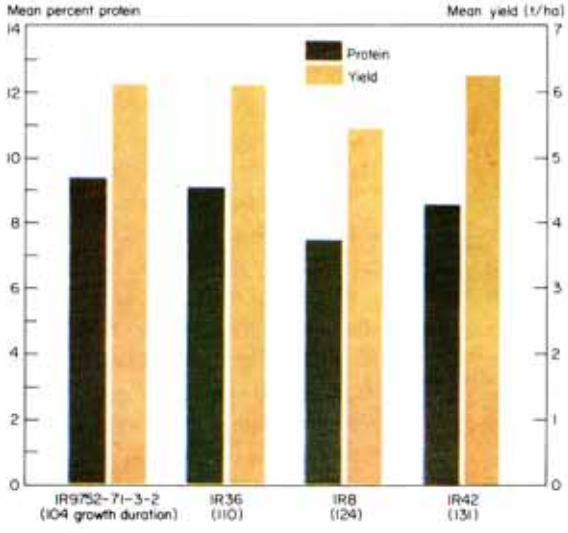
We know that nitrogen fixed by blue-green algae in conjuction with the water fern azolla can help reduce the need for purchased nitrogen fertilizer (Fig. 3). We have discovered, however, that azolla grows poorly in phosphate-deficient soils. Soils containing more than 25 μg available phosphorus per gram of soil could support good azolla growth without fertilizer. In 1982, trials to determine the extent that azolla can replace nitrogen fertilizer and improve soil fertility were conducted at 15 sites in 10 countries. In areas with sufficient phosphorus, we are working to help popularize azolla use by farmers and to determine optimum procedures for distribution, use, and maintenance of the beneficial water fern.

GEU program is 10 years old

The anticipatory research of our Genetic Evaluation and Utilization (GEU) program has enabled us to stay one step ahead on several fronts. The GEU program, IRRI's largest endeavor, is now in its 11th year. It has enabled us to develop multi-insect and disease resistant varieties. The inputs of our soil chemists, entomologists, plant pathologists, plant physiologists, agronomists, and plant breeders on the GEU team have also produced rices with tolerance to adverse soils, salinity, drought, cold, and submergence (Fig. 4).



5. IR36 has about a one percentage point higher protein content than IR varieties of longer growth duration. One promising line, IR9752-71-3-2, which has a yield similar to IR36, matures about 1 week earlier and has a protein content that is as high as, and at times higher than, that of IR36. Replicated trials, 1978-82 dry seasons.



In a somewhat unexpected development, we have found that our new early-maturing varieties that combine multiple resistance to insects and diseases also have a high protein content. Since 1978, replicated yield trials have shown that we can maintain yield potential and the characteristic of higher protein content associated with short-duration varieties such as IR36 (Fig. 5). Early-maturing varieties also help farmers produce two or more crops in irrigated areas.

6. Rice scientists from Latin America, Africa, and Asia review dryland breeding material at the International Institute of Tropical Agriculture substation at Onne, Nigeria.





7. Plans are being made to utilize the new Rainfed Rice Research Station site at Bamban, Tarlac.

Dryland rice research

In 1982 a detailed strategy for dryland rice research was developed during an international workshop at Bouake, Ivory Coast. Before the workshop, IRRI scientists joined other researchers from Latin America, Asia, and Africa in a monitoring tour to review dryland rice improvement efforts in Nigeria and Ivory Coast (Fig. 6).

In his World Food Day convocation address at IRRI on 16 October, President Ferdinand E. Marcos announced that the Philippine Government would make available 100 hectares of land at Bamban in Tarlac (Fig. 7) to help IRRI intensify dryland and rainfed rice research.

IRRI's third decade

The "Plan for IRRI's Third Decade" was completed during 1982. It is based on priorities suggested by the Board of Trustees and the Second Quinquennial Review team which reported on IRRI's progress to the Consultative Group for International Agricultural Research (CGIAR). The advice of the Technical Advisory Committee to CGIAR was very helpful in finalizing the research strategies. The Plan describes how IRRI will intensify and expand its collaboration with national programs in their rice improvement activities during the next 10 years.

The Articles of Incorporation and By-laws of IRRI were amended in October 1982 to make them compatible with IRRI's position as an international agricultural research center supported by CGIAR.

Awards

The first King Baudouin International Agricultural Research Award was presented to IRRI in November during the CGIAR meeting in Washington, D. C. (Fig. 8). The award recognized the continuing vitality and recent advances of IRRI's breeding programs as illustrated by the development of IR36.

The Third World Foundation for Social and Economic Studies

announced that IRRI had been named the 1982 recipient of the Third World Prize for its outstanding contributions to the Third World (Fig. 9). The citation reads, in part: "Over the last two decades when so much else faltered in the struggle against hunger and poverty, IRRI's quiet, persistent, highly professional and wholly dedicated work touched the lives of millions in the Third World, improving the human condition in truly practical and lasting ways. That such a contribution should have been the result of fruitful cooperation between scientists and food technology experts from developed and developing countries alike is in itself a cause of satisfaction and encouragement."



8. Dr. Guy Camus, chairman of the Technical Advisory Committee (TAC) of the CGIAR, presents Dr. M. S. Swaminathan, IRRI director general, with the 1982 King Baudouin International Agricultural Research Award.



9. His Excellency Zhao Ziyang, Premier, State Council of the People's Republic of China, presents Third World Prize Scroll to Dr. M. S. Swaminathan.

Genetic evaluation and utilization (GEU) program

Genetic resources program

Plant Breeding and Statistics Departments

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FIELD COLLECTION

Plant Breeding Department

The national rice research centers of Bangladesh, Nepal, and Thailand continued their search for uncollected rice cultivars in remote areas. The efforts were sustained with funds provided by the International Board for Plant Genetic Resources (IBPGR) and channeled through IRRI. Several other national centers carried out their own field canvassing activities. During 1982, IRRI received 2,764 seed samples from these activities.

Several institutions in developed countries also made plant exploration missions in Asian countries with IBPGR support. When rice germplasm was included in the field collection, IRRI was notified. Upon its request, IRRI was provided with a duplicate set of the rice seeds. During 1982, IRRI received from Bhutan 62 seed samples collected by the Royal Botanic Garden Kew (U.K.). The Dutch Foundation for Agricultural Plant Breeding sent four varieties collected from Pakistan.

Anthropologists working in the remote areas of Indonesia and the Philippines also provided IRRI with samples of their rice collections.

Table 1 summarizes the results of 12 years' collection in 14 countries.

Table 1. Indigenous rice varieties collected with IRRI's direct or indirect participation in 14 collaborating countries, 1971-1982.

Country	Years	Indigenous varieties collected (no.) with IRRI's	
		Direct participation	Indirect participation
Bangladesh	1973-82	2 451	3 060
Bhutan	1975-76, 1981	—	1 249
Burma	1973-74, 1976 1980-81	225	1 528
India	1976, 1978-82	—	2 266
Indonesia	1972-76, 1978-82	5 103	4 730
Kampuchea	1973	280	—
Laos	1972-73	—	898
Malaysia	1973-81	—	1 422
Nepal	1971-72, 1979-82	—	2 408
Pakistan	1972-73, 1976, 1979	—	776
Philippines	1973-76 1977-82	630	2 565
Sri Lanka	1972, 1975-76 1978-81	1 675	551
Thailand	1973, 1975-76 1978-82	—	3 365
Vietnam	1972-75, 1978-81	108	710
Total	1971-82	10 472	25 528

INSTITUTIONAL EXCHANGES

Plant Breeding Department

IRRI continued to receive duplicate samples from the rice collections of other institutions. The major donors of 4,514 samples deposited into the germplasm bank were:

National centers

- Bangladesh Rice Research Institute — 139 varieties.
- Kiangsu Provincial Academy of Agricultural Sciences (China) — 500 samples; Hunan Academy of Agricultural Sciences — 4 deepwater rices; Institute of Biology, Sichuan Province — 10 varieties.
- M. P. Rice Research Institute, Raipur; Agricultural Research Station, Pulla; Central Rice Research Institute (CRRI) Regional Research Unit and the Rice Research Station, Anakapalli (AP); CRRI, Cuttack (India) — 990 samples.
- Malaysia — 450 varieties from Sabah State.
- Nepal — 297 varieties.
- Yale University anthropology project in the Mountain Province of the Philippines — 42 varieties.
- Vietnam — 60 varieties.
- Thailand — 4 varieties adapted to acid-sulfate soils; 53 varieties from the hilly regions; and 545 varieties from the national rice collection.

Developed countries

- The Netherlands —the Foundation for Agricultural Plant Breeding donated four Pakistani varieties sampled from the Baluchistan Provinces.
- United Kingdom — Royal Botanic Garden Kew supplied 62 samples collected from Bhutan.

Other international/regional centers

- International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria — 255 samples of IITA's breeding materials.
- West Africa Rice Development Association (WARDA), Monrovia, Liberia — 63 mangrove swamp varieties collected from Sierra Leone.

- FAO/UNDP — 1,026 rice varieties collected from Liberia, of which 958 samples were received in 1975.

Replacement samples also were obtained for 199 accessions that had become nonviable during storage.

The International Rice Testing Program (IRTP) furnished 234 promising entries from international nurseries for preservation.

The National Institute of Agricultural Sciences (NIAS) of Japan and IRRI continued to systematically consolidate their rice collections. The two institutes compared accession lists to identify duplicate samples and nonduplicate holdings. NIAS furnished IRRI with 107 Chinese varieties not in the IRRI collection.

INVENTORY, CHARACTERIZATION, AND DATA PROCESSING

Plant Breeding and Statistics Departments

At the end of 1982, the IRRI germplasm bank had registered 60,181 accessions of *O. sativa,* 2,614 accessions of *O. glaberrima,* 1,100 populations of wild species, and 691 genetic testers and mutants. About 5,042 recently received seed samples await initial planting and seed increase. During the past 11 yr, more than 13,152 additional seed samples were not counted as registered accessions because the seeds either did not germinate or were obvious duplicates.

During 1982, the morphoagronomic traits in the field of 7,252 accessions were systematically described. Laboratory measurements of panicle and grain characters on 4,980 accessions were completed. By the end of the year, field records of 59,512 accessions had been made, but only 45,599 accessions were completely characterized because of a shortage of laboratory manpower.

Data on 56,144 accessions of *O. sativa* have been entered in the computerized files. During the year, the morphoagronomic file and the GEU-traits file were used extensively to identify accessions requested by rice researchers.

SEED INCREASE, REJUVENATION, AND DISTRIBUTION

Plant Breeding Department

In the DS, 3,277 plots were grown for initial seed increase and 5,066 accessions were rejuvenated to provide seed for canning. In the WS, 7,252 plots were planted for characterization and 4,034 accessions were rejuvenated.

The germplasm bank continued to supply seed to rice researchers throughout the world. In response to 154 requests, it sent 11,075 seed samples to foreign researchers. It filled 279 requests within IRRI for 33,975 samples. Moreover, it distributed 816 samples of African rices and wild species. The total number of seed samples supplied by the germplasm bank in 1982 was higher than the numbers supplied in the last 4 yr (Table 2).

A large collection of traditional cultivars known locally to have special characteristics has been assembled by field collectors of national centers and IRRI. Seeds are distributed to IRRI's GEU scientists for evaluation soon after the initial cycle of seed multiplication is completed. During 1982, special types provided to IRRI staff included 939 deepwater rices, 36 varieties tolerant of adverse soil factors, 4,110 drought-resistant or dryland varieties, 370 insect-resistant varieties, and 601 reputedly pest-resistant accessions.

PROCESSING SEED FOR MEDIUM- AND LONG-TERM STORAGE

Plant Breeding and Statistics Departments

The vacuum-packing process of canning rice seed in aluminum cans for medium- and long-term

Table 2. Progress of the IRRI Genetic Resources Program in the preservation and distribution of seed of *Oryza sativa* cultivars, 1973-1982.

Year	Distinct accessions in germplasm bank	Samples distributed[a]	
		Inside IRRI	National programs
1973	24 162	8 275 (66)	9 777 (95)
1974	26 818	20 498 (108)	2 603 (83)
1975	30 332	22 155 (151)	4 043 (150)
1976	34 229	40 200 (194)	4 819 (137)
1977	36 956	50 354 (196)	4 126 (148)
1978	40 768	31 941 (182)	7 316 (142)
1979	47 743	26 694 (268)	3 260 (157)
1980	53 431	29 734 (337)	3 659 (156)
1981	57 027	29 053 (319)	4 376 (206)
1982	60 181[b]	33 975 (279)	11 075 (154[c])

[a]Numbers in parentheses indicate the number of seed requests processed. [b]About 4,566 recently received seed samples are yet to be grown and registered; 8,630 duplicate accessions and 4,823 nonviable seed samples were removed from the registry during 1973-82. [c]Excluding 19 requests of 254 samples being delayed by quarantine clearance.

storage has been in use since mid-1980. By the end of 1982, 9,128 of the 36,793 accessions grown for this purpose had been packed. The very low percentage of accessions being canned can be ascribed to the meager quantity of high-quality seed suitable for canning after rigorous visual selection. Poorly filled, discolored seeds and mechanical mixtures often made up a large portion of a harvested seedlot.

When an accession has produced sufficient seed for canning, a second 30-g seedlot is sealed in an aluminum foil envelope and sent to the U.S. National Seed Storage Laboratory in Ft. Collins, Colorado, for duplicate storage. This duplication adds to the security of the collection. Duplicates of 3,038 accessions were processed during 1982.

Records on seed rejuvenation and canning were entered in the computerized files.

To rejuvenate accessions under relatively disease- and insect-free conditions, a 5-ha area was rented in Masapang village of a neighboring district for seed production during December 1982.

COMPARISON OF SEED PACKING MATERIALS AND STORAGE CONDITIONS

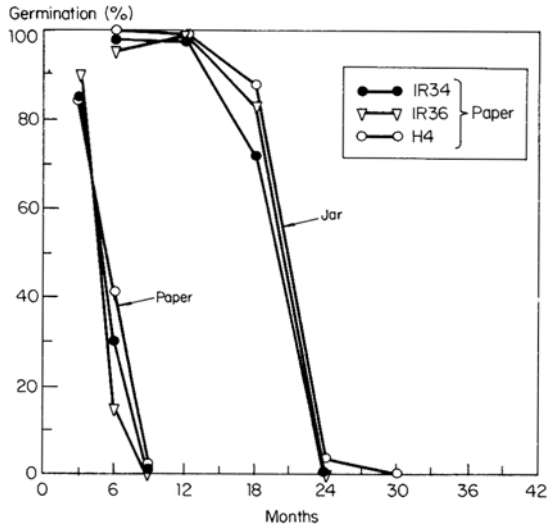
Plant Breeding Department

During March 1979, a seed storage experiment was begun to compare the life span of three rice cultivars with various degrees of grain dormancy and initially dried down to two moisture contents (MC) (6 and 12%). Seeds were placed in three kinds of packaging materials (kraft paper bags, aluminum foil-polyethylene envelopes, and hard polyethylene grain-sample bottles) and stored under six types of storage conditions (ambient temperature 24° -32° C) and relative humidity (RH) 80-100% in a basement room; 19° C and 55% RH in the short-term storage room; 5° -6° C in a refrigerator; 2° -4° C in the medium-term storeroom; −10° C in the long-term storeroom; and −20° C in a laboratory freezer.

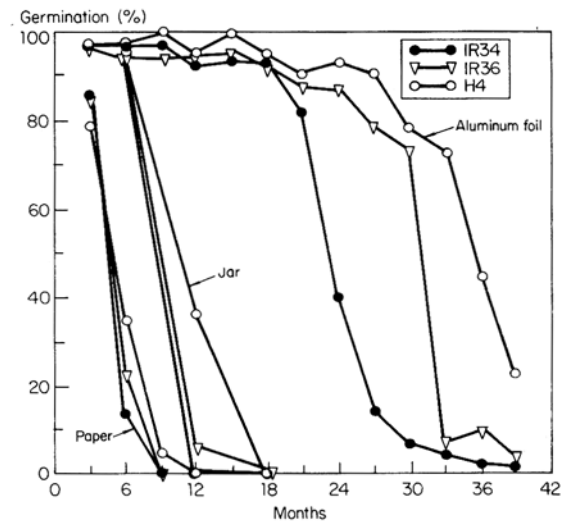
Marked changes in seed viability and moisture content were observed after 4 yr of storage. Seeds of 6 and 12% MC packed in paper bags lost all their viability within 9 mo when stored in the basement (Fig. 1, 2). The strongly dormant H4 was the most viable while the nondormant IR36 was viable for only 6 mo.

Inside the −20° C freezer, seeds with 12% MC in paper bags remained viable up to 12 mo; seeds of 6% MC stored the same way still retained 43-98% viability at the end of 36 mo.

The viability of seeds with 6% MC sealed inside hard plastic jars and kept in the basement remained high (above 80%) during the first 18 mo, after which it dropped rapidly. At the end of 24 mo, seeds of the weakly and nondormant varieties were dead; H4 retained 3% viability. In the seedlots with



1. Changes in germinability of three rice varieties dried to 6% moisture content and stored inside different packaging materials in an ambient room (24° -32° C and 80-100% relative humidity). IRRI, 1982.



2. Changes in germinability of three rice varieties dried to 12% moisture content and stored inside different packaging materials in an ambient room (24° -32° C and 80-100% relative humidity). IRRI, 1982.

12% MC loss of viability began sooner and germinability dropped to zero between 12 mo (for IR36) and 18 mo (for H4).

Seeds with 12% MC sealed inside aluminum foil envelopes showed little decline in viability until the 21st month in the basement. Then, a rapid loss in viability occurred. Seeds of IR34 and IR36 were viable only for 39 mo; those of H4 showed 23% germinability at the end of the period (Fig. 2).

Seeds of three varieties at both MC levels maintained their viability with no sign of deterioration for 45 mo in the short-term storeroom, even though they were packed in rather porous paper bags. Seeds stored inside plastic jars and aluminum foil envelopes also kept well for the same period in the same room.

Seed MC increased markedly under ambient room conditions in both paper envelopes and plastic jars. Seeds with 6% MC packed in paper envelopes had 21% MC after 12 mo; those stored in plastic jars showed a gradual increase in MC, which reached an equilibrium of 14% at 30 mo.

Seeds with 6% MC showed a 2% increase in MC when stored in the plastic jars both in the refrigerator and in the short-term storeroom. The increase was slightly lower inside paper bags. On the other hand, seeds with 12% MC stored in paper bags lost 3-6% MC; those inside jars lost 2-4% MC. The least MC change occurred inside the aluminum foil envelopes.

CYTOGENETICAL AND ELECTROPHORETIC ANALYSES OF THE GENETIC AFFINITY AMONG AUS, BULU, AND DRYLAND RICES

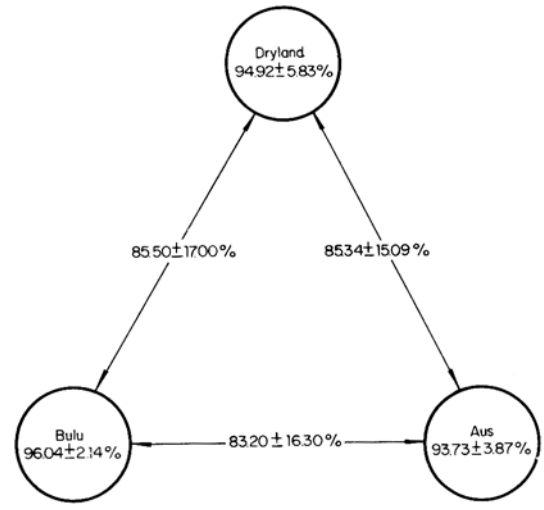
Plant Breeding Department

The bulu varieties of Indonesia and the traditional dryland (hill) rices of Southeast Asia have many common morphological characteristics: tall stature, low tillering, thick culms, long and broad leaves, long and well-exserted panicles, large and bold grains, and nonshattering habit. However, bulu rices are grown in wetland fields while the dryland rices are generally grown under rainfed-dryland culture and are high in drought resistance. The aus varieties of eastern India and Bangladesh are early, drought-resistant, and grown in a rainfed regime. Earlier studies in Japan suggested the close relationship of aus and bulu rices to each other and also to Japanese varieties. However, the genetic relationship between bulu and dryland rices has not been explored.

Crosses among four aus, four bulu, and five dryland rices were made and the pollen and spikelet fertility, meiotic chromosomes, seed protein profiles, esterase, and peroxidase zymograms of the parents and their F_1 hybrids were studied to elucidate their interrelationships. The pollen fertility readings are in Figure 3. A combining ability analysis of a seven-parent diallel cross indicated that the variations in F_1 pollen fertility could be largely attributed to dominance and additive effects.

Measurements of length, arm ratio, and shape of the pachytene chromosomes showed that the three varietal groups have similar chromosome complements. During the meiotic division, the F_1 hybrids showed loose pairing, univalents, chain-of-four, bridges and fragments, and laggards. But the frequencies were too low to account for the low level of pollen sterility found in the F_1s. Moreover, most of the parents also showed such minor chromosomal aberrations and at slightly lower frequencies.

Seeds of the aus varieties produced the lowest number of protein bands (22-27) among the three ecotypes but showed the largest within-group variation among the three groups. The dryland rices yielded the largest number of bands (26-29), which indicates an advanced state in evolutionary dif-

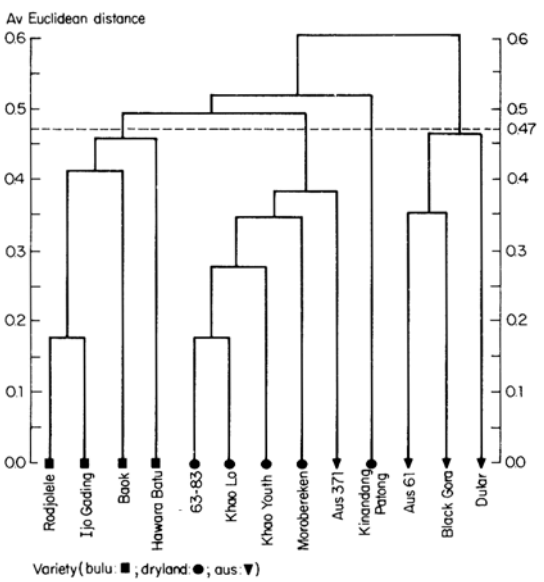


3. Mean pollen fertility of intragroup and intergroup hybrids among bulu, aus, and dryland rices. IRRI, 1982.

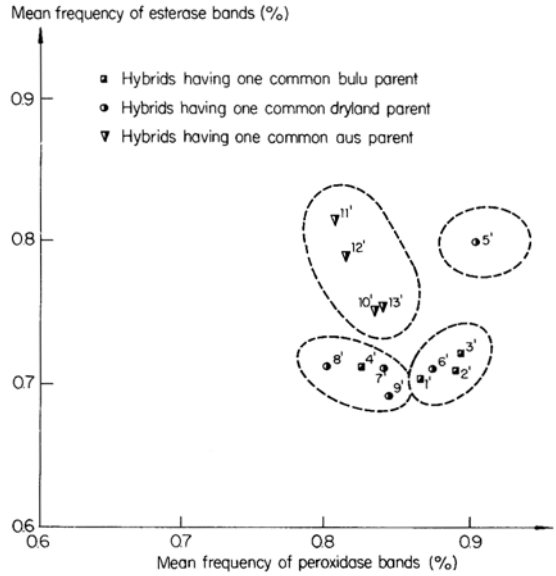
ferentiation. The bulu rices were intermediate. The seed protein profiles concur with the morpho-agronomic traits of each group with respect to the relative state of differentiation.

Between esterase and peroxidase isozymes, the variation in the esterase bands was greater than that in the peroxidase bands. The aus varieties showed the largest within-group similarity indices for both enzymes. The aus and dryland comparison showed higher similarity indices than the other two between-group comparisons.

Based on the weighted pair-group method, dendrograms for each electrophoretic system were constructed. The dendrogram of seed protein provides a clear differentiation among the three ecotypes except that the Philippine dryland variety Kinandang Patong appeared to be independent and Aus 371 fell into the dryland group (Fig. 4). The dendrograms based on esterase and peroxidase isozymes showed a more diverse pattern of association. However, the combined frequencies of esterase and peroxidase bands taken from the arrays of F_1 hybrids gave a clear separation of the hybrids having one common aus parent from the others (Fig. 5). The hybrids from bulu or dryland rices indicated some overlapping, while hybrid progenies



4. Dendrogram showing intervarietal relationships obtained by the weighted pair-group method of clustering protein electrophoretic data. IRRI, 1982.



5. Distribution of the 13 hybrid populations based on mean frequencies (%) of all isozymic bands of the two enzymes (esterase and peroxidase). IRRI, 1982.

of Kinandang Patong appeared independent of all others.

The following preliminary conclusions may be drawn from the preceding analyses:

- The three ecotypes are genetically closely related to each other, with the bulus and dryland rices showing a slightly higher affinity than the aus/bulu and aus/dryland hybrids.
- Chromosome behavior also indicated the higher levels of affinity among the three ecotypes than in indica/bulu, indica/indica, and indica/japonica crosses of earlier studies at IRRI.
- Electrophoretic analyses generally support the morphological and genetic studies but the similarity indices varied considerably from one system to another. More enzyme systems need to be studied to identify those that would be useful for varietal distinction and identification.

TRAINING GENETIC STOCK OFFICERS

Plant Breeding Department

IRRI continued to provide short-term training on rice genetic resources management. The trainees were given responsibility for maintaining local rice

collections at their home stations. One Indian GEU trainee spent 3 wk with the staff of the germplasm bank to learn about different aspects of genetic conservation. A staff member from the Guangdong Academy of Agricultural Sciences in China spent 4 mo working on the wild taxa.

Genetic evaluation and utilization (GEU) program

Agronomic and related characteristics

Agronomy and Plant Breeding Departments

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YIELD PERFORMANCE AND NITROGEN RESPONSE OF RICE VARIETIES AND SELECTIONS

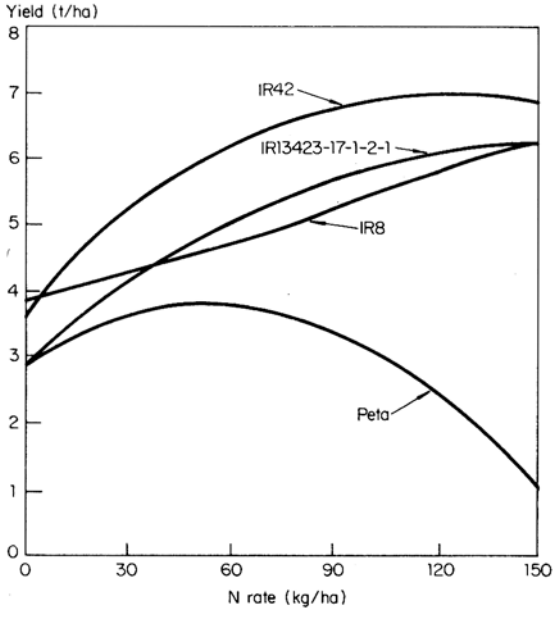
Agronomy Department

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

IRRI. Table 1 shows the response of 6 IR varieties and 32 promising breeding lines at five N levels. During the dry season (DS), a new breeding line, IR22082-41-2, gave the highest yield of 7.5 t/ha at the high N rate. IR42 outyielded (6.4 t/ha) all entries at the low N rate. Without N fertilizer, IR19743-46-2-3-3-2 yielded 5.1 t/ha.

Among the early-maturing lines, IR9729-67-3 yielded 6.6 t/ha — the highest at the high N rate. IR42 outyielded all the test varieties or lines in the late-maturing group (Fig. 1).

In the wet season (WS), most rice yields declined at the high N rate (Table 1). IR13525-43-2-3-1-3-2 gave the highest yield (5.2 t/ha). IR42 favorably responded to the low N rate application. IR25882-32-1-3 yielded higher than IR36 (Fig. 2). Medium-maturing IR13525-43-2-3-1-3-2 and late-maturing IR42 yielded well at 60 and 90 kg N/ha.



1. N response of late-maturing irrigated rices. IRRI, 1982 DS.

Farmer's field. IR varieties and promising lines were evaluated at four N fertilizer levels. The trial was on a farm previously used for rainfed N response trials but converted to an irrigated field.

In the DS, IR21015-80-3-3-1-2 yielded the highest (8.4 t/ha) at 50 kg N/ha. Without N fertilizer, IR36 yielded 7.8 t/ha (Table 2).

During the WS, IR22082-41-2 yielded 5.5 t/ha at 80 kg N/ha, but a similar 5.4 t/ha with no N fertilizer. Without N fertilizer, all except IR9752-71-3-2 yielded 4.0 t/ha or better. IR42 and IR22082-41-2 responded similarly across the different N rates (Table 2).

Maligaya. Most rices responded favorably to N application during the DS. At the highest N rate, IR42 outyielded (8.6 t/ha) all other entries (Table 3). IR42, IR54, and IR22082-41-2 produced the highest average yield. In unfertilized plots, IR13423-10-2-3 performed best (4.0 t/ha).

IR13423-17-1-2-1 had the highest yield increase at 60 kg N/ha, producing about 63 kg rough rice/kg N.

Among the very early-maturing rices (≤115 d), IR9752-71-3-2 performed the best by progressively responding to the increasing N rates.

During the WS, only IR42 yielded more than 6.0 t/ha. Most entries suffered bacterial leaf streak. Rats and birds caused the low yields of the very early-maturing rices. They destroyed IR9752-71-3-2.

Bicol. In the DS, IR13423-10-2-3 performed well across all N levels. It yielded similarly to IR42 (4.8 t/ha) without added N fertilizer and the highest (7.8 t/ha) among the entries at 120 kg N/ha. However, this line's maturity was not uniform. Similar problems were observed with sister line IR13423-171-2-1.

IR21015-80-3-3-1-2 and IR22082-41-2 also appear promising. Both rices yielded comparably to IR42 and IR13423-10-2-3 in plots without N fertilizer (Table 4).

The DS yields of the rices tested were consistently highest at 120 kg N/ha.

In the WS, only IR42 and IR19672-140-2-3-3-2 yielded more than 6.0 t/ha. IR42 consistently outyielded most entries at all N levels.

The yield response of very early-maturing rices to N fertilizer was relatively low.

Visayas. IR22082-41-2 had the highest DS yield

Table 1. Yields of IRRI varieties and promising lines at five N levels (0-150 kg/ha) in irrigated plots, IRRI, 1982.[a]

Variety or line	DS						WS					
	Maturity (d)	Yield[b] (t/ha)					Maturity (d)	Yield[b] (t/ha)				
		0	60	90	120	150		0	30	60	90	120
IR8	138	3.8	4.7	5.2	5.8	6.3	126	2.0	2.6	2.3	3.0	3.3
IR20	119	4.1	4.9	5.2	4.9	4.8	126	2.5	2.7	3.1	3.2	2.4
IR36	114	3.0	5.3	6.3	6.3	6.1	113	2.9	4.1	4.3	4.5	3.3
IR42	138	3.7	6.4	6.5	7.1	6.9	141	2.6	4.3	4.4	5.1	4.7
IR54	109	3.3	4.8	6.3	6.1	6.7	126	2.8	4.2	4.2	4.6	3.8
IR56	114	3.4	5.0	6.0	5.2	5.3	113	3.0	3.4	3.8	3.5	3.0
IR9729-67-3	103	3.3	5.2	6.6	6.8	6.6	105	2.7	4.1	4.4	4.1	3.5
IR9752-71-3-2	103	4.6	5.8	6.5	6.8	6.2	102	2.2	2.6	3.8	3.8	4.5
IR13429-299-2-1-3-1	109	3.4	5.5	5.6	5.9	5.7	110	2.8	3.4	3.9	4.5	4.0
IR13423-10-2-3	139	2.5	4.2	5.6	5.7	6.5		—	—	—	—	—
IR13423-17-1-2-1	140	3.1	4.5	6.4	5.8	6.3		—	—	—	—	—
IR13525-43-2-3-1-3-2	119	3.1	4.6	4.6	5.8	5.6	123	2.9	3.8	4.5	5.2	5.2
IR13540-56-3-2-1	119	2.8	5.3	5.6	6.1	5.5	130	3.1	3.7	4.7	4.9	4.4
IR15314-43-2-3-3	138	3.1	3.5	3.8	4.9	5.5		—	—	—	—	—
IR17494-32-1-1-3-2	138	2.7	3.6	4.0	5.1	5.2	130	2.4	3.3	3.8	3.9	3.8
IR18348-36-3-3		—	—	—	—	—	123	2.7	3.5	4.2	4.5	4.7
IR19058-107-1	114	2.9	5.0	6.0	5.8	5.7		—	—	—	—	—
IR19661-131-1-3-1-3	138	1.8	3.2	4.0	3.8	4.4		—	—	—	—	—
IR19672-140-2-3-2-2		—	—	—	—	—	130	3.0	4.0	4.6	4.7	4.6
IR19672-155-2-1-1-3	139	3.6	4.5	5.6	5.7	6.4	130	3.4	3.8	4.6	4.9	4.2
IR19728-0-3-2-3-3	103	2.9	4.8	5.2	4.8	5.0		—	—	—	—	—
IR19735-5-2-3-2-1	108	3.9	5.4	5.9	5.7	6.2		—	—	—	—	—
IR19743-25-2-2-3-1	108	4.2	5.6	6.6	6.8	6.2		—	—	—	—	—
IR19743-46-2-3-3-2	103	5.1	5.4	5.7	6.4	5.7	102	2.3	2.5	2.9	3.4	3.2
IR19746-28-2-2-3	108	3.9	5.3	6.0	5.7	5.7		—	—	—	—	—
IR21015-80-3-3-1-2	109	3.6	5.3	6.1	6.6	6.3	123	3.0	3.9	4.1	4.5	3.6
IR21848-65-3-2		—	—	—	—	—	130	2.8	3.4	4.0	4.1	4.2
IR22082-41-2	119	3.4	4.1	5.8	6.8	7.5	126	3.0	4.1	4.3	4.6	4.3
IR24632-60-3-3-2	108	4.6	5.2	6.6	6.3	6.3		—	—	—	—	—
IR25588-7-3-2		—	—	—	—	—	110	3.2	3.4	4.5	4.0	4.2
IR25588-32-2	108	3.5	5.7	6.1	5.9	6.3		—	—	—	—	—
IR25621-94-3-2		—	—	—	—	—	110	2.6	3.3	3.7	3.8	3.9
IR25863-8-2-3		—	—	—	—	—	105	3.2	3.6	3.8	3.9	3.8
IR25882-32-1-3		—	—	—	—	—	105	3.2	3.9	4.8	4.9	4.5
IR25901-9-2-3		—	—	—	—	—	103	2.5	3.4	3.5	3.8	4.0
IR25922-39-3-2		—	—	—	—	—	105	2.6	3.4	3.6	3.8	3.2
IR25924-92-1-3		—	—	—	—	—	103	3.3	3.5	4.2	4.5	4.0
IR28128-45-2		—	—	—	—	—	103	3.4	3.8	4.4	4.2	3.9
Peta	148	3.0	4.0	3.7	2.0	1.1	141	1.7	1.9	1.9	1.5	1.3

[a]Av of three replications. Each treatment includes 30 kg N/ha topdressed 5-7 DBPI in the DS and 10 kg N/ha topdressed 5-7 DBPI in the WS. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.97 t/ha. In the WS, IR8 was affected by virus, Peta lodged at all N levels, and early-maturing rices were severely damaged by a typhoon.

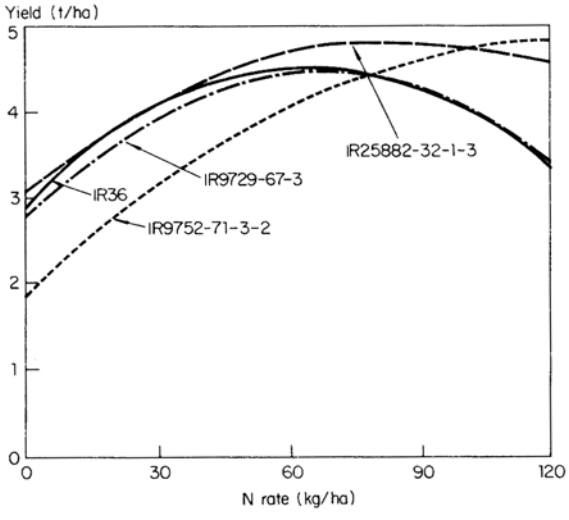
(6.8 t/ha) across all N rates at 90 kg N/ha (Table 5). Relatively low yields were due to water shortages in the DS. Maximum yield responses occurred within the range of 90-120 kg N/ha. IR15314-43-2-3-3 produced 4.6 t/ha without N fertilizer. Peta responded negatively to N application because a March storm resulted in widespread lodging in plots that received N fertilizer applications.

In the WS, IR22082-41-2 produced the highest yield (7.7 t/ha) at 120 and 150 kg N/ha.

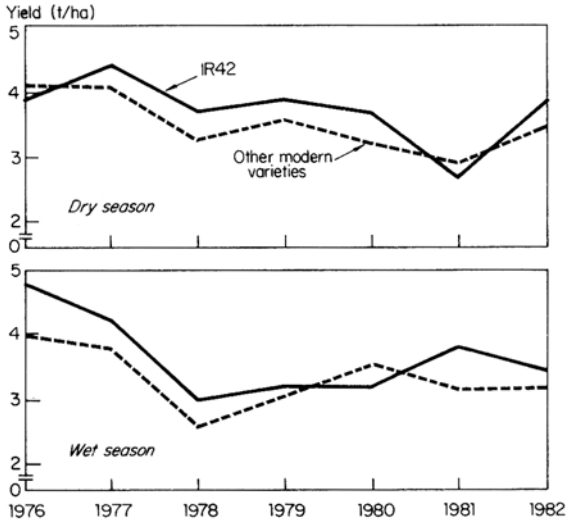
Performance of IR42 without N fertilizer. From 1976 to 1982, IR42 usually yielded higher than other MVs without N fertilizer as shown by summarized data for the 7-yr period at four experimental stations (Fig. 3).

Rainfed rice. *IRRI.* The yield potentials of four varieties and eight IR lines were tested at five N levels. Without N fertilizer, IR21015-80-3-3-1-2 outyielded all other entries (Table 6). IR21820-154-3-2-2-3 yielded 4.4 t/ha at 30 kg N/ha.

Farmer's field. IR42 and IR46 outyielded all other rices (Table 7). IR46 yielded 5.7 t/ha at



2. N response of early-maturing irrigated rices. IRRI, 1982 WS.



3. Yields of IR42 and other modern varieties without N fertilizer in four Philippine locations (IRRI, Maligaya, Bicol, and Visayas) during the 1976-1982 cropping seasons.

120 kg N/ha. At 80 kg N/ha, IR42 yielded 5.3 t/ha and IR46 yielded 5.4 t/ha.

SOURCES OF SEMIDWARFISM

Plant Breeding Department

IRRI continues to search for new sources of the recessive genes that provide semidwarfism. The principal recessive gene (sd_1) was derived from Dee-geo-woo-gen (Dgwg) of Taiwan, China, and has been used extensively by the rice breeders of tropical Asia. Allelism tests were made by crossing every new semidwarf with one of the IR varieties carrying the sd_1 gene of Dgwg.

Seventeen crosses were evaluated: five were new accessions; nine were previously studied semidwarfs and did not appear to carry the sd_1 gene; and the remaining crosses were tall/tall, which were reported to have promising semidwarfs in their progenies.

From the segregation pattern of F_2 populations, it was found that each of the five new accessions have one or more height genes different from the

Table 2. Yields of IR varieties and promising lines at four N levels (0-15 kg/ha) on an irrigated farm, Laguna, Philippines.[a] 1982 DS and WS.

Variety or line	DS					WS				
	Maturity (d)	Yield (t/ha)				Maturity (d)	Yield (t/ha)			
		0	50	100	150		0	40	80	120
IR8	133	7.3	6.4	6.3	5.9	128	4.2	4.9	3.6	4.0
IR36	112	7.8	7.6	7.9	7.1	111	4.0	4.5	4.5	4.0
IR42	140	7.6	7.2	6.8	5.6	133	5.4	5.1	5.2	4.8
IR56	109	6.8	6.8	6.6	6.4	–	–	–	–	–
IR9729-67-3	103	7.2	7.3	7.5	6.9	107	4.4	4.3	4.4	4.2
IR9752-71-3-2	104	6.3	6.4	7.4	7.8	111	3.8	4.2	4.4	4.2
IR13429-299-2-1-3	112	7.6	8.1	7.8	7.4	–	–	–	–	–
IR19672-155-2-1-1-3	–	–	–	–	–	128	4.8	4.9	5.0	4.0
IR21015-80-3-3-1-2	126	7.7	8.4	8.3	7.9	128	5.0	4.5	4.8	4.7
IR22082-41-2		–	–	–	–	114	5.4	5.3	5.5	4.7

[a] Av of three replications. Each treatment includes 20 kg N/ha topdressed at panicle initiation in both seasons.

Table 3. Yields of rice varieties and promising lines at six N levels[a] (0-180 kg/ha) in irrigated plots. N Response of Promising Lines. Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, Philippines. 1982 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	137	3.3	4.5	6.2	6.4	6.4	6.8	124	3.2	3.3	4.4	4.8	5.1	4.6
IR20	124	2.4	4.4	5.8	6.7	6.8	6.6	124	2.6	3.9	4.0	4.9	5.0	5.1
IR36	116	3.2	6.1	6.4	7.2	6.9	7.7	109	2.7	3.7	4.4	4.8	4.4	4.4
IR42	137	3.3	5.4	6.2	7.8	8.1	**8.6**	132	3.5	3.7	5.5	6.2	6.3	6.4
IR54	124	3.6	5.4	6.4	8.1	7.1	7.5	122	3.5	3.9	4.8	5.0	5.4	4.9
IR56	110	3.5	5.1	6.5	6.4	6.9	7.2	105	2.4	3.3	3.4	4.0	3.9	3.7
IR9729-67-3	102	2.0	3.5	3.9[b]	4.5	4.2	3.8	101	2.4	2.8	3.0	2.9[b]	4.4[b]	2.9
IR9752-71-3-2[c]	102	2.6	4.6	4.5	6.4	6.7	7.3	96	—	—	—	—	—	—
IR13423-10-2-3	125	**4.0**	6.1	6.7	7.0	7.6	7.1	—	—	—	—	—	—	—
IR13423-17-1-2-1	131	2.4	6.2	5.5	6.7	6.7	7.1	—	—	—	—	—	—	—
IR13429-299-2-1-3-1	110	2.6	5.0	6.6	6.3	6.6	7.1	105	2.5	3.1	3.7	3.9	3.0	2.8
IR13525-43-2-3-1-3-2	131	3.3	6.5	6.4	6.9	7.1	7.2	122	2.9	4.3	5.2	5.8	5.5	5.8
IR15314-43-2-3-3	131	2.6	5.1	6.0	6.2	6.4	6.4	—	—	—	—	—	—	—
IR17494-32-1-1-3-2	125	2.7	3.9	5.0	5.9	5.7	5.6	—	—	—	—	—	—	—
IR9672-140-2-3-3-2	—	—	—	—	—	—	—	124	3.6	4.3	5.0	5.6	4.4	4.6
IR19672-155-2-1-1-3	—	—	—	—	—	—	—	124	3.2	4.4	5.4	4.7	5.7	4.0
IR19728-9-3-2-3-3	102	3.2	4.5	5.6	6.3	6.0	5.8	—	—	—	—	—	—	—
IR21015-80-3-3-1-2	116	3.3	5.5	6.0	6.9	7.4	7.5	109	3.1	3.4	4.3	4.4	4.5	3.5
IR22082-41-2	125	2.7	6.1	6.8	7.6	7.5	8.3	115	2.8	3.7	4.8	4.9	5.6	4.5
IR25882-32-1-3	—	—	—	—	—	—	—	101	2.4	2.7	2.9	3.8[b]	4.2	3.0[b]
IR25901-9-2-3	—	—	—	—	—	—	—	96	2.0	2.1	2.2	2.2	3.1[c]	2.8
IR25924-92-1-3	—	—	—	—	—	—	—	96	1.4	1.7	2.1	3.0[b]	3.5	3.1
Peta	137	3.1	4.9	5.8	5.9	5.7	3.7	137	3.6	3.3	3.6	2.6	2.5	2.3

[a]Each treatment includes 20 kg N/ha topdressed 5-7 DBPI in both seasons. [b]Average of two replications due to rat and bird damage. [c]During the WS yield data were available in one replication only.

Table 4. Yields of rice varieties and promising lines at six N levels (0-180 kg/ha) in irrigated plots.[a] N response of promising lines. Bicol Experiment Station, Pili, Camarines Sur, Philippines. 1982 DS and WS.

Variety or line	DS							WS						
	Duration (d)	Yield (t/ha)[b]						Duration (d)	Yield (t/ha)[b]					
		0	60	90	120	150	180		0	30	60	90	120	150
IR8	134	4.5	3.5	4.8	5.6	5.1	6.3	124	2.9	3.6	5.5	4.8	4.3	3.6
IR20	120	3.7	5.7	6.2	6.7	7.1	6.6	121	3.3	4.5	4.4	4.5	4.6	3.3
IR36	111	3.5	5.5	6.5	7.1	6.5	6.3	104	3.4	5.0	5.2	4.5	5.4	4.7
IR42	134	**4.8**	6.3	6.5	6.5	7.4	6.3	139	4.5	5.9	5.3	**6.4**	5.9	**6.2**
IR54	121	3.5	6.0	5.9	7.0	7.3	7.1	123	3.7	4.6	4.9	5.7	5.3	4.7
IR56	111	4.1	5.6	6.0	7.2	7.1	6.9	109	3.7	4.1	4.4	5.1	4.4	2.4
IR9729-67-3	99	2.6	4.4	5.2	6.0	5.7	6.4	100	2.8	2.9	3.2	3.8	3.6	3.4
IR9752-71-3-2	99	2.9	4.9	5.1	5.7	5.5	6.4	100	2.5	2.8	2.9	3.5	3.6	3.4
IR13423-10-2-3	122	**4.8**	7.0	6.2	**7.8**	6.9	7.2	—	—	—	—	—	—	—
IR13423-17-1-2-1	117	3.8	6.0	5.7	6.2	6.1	6.4	—	—	—	—	—	—	—
IR13429-299-2-1-3-1	111	3.8	5.1	5.9	6.1	6.0	5.9	105	2.8	4.0	4.7	4.7	4.5	3.8
IR13525-43-2-3-1-3-2	112	3.8	5.5	6.0	6.5	6.5	6.9	120	3.8	4.5	5.5	5.7	5.8	4.5
IR15314-43-2-3-3	128	4.0	5.1	6.0	6.6	6.3	5.6		—	—	—	—	—	—
IR17494-32-1-1-3-2	126	3.7	5.2	5.8	5.6	5.8	6.0		—	—	—	—	—	—
IR19672-140-2-3-3-2	—	—	—	—	—	—	—	129	3.9	4.6	5.3	**6.4**	5.2	4.1
IR19672-155-2-1-1-3	—	—	—	—	—	—	—	133	3.9	4.0	5.3	4.7	5.2	5.6
IR19728-9-3-2-3-3	108	3.1	4.9	5.5	4.4	5.8	5.6		—	—	—	—	—	—
IR21015-80-3-3-1-2	120	**4.4**	6.9	6.8	7.0	7.2	7.2	116	3.7	3.8	5.3	4.7	4.6	3.8
IR22082-41-2	124	**4.4**	6.8	7.3	7.4	7.1	6.6	121	3.3	4.1	4.7	5.2	5.1	4.7

Continued on next page

Table 4 continued

Variety or line	DS							WS						
	Duration (d)	Yield (t/ha)[b]						Duration (d)	Yield (t/ha)[b]					
		0	60	90	120	150	180		0	30	60	90	120	150
IR25882-32-1-3	—	—	—	—	—	—	—	108	3.2	3.9	4.1	4.3	4.6	4.4
IR25901-9-2-3	—	—	—	—	—	—	—	107	2.7	3.2	3.5	3.9	4.0	3.4
IR25924-92-1-3	—	—	—	—	—	—	—	100	2.9	2.9	4.3	4.0	4.1	4.4
Peta	138	3.9	4.2	1.9	1.9	3.1[b]	1.4	141	4.8	4.5	2.3	3.6	3.8	3.8

[a]Each treatment includes 20 kg N/ha topdressed 5-7 DBPI in both seasons. [b]Two replications only.

Table 5. Yields of rice varieties and promising lines at six N levels (0-180 kg/ha) in irrigated plots.[a] N response of promising lines. Visayas Experiment Station, Iloilo. 1982 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	134	3.0	5.5	6.1	6.5	5.7	5.4	124	4.8	6.0	6.2	6.9	6.9	7.0
IR20	119	4.1	5.1	5.3	5.8	5.7	5.3	124	5.3	6.0	6.8	6.8	6.6	6.5
IR36	106	3.8	4.5	4.5	4.7	4.9	4.8	107	4.0	4.9	5.0	5.1	5.7	5.9
IR42	138	3.9	6.3	6.5	6.0	5.8	6.0	137	4.0	5.5	5.7	5.7	6.3	5.5
IR54	113	4.0	6.1	6.7	6.6	6.1	6.1	122	5.1	6.1	6.9	6.7	6.5	5.4
IR56	108	3.8	4.9	5.5	5.3	5.1	4.9	107	4.4	4.9	5.6	5.7	6.0	5.2
IR9729-67-3	104	2.9	3.4	4.3	4.7	4.1	3.9	103	3.9	4.3	4.4	4.6	4.9	5.5
IR9752-71-3-2 (IR58)	104	2.8	3.7	5.6	5.5	4.9	5.0	100	2.6	4.1	4.2	5.4	5.1	5.2
IR13423-10-2-3	113	3.6	5.5	6.2	6.4	6.7	6.1	—	—	—	—	—	—	—
IR13423-17-1-2-1	113	4.2	5.6	5.7	5.8	5.5	5.4	—	—	—	—	—	—	—
IR13429-299-2-1-3-1	106	3.0	5.0	5.7	5.7	5.2	5.2	107	3.7	4.5	5.0	5.5	6.0	6.0
IR13525-43-2-3-1-3-2	113	2.9	5.0	5.7	5.3	5.0	5.1	120	5.0	6.3	6.4	6.3	6.1	6.0
IR15314-43-2-3-3	126	**4.6**	6.0	5.8	5.8	5.4	5.2		—	—	—	—	—	—
IR17494-32-1-1-3-2	126	3.9	5.1	5.5	5.9	5.2	4.8		—	—	—	—	—	—
IR19672-140-2-3-3-2		—	—	—	—	—	—	130	4.3	5.2	5.7	5.8	5.0	5.7
IR19672-155-2-1-1-3	—	—	—	—	—	—	—	130	3.5	4.8	5.1	5.6	5.2	4.6
IR19728-9-3-2-3-3	104	3.0	4.2	5.4	6.0	5.5	5.3	—						
IR21015-80-3-3-1-2	109	3.7	5.2	6.0	6.3	6.5	5.3	115	4.5	5.4	6.2	6.3	6.7	5.7
IR22082-41-2	121	3.9	5.8	**6.8**	6.7	6.6	6.7	124	4.5	6.0	6.3	6.7	**7.7**	**7.7**
IR25882-32-1-3	—	—	—	—	—	—	—	103	3.2	4.6	4.9	5.5	5.5	5.7
IR25901-9-2-3	—	—	—	—	—	—	—	103	2.8	3.8	4.5	4.8	5.1	5.1
IR25924-92-1-3	—	—	—	—	—	—	—	103	2.9	4.4	4.6	5.3	5.3	4.9
Peta	148	3.1	2.1	1.8	1.4	1.0	0.7	141	4.4	4.7	3.0	2.7	2.6	2.5

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

Dgwg source as indicated by a wide range of segregation for height. These accessions include:

- the Kalimonch Dwarf Mutant, a spontaneous dwarf mutant from India,
- M7, a selection from Calrose 76 ("d_1")/CS-M3 developed by the California Cooperative Rice Research Foundation, University of California at Davis and the USDA,
- CI9649/CI9722,
- Short Straw Dawn from the United States, and
- Fukunishiki.

The F_2 population of Fukunishiki, a Japanese variety, crossed with IR36, showed few tall segregates, which could indicate that such a source may share a portion of the compound semidwarfing locus.

Eight semidwarfs not allelic to the sd_1 alleles included: D66 ("d_2") and CI9858 ("d_3") from the United States; Hoyoku and Kochihibiki from Japan; P-3 Basmati Dwarf Mutant, Gora (NCS 16), Shiranui/Gionchiew 61-54, and Synthetic Sativa from India. Their allelic relationship was studied further.

Table 6. Yields of IR varieties and promising lines at five N levels (0-12 kg/ha) on rainfed farms.[a] IRRI, 1982 WS.

Variety or line	Maturity (d)	Yield (t/ha)				
		0	30	60	90	120
IR36	110	3.0	3.4	3.1	3.8	3.2
IR42	131	2.7	3.2	3.2	3.0	2.9
IR46	121	3.9	3.9	4.2	3.6	3.9
IR52	117	2.6	3.0	3.0	3.1	2.6
IR9729-67-3	98	2.9	3.3	3.4	3.3	3.4
IR9752-71-3-2 (IR58)	98	2.9	3.3	3.4	3.6	3.5
IR15791-163-1	135	3.2	3.6	3.7	3.8	3.6
IR21015-80-3-3-1-2	117	4.1	3.8[b]	4.3	4.1	3.6
IR21820-154-3-2-2-3	121	3.0	4.4	3.9[b]	4.4	4.2
IR21848-65-3-2	121	2.5	3.5	3.7	4.1	3.1
IR22082-41-2	121	3.8	3.5	4.1	3.9	4.0
IR2586-124-3-3	106	1.6	2.3	1.9	2.6	3.0
N-mean		3.0	3.4	3.5	3.6	3.4

[a]Av of three replications. Each treatment included 20 kg N/ha topdressed 5-7 DBPI. [b]Rat damage.

Table 7. Yields of IR varieties and promising lines at four N levels (0-120 kg/ha) in a farmer's rainfed field, Laguna, Philippines.[a] 1982 WS.

Variety or line	Maturity (d)	Yield (t/ha)				
		0	40	80	120	Mean
IR36	104	1.9	2.3	3.8	2.9	2.7
IR42	137	4.0	4.4	5.3	4.9	4.7
IR46	116	4.0	4.8	5.4	5.7	5.0
IR52	110	3.0	3.7	3.6	3.1	3.3
IR21015-80-3-3-1-2	110	2.4	3.1	3.8	2.9	3.1
IR21820-154-3-2-2-3	118	4.0	3.2	4.7	4.3	4.0
IR22082-41-2	116	3.3	4.0	3.2	3.6	3.5
				Mean[b]		
		3.2	3.6	4.2	3.9	3.8

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

[b]Comparison	LSD (5%)	LSD (1%)
2 N-means	0.68	1.02
2 N-means at same or different variety	1.013	1.57

Crosses between semidwarfs originating from India produced a great majority of the semidwarfs in the F_2. Some intermediate plants and a few tall plants were also found. The data indicate that they probably have a common gene but different modifiers.

The cross between two Japanese varieties (Hoyoku/Kochihibiki) gave a unimodal distribution consisting mostly of short F_2 plants within the parental range and a small number of slightly taller plants in the semidwarf class. The two varieties appear to have the same major gene for shortness but differ in the modifiers.

However, a cross between two U.S. varieties (D66/CI9858) produced a unimodal distribution with many transgressive segregants on the tall end. Most of the F_2 plants fell into the semidwarf class. The distribution did not conform to the expected nine tall: seven semidwarf-dwarf ratio, which is based on the earlier U. S. report that the D66 carried the d_2 gene and CI9858, d_3.

Crosses between a U.S. semidwarf and a Japanese semidwarf (D66/Kochihibiki and CI9858/Kochihibiki) produced many semidwarf F_2 plants within the parental range. The parents appeared to have the same major gene for semidwarfism.

A cross between an Indian semidwarf and a U.S. semidwarf (P-3 Basmati Dwarf mutant/CI9858) showed a distinct segregation of very short and tall plants.

Some Indian workers had obtained semidwarf segregants by crossing two tall varieties. Baok, a tall traditional Indonesian variety, was crossed with GEB 24, MTU 15, and Mahsuri to test their findings. A few semidwarf segregants were obtained. Further testing is needed to confirm if the short F_2 plants will breed true for short stature.

Genetic evaluation and utilization (GEU) program

Grain quality

Chemistry and Plant Breeding Departments

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BREEDING PROGRAM

Plant Breeding and Chemistry Departments

More intermediate-amylose lines continue to be evaluated in the breeding program. Additional quality indices were needed to discriminate among the intermediate-amylose lines.

Gel consistency as quality index. Although originally developed in 1973 as an index of the rate of hardening of cooked high-amylose rice, gel consistency (GC) could not distinguish between C4-63G and BPI-121-407, intermediate-amylose rices, despite the 1-kg difference in cooked-rice hardness (Annual report for 1980). A follow-up study on 21 intermediate-amylose and 2 low-amylose elite lines from the 1982 DS crop showed a fairly wide range in properties. Cooked-rice hardness (r = -0.60**, n = 23) and 12% paste Amylograph consistency (r = -0.67**, n = 22) were better correlated with GC than with amylose content (AC) (r = 0.56**, 0.51*). GC and AC were also negatively correlated (r = -0.63**, n = 23).

When the two low-amylose samples were removed from the correlation (n = 21), quality indices were no longer significantly correlated with cooked-rice hardness (Table 1). GC still correlated better with Amylograph consistency than AC, but alkali spreading value became significantly correlated with Amylograph (r = 0.62**, n = 20) and gel (r = -0.61**, n = 21) consistencies. AC was no longer correlated with GC. GC and the alkali spreading value may be useful additions to AC as quality indicators among intermediate-amylose rices.

Nature of rice aroma. Aromatic rices carry a price premium in tropical Asia. The chemical nature of the aroma principles of aromatic rices still needs elucidation. In late 1981, a cooperative study was established with food chemists at the USDA Western Regional Research Center (WRRC). Researchers are characterizing the aroma principles of selected rices and trying to develop an objective gas-chromatographic screening method that is rapid, reproducible, not subject to saturation, and applicable to the IRRI rice breeding program.

Brown-rice samples of aromatic rices were obtained from Indonesia, Japan, Pakistan, Philippines, and Thailand and shipped by air to WRRC. They were milled shortly before cooking. WRRC chemists identified and synthesized 2-acetyl-1-pyrroline, the characteristic odor in the steam volatile oils of cooked aromatic brown and milled rices. The higher concentration of 2-acetyl-1-pyrroline in brown rice than in milled rice suggested its higher level in bran-polish than in milled rice (Table 2). IR841-76-1 had the same level of the compound as Khao Dawk Mali, one of its parents.

The 2-acetyl-1-pyrroline ranged from 0.04 to 0.09 ppm in cooked rice by dry basis in the eight aromatic rices, but was only less than 0.01 ppm in the two nonaromatic rices (Table 2). Judges ranked the rices in terms of the characteristic aroma closely in the same order of 2-acetyl-1-pyrroline concentration (Table 2). The sample with the highest 2-acetyl-1-pyrroline level was Malagkit Sungsong, a waxy rice known to have an aroma distinct from that of the seven nonwaxy aromatic rices in the test. Experiments are under way to determine the source of 2-acetyl-1-pyrroline and its level in uncooked rice, and to develop an effective screening method for it.

2-acetyl-1-pyrroline belongs to the group of "cracker-like" odor compounds including 2-acetyl-1,4,5,6-tetrahydropyridine, 2-acetylpyrazine, and

Table 1. Range of properties and correlation coefficients of 21 intermediate-amylose elite lines. IRRI, 1982 DS.

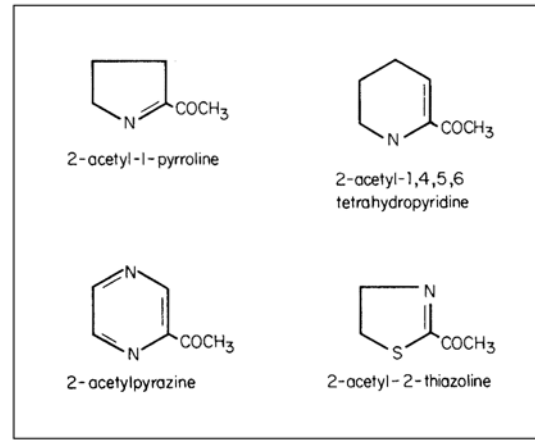
Property	Range of values	Correlation coefficient with				
		Amylose	Alkali spreading value	GC	12% paste Amylograph consistency[a]	Cooked-rice Instron hardness
Protein content (%)	7.0– 11.1	-0.72**	0.13	-0.27	-0.25	0.24
AC (% dry basis)	21.2– 23.4		0.36	-0.10	0.55*	-0.14
Alkali spreading value	3.2– 7.0			-0.61**	0.62**	0.13
GC (mm)	36 – 64				-0.66**	-0.30
Amylograph consistency (BU)	210 –380					-0.27
Cooked-rice Instron hardness (kg)	5.2– 6.9					

[a] n = 21, except for Amylograph consistency (n = 20).

Table 2. Concentration of 2-acetyl-1-pyrroline in cooked rice of eight aromatic and two nonaromatic varieties and ranking of cooked milled-rice samples based on the decreasing characteristic aroma. USDA Western Regional Research Center and IRRI, 1982.

Variety or line	Concn of 2-acetyl-1-pyrroline (ppm dry basis)		Ranking by judges of cooked milled rice for characteristic aroma[a]
	Milled rice	Brown rice	
Malagkit Sungsong	0.09	0.02	1
Milagrosa	0.07		2
Khao Dawk Mali 105	0.07	0.2	3
IR841-76-1	0.07	0.2	4
Basmati 370	0.06	0.17	5
Seratus Malam	0.06		6
Azucena	0.04	0.16	7
Hieri	0.04	0.1	8
Labelle (check)	0.008		10
Calrose (check)	0.006		9

[a]Groups of two or three cooked-rice samples were presented to 21-23 judges and ranked in terms of the greatest characteristic aroma. Common samples were used so that comparisons could be overlapped and the whole set could be ranked in terms of aroma.



1. Structure of "cracker-like" odor compounds. Western Regional Research Center, Berkeley, Calif., and IRRI, 1982.

2-acetyl-2-thiazoline (Fig. 1). Among them, 2-acetyl-1-pyrroline, with a threshold of 0.1 ppm in water, seems the most potent.

Milled-rice properties of the eight aromatic rices showed 6.8-9.3% protein, intermediate or low amylose or waxy, low to intermediate gelatinization temperature (GT) based on alkali spreading value, and variable GC (Table 3). To give aroma to nonaromatic rice, pandan (*Pandanus amaryllifolius* or fragrant screw pine) leaves are added during cooking in the Philippines and other Asian countries. WRRC found that freeze-dried pandan leaves contain 2-acetyl-1-pyrroline as a principal volatile constituent.

POSTHARVEST QUALITY

Chemistry Department

Factors affecting milling quality. Milling quality is usually measured as the percentage recovery of total milled rice and head (whole-grain) rice from rough rice using a standard McGill mill. Correlation analyses were continued for the elite lines in the Agronomy yield trials for the 1981 WS and the 1982 DS. As expected, the percentage of hulls and total milled rice yield were negatively correlated for both crops ($r = -0.90^{**}$ WS, $n = 15$ and $r = -0.85^{**}$

Table 3. Physicochemical properties of milled rice from aromatic or scented brown rices sent to the USDA Western Regional Research Center, Berkeley, California. IRRI, 1982.

Variety or line name	Source and crop year		Milled-rice property			
			Protein (% at 12% H_2O)	Amylose (% dry basis)	Alkali spreading value	GC (mm)
Azucena	Philippines	1981	7.6	23.2	5.1	50
Basmati 370	Pakistan	1981	6.8	23.2	6.6	47
Hieri	Japan	1981	7.6	20.3	4.7	88
IR841-76-1[a]	IRRI	1981	8.6	19.2	7.0	83
Khao Dawk Mali 105	Thailand	1981	7.7	14.5	7.0	60
Malagkit Sungsong	Philippines	1982	9.3	1.2	7.0	74
Milagrosa	Philippines	1981	6.9	23.2	4.7	49
Seratus Malam	Indonesia	1981	8.7	23.0	6.0	38

[a]Peta3/Taichung Native 1//Khao Dawk Mali 105.

DS, $n = 14$). Total milled rice yield and degree of milling also were negatively correlated ($r = -0.92^{**}$ WS and -0.78^{**} DS). Head rice yield correlated positively with rough rice Instron bending hardness ($r = 0.50^{*}$ WS and 0.64^{*} DS) but not with brown-rice hardness. The selection of grain samples for the hardness test probably was more objective for rough rice than for brown rice because the physical features of the brown rice are hidden in rough rice. Milled-rice whiteness (Kett meter) was not consistently correlated with any of these milling quality indicators.

In field samples subjected to grain stresses during postharvest operations, grain fissuring or cracking before milling may be a more important factor than grain hardness alone. This may be revealed better by the bending hardness test than by the cracking hardness test used in 1981.

Among 12 Thai floating rices tested at IRRI, total milled-rice yield correlated negatively with percentage hull ($r = -0.87^{**}$) and degree of milling ($r = -0.75^{**}$) and positively with brown-rice bending hardness ($r = 0.61^{*}$). Head rice yield and whiteness of milled rice were not significantly correlated with any of the properties tested. Rough rice and brown rice bending hardness values were correlated positively ($r = 0.83^{**}$) and both correlated negatively with degree of milling ($r = -0.72^{**}$).

VARIETY PREFERENCE

Chemistry Department

Country samples. Grain samples from 10 countries were obtained for routine evaluation of grain quality (Table 4). Two long-grained rices from Australia had intermediate AC, intermediate or low GT, and soft GC. Wetland and dryland selections from Burma differed in starch properties. Samples from China differed widely in properties, with indica samples having higher AC and higher values for cooked-rice hardness than japonica samples. Two japonica waxy rices had the softest cooked rice (hardness values of 4.4 and 4.7 kg). One hybrid each of indica and japonica rice had grain with properties similar to those of normal rice. Rices from India were high in AC, but a greater proportion had low GT and hard GC than before.

The Italian rices had a narrow AC range (19-22%) and none approached the AC (24-25%) and hard GC of the variety Raffaello. Japanese rices also had a 19-22% AC range and the analysis did not show the better quality of Sasanishiki. West African rices differed widely in starch properties. Rices differing in eating quality from Sabah, Malaysia, had high and intermediate AC. The three intermediate-amylose rices had good grain properties; two of the three high-amylose rices had

Table 4. Range of milled-rice properties of country samples. IRRI, 1982.

Source	Sample no.	Protein (%)	AC[a]	GT[b]	GC[c]	Cooked-rice hardness[d] (kg)
Australia	2	5.6-7.6	I	I, L	S	5.3-5.9
Burma	10	5.7-11.0	H, I>L	I, L>HI	M, H>S	4.9-8.4
China indica	13	7.2-13.0	H>I, L	I>L	H>M	6.6-8.6
japonica	13	6.6-9.7	L>I>Wx	L>I, HI	S>M	4.0-7.0
India	8	5.7-9.0	H	L>I	H>S>M	7.1-9.6
Italy	8	–	I>L	L	S>M	3.2-5.2
Japan	5	5.4-7.2	I>L	L	M>S	4.7-5.8
Liberia (WARDA)	9	5.9-9.3	H>I>L	I>L>H	S, M>H	5.8-8.0
Malaysia-Sabah	10	5.8-8.2	H>I	L>I>HI	M>H	5.1-8.2
Malaysia-Sarawak	7	5.1-8.4	H>L>I	I>L, HI	M, S, H	4.3-7.0
Nepal	3	6.5-7.6	H, L	I	S	6.6-7.0
Philippines	10	–	H>I, Wx	I>H	S>H	5.2-8.9
Thailand - RD series	12	5.9-11.2	H>I, L, Wx	L>I	H, M, S	3.7-8.4
Thailand - floating rices	10	–	H>Wx	I>L	H>S>M	–

[a]Amylose content: H = high, >25%; I = intermediate, 20-25%; L = low, 10-20%; and Wx = waxy, 1-2%. [b]Gelatinization temperature based on alkali spreading value: L = low, 6-7; I = intermediate, 4-5; HI = high intermediate, 3; and H = high, 2. [c]Gel consistency: S = soft, 61-100 mm; M = medium, 41-60 mm; and H = hard, 27-40 mm. [d]Cell area of 6.5 cm^2.

good quality, but hard GC. Samples from Sarawak, Malaysia, although having good quality also differed widely in grain properties. All three Nepalese popping rices had high AC, intermediate GT, and soft GC.

Philippine selections from the Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, except one intermediate-amylose and one waxy sample, had predominantly high AC. There were three high-AC samples with low GT and hard GC, and they had higher cooked-rice hardness than the others. The Thai Rice Division (RD) varieties had predominantly high AC, low GT, and variable GC. Waxy and low-AC samples had lower cooked-rice hardness values than high- and intermediate-AC samples. Among the floating rices, all had high AC (except one waxy rice), mainly intermediate GT, and variable GC.

FACTORS AFFECTING COOKED-RICE QUALITY

Chemistry Department

Water solubles complexing with starch gel. In the starch complexing test using defatted IR29 (waxy) starch, fatty acids such as palmitic acid complexed with and hardened the starch gel in water (Annual report for 1980). Recent studies elsewhere reported that potato amylopectin did not complex with palmitic acid at 80° C on the basis of gel viscosity. To resolve this apparent contradiction, gel viscosity of potato amylopectin and two waxy rice starches (98-99% amylopectin in water without and with palmitic acid) were measured at 20° and 80° C. Results confirmed that, although potato amylopectin has very low gel viscosity even with palmitic acid added, waxy rice starch complexed with palmitic acid with an increase of viscosity even at 80° C (Table 5).

A survey of the complexing ability on IR29 starch by commercially available gums revealed hardening by guar gum, gum tragacanth, gum karaya, locus-bean gum, and tamarind-seed polysaccharide; slight hardening by pectin and gum ghatti; no effect from gum arabic ex acacia tree and sodium carboxymethyl cellulose; and softening by polygalacturonic acid. Most gums hardened rice amylopectin gels at 1-2 mg/100 mg IR29 starch in 1.6 ml of water.

Table 5. Effect of palmitic acid on gel viscosity of potato amylopectin and waxy rice starch at 20° and 80°C. IRRI, 1982.

Amylopectin[a]	Gel viscosity (cps)			
	20°C		80°C	
	Control	P. A.[b]	Control	P. A.[b]
Potato	13	13	6	6
Niaw San Pahtawng	96	128	38	46
Señorita	253	349	125	141

[a]150 mg in 1.6 ml water. [b]1 mg palmitic acid added.

Water solubles during cooking. Further study was made of the materials that leach out in the cooking water of C4-63G and IR32 milled rice. Both were previously washed with cold water before cooking. The cooking water was freeze-dried and extracted with petroleum ether and hot 80% ethanol; part of the residue was destarched with glucoamylase. Addition of 1-2 mg of the various fractions to 100 mg IR29 defatted starch in the modified aqueous GC test (Annual report for 1980) demonstrated that the petroleum ether fraction complexed best with amylopectin, followed by the residue (starch, protein, and nonstarch polysaccharides), and the 80% ethanol (polar lipids and sugars) fractions. The destarched residue complexed less with amylopectin than the whole residue, suggesting that amylose (45-68%) was mainly responsible for complexing with amylopectin in this fraction.

Chloroform-soluble lipids removed from eight milled rices during washing with water ranged from 0.13 to 0.37% by weight; 0.13-0.27% were subsequently extracted during cooking. The lipids in the petroleum ether and hot 80% ethanol fraction of hot-water solubles of the eight rices were analyzed by thin-layer chromatography. The petroleum ether fraction had mainly nonpolar lipids (free fatty acids, diglycerides, and triglycerides). The 80% ethanol extract had, in addition to the nonpolar lipids, phospholipids (lysophosphatidyl choline, lysophosphatidyl ethanolamine, and phosphatidyl choline) and glycolipids (monogalactosyl and digalactosyl diglycerides). The chloroform-soluble lipid fraction of the 80% ethanol extract ranged from 30 to 100% of the extract. Sucrose and maltose were the main sugars in the

80% ethanol fraction. The residue was mainly starch with very little nonstarch polysaccharides and protein.

Bran, germ, and hull polysaccharides. Cold water- and hot water-soluble material from previously prepared IR32 bran and germ cell walls and from IR29 and IR32 hulls was about 1% by weight. These water-soluble fractions hardened IR29 starch gel in water although the whole bran and germ cell wall preparation softened the starch gel. Cold-water bran extracts were richer in arabinose and galactose, but poorer in glucose than the hot-water extracts. The major sugars were arabinose, galactose, glucose, and xylose. The extracts also contained 4-7% uronic acid.

Solubility fractionation of rice hulls showed the major fraction to be the residue insoluble in 6 *M* NaOH, 50% in IR29 and 55% in IR32 hulls. The other major fractions were the alkali-soluble fractions: 12% in 0.5 *M* KOH, 19-21% in 4.27 *M* KOH, and 11-13% in 6 *M* NaOH. Together these constituted 95-96% of the hull dry weight. The major sugars of the rice hull polysaccharides were 61-62% glucose, 28-30% xylose, and 4-5% arabinose.

ICC study group 21-II. The International Association for Cereal Chemistry (ICC) Working Group 21-II "Test Methods for Rice - Cooking Properties" undertook four cooperative ring tests based on the 1981 survey of cooking methods. The objective was to rationalize the various methods scientists use for assessing cooking properties of rice.

The first test involved the texture measurement for five rice samples cooked to the same water content of 75% wet basis. Cooking was either in excess or in the measured amount of cooking water. The samples included one waxy, one low-amylose, one intermediate-amylose, and two high-amylose (one soft- and one hard-GC) rices. Cooperators used taste panels or instruments to measure cooked-rice hardness and stickiness.

The second test used the same five samples but compared using one to three grains with using bulk samples of cooked rice for measuring hardness and stickiness.

The third test dealt with measuring the tendency of some rices, such as Basmati and Sadri varieties, to elongate during cooking. The major sources of variation are difficulty in reproducing the boiling time, particularly for samples immersed in cold water in test tubes and the curling tendency of overcooked grains. Some analysts cooked the grains for a minimum time or until the center became translucent. The proposed common method used 30-min presoaking in cold water, a sample container with a perforated bottom to allow drainage of the soaking water and instantaneous entry of boiling water, and a fixed boiling time of 10 min. Presoaking reduced the cooking time and the short boiling time prevented overcooking and grain curling. Boiling the grains for 10 min was reproducible because the cold soaking water was excluded from the cooking step. The five rices were ranked similarly by 17 cooperators, but the range in values was wide — probably reflecting differences in actual boiling water temperature or degree of cooking (Table 6). Nine cooperators found that

Table 6. Range of mean elongation ratio and of elongation index during 10-min cooking of 10 presoaked milled grains of five rice varieties in tests conducted by 17 participants in the International Association for Cereal Chemistry (ICC) Working Group 21 II, Study C, "Grain elongation during cooking." IRRI, 1982.

Variety	Elongation ratio[a]		Elongation index[b]	
	Range of mean	Overall mean	Range of mean	Overall mean
Basmati 370	1.71 - 2.41	2.15	1.15 - 1.89	1.63
Dumzard	1.53 - 2.09	1.82	1.14 - 1.66	1.37
Labelle (check)	1.38 - 1.74	1.57	0.98 - 1.18	1.08
Milyang 49	1.54 - 2.04	1.79	1.12 - 1.48	1.32
Nga Kywe (D25-4)	1.94 - 2.48	2.25	1.44 - 2.18	1.82
Mean	1.38 - 2.48	1.92	0.98 - 2.18	1.42

[a] Length of cooked grain/length of raw grain. Nga Kywe had the highest value for 13 cooperators and Basmati 370 for 4 cooperators. [b] Length/width of cooked grain ÷ length/width of raw grain. Nga Kywe had the highest value for 15 cooperators and Basmati 370 for 2 cooperators.

the proposed method generally showed a wider spread of values among the samples than their own laboratory method.

The greatest variation was shown in the Amylograph test on four aged, milled-rice flours. Ten cooperators, using IRRI-ground flour and laboratory-ground flour from milled rice, found that the biggest source of variation was the Amylograph instrument. Four cooperators, who estimated GT using a 20% paste based on the temperature of initial increase of paste viscosity in the Amylograph, obtained similar GT values. A fifth cooperator used a 350-cm·g instead of the 700-cm·g sensitivity cartridge.

Correlation of starch and milled-rice properties. Correlation analysis was done for properties of milled rice and starch and starch fractions of 8 waxy and 27 nonwaxy (8 low-amylose, 12 intermediate-amylose, and 7 high-amylose) rices differing in GT.

Among waxy samples, the sedimentation coefficient $S_{20,w}$ of amylopectin was significantly correlated with GT ($r = 0.80^*$, $n = 8$) and with milled-rice neutral gel consistency in potassium acetate ($r = -0.85^*$, $n = 7$). Surprisingly, the neutral GC in potassium acetate and in the water of 200 mg milled rice in 2-ml solvent were negatively correlated ($r = -0.89^{**}$, $n = 7$). However, the neutral GC of milled rice was positively correlated with GC of starch in water at 150 mg ($r = 0.86^*$, $n = 7$) and 200 mg/2 ml H_2O ($r = 0.90^{**}$, $n = 7$). Cooked-rice Instron hardness and stickiness values were negatively correlated ($r = -0.85^{**}$, $n = 8$). Cooked-rice Instron hardness correlated negatively with aqueous GC of amylopectin at 115 mg ($r = -0.94^{**}$, $n = 8$) and 165 mg/2 ml H_2O ($r = -0.90^{**}$, $n = 7$). GT and cooked-rice stickiness were significantly correlated ($r = -0.79^*$, $n = 8$). Starch amylograph consistency was negatively correlated with starch GC of 200 mg/2 ml H_2O ($r = -0.87^*$, $n = 6$).

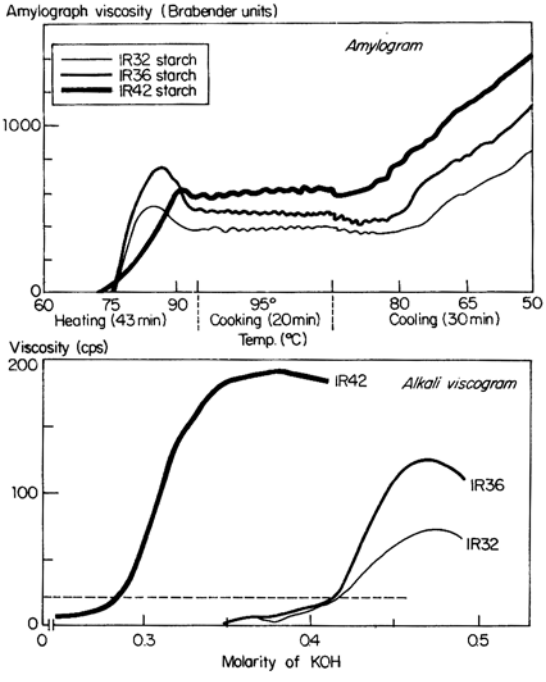
Among nonwaxy samples, the correlations were not as high, probably because of the wide range of AC. The GC of milled rice in 0.2 *M* KOH correlated with starch Amylograph consistency ($r = -0.60^*$, $n = 16$) and setback ($r = -0.54^*$, $n = 16$). However, the reverse was true with GC of starch in water, as it correlated with starch Amylograph consistency ($r = -0.66^{**}$, $n = 16$) and setback ($r = -0.50^*$, $n = 16$). Amylopectin GC in water (165 mg/2 ml) was also negatively correlated with starch Amylograph consistency ($r = -0.69^{**}$, $n = 15$) and positively correlated with GC of starch in water ($r = 0.41^*$, $n = 25$) and of milled rice in 0.2 *M* KOH ($r = 0.55^*$, $n = 25$) and water ($r = 0.45^*$, $n = 20$). The amylopectin $S_{20,w}$ value was positively correlated with starch Amylograph peak viscosity ($r = 0.73^{**}$, $n = 16$) and negatively with Amylograph setback ($r = -0.65^{**}$, $n = 16$). AC was significantly correlated with cooked-rice stickiness ($r = -0.48^*$, $n = 27$) but not with hardness ($r = 0.11$).

Properties of high-amylose starch. Earlier studies have shown that differences in cooked-rice texture among high-amylose milled rices were attributable to the starch fraction. Rices that are hard after cooking (IR8 and IR42) have a higher Amylograph setback and cold paste viscosity than rices that are soft after cooking (IR5 and IR32). Some high-amylose rices (IR36) have intermediate properties and medium GC.

Detailed studies were made of the properties of the dodecyl benzene sulfonate (DoBS)-prepared starches of IR32 (soft GC), IR36 (medium GC), and IR42 (hard GC). Amylograph runs of 9% pastes confirmed the characteristic pasting properties for each type. IR42 had almost no drop in viscosity during cooking at 95° C and had the highest cooled-paste viscosity (Fig. 2). IR32 and IR36 showed the expected greater breakdown or drop in viscosity on cooking, and lower cold paste viscosity than IR42, proportionate to their GC ratings. Also, IR42 achieved peak viscosity at a higher temperature (91° C) than the other starches (84.5° and 85.5° C), although it started gelatinizing at a lower temperature.

Alkali viscograms of 2.0% starch also showed highest peak viscosity for IR42 and lowest for IR32 as predicted from GC (Fig. 2). Alkali (KOH) molarity for gelatinization was lowest for IR42 and followed closely the photometric GT of the starches. GC values of starch in 0.2 *M* KOH for IR32, IR36, and IR42 were 100, 97, and 65 mm at 100 mg/2 ml; 88, 79, and 34 mm at 120 mg/2 ml; and 73, 33, and 28 mm at 135 mg/2 ml. Corresponding gel viscosity values again denote the IR42 starch to be more viscous than IR32 and IR36 starches.

Earlier studies have shown that soft-GC, high-AC rices leach out more amylopectin and amylose



2. Comparative Amylograph viscosity and alkali viscograph curves of IR32 (soft gel), IR36 (medium gel), and IR42 (hard gel) high-amylose starches. IRRI, 1982.

during cooking than hard-GC, high-AC rices. Extraction at 75° C and then at 98° C from the three starches in water resulted in a better leaching of amylose and amylopectin in IR32 even at 75° C than in IR36 and IR42. At 98° C, the additional starch leached out was also highest in IR32, but was slightly higher in IR36 than in IR42 starch. The three starch samples had similar lipid contents (0.9-1.0%). The starch extracted at 75° C was richer in amylose (82-90%) than that subsequently extracted at 98° C (66-76%) on the basis of iodine blue value.

A study of the amylose and amylopectin fractions of the starches showed amylose degree of polymerization of 831 glucose units for IR42, 763 for IR36, and 1,210 for IR32. The respective GC values of amylopectins for IR42, IR46, and IR32 were 55, 82, and 81 mm at 115 mg/2 ml 0.2 *M* KOH, and 29, 59, and 75 mm at 165 mg/2 ml solvent. The GC values for amylopectin were consistent with the relative GC values for the starch and milled rice. Amyloses were confirmed to contribute much less to gel viscosity and consistency than amylopectin.

Differential scanning calorimetry of rice starch. Differential scanning calorimetry (DSC) of cereal starches has shown the presence of another endotherm at 95°-105° C representing amylose-lipid complex melting, in addition to the gelatinization endotherm. A cooperative study was undertaken to determine the extent of variation in gelatinization enthalpy among rice starches differing in AC and photometric GT. Eight starches prepared by DoBS extraction of protein from milled-rice flour showed a range of gelatinization enthalpy of 11.3 to 17.3 J/g at starch:water of 1:4 dry basis (Table 7). Starch GT correlated positively with gelatinization enthalpy ($r = 0.94^{**}$) and onset, maximum, and completion temperatures of DSC gelatinization ($r = 0.98^{**}$ to 1.00^{**}), but only completion temperature was significantly correlated with AC ($r = -0.85^{*}$). Typical DSC curves are represented in Figure 3.

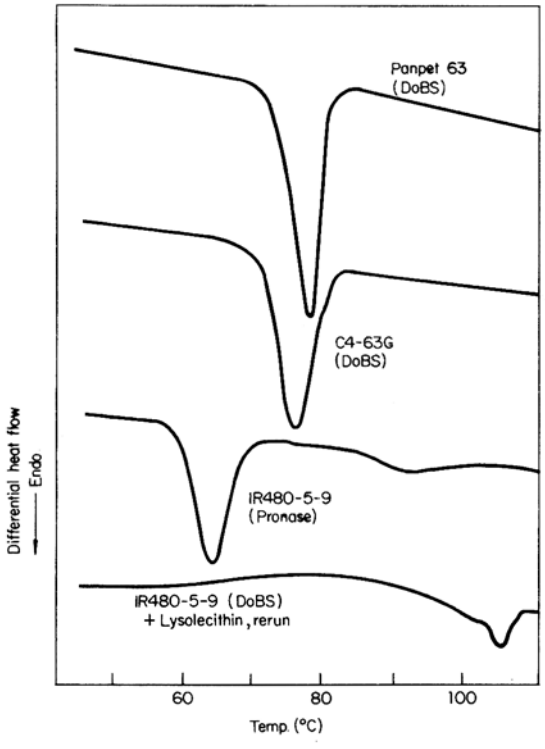
Heat of cooking was estimated from total enthalpy from 20° to 100° C and overlapped between the GT classes (Table 7, $r = -0.41^{ns}$). Heat of cooking correlated negatively with AC ($r = -0.76^{*}$), but may not be significantly different among the samples. Gelatinization enthalpy was just about 1% of the heat of cooking.

The reversible enthalpy peak at 95°-105° C was not distinct, particularly in the waxy starch samples. Because DoBS is known to partially defat rice

Table 7. Range of properties and differential scanning calorimetry (DSC) data of eight dodecyl benzene sulfonate-prepared rice starches differing in AC and photometric GT. Flour Milling and Baking Research Association, Chorleywood, UK, and IRRI, 1982.

Property	Low GT ($n = 4$)	Intermediate-high GT ($n = 4$)
Final photometric GT (°C)	63.0-66.0	73.0-76.0
Apparent amylose (% dry basis)	1.7-30.2	1.7-30.3
Starch lipids (% dry basis)	0.2-0.9	0.1-0.9
DSC data[a]		
Gelatilization enthalpy (J/g)	11.3-12.9	13.3-17.3
Gelatinization temp. (°C)		
T_o	56.0-59.0	67.0-71.0
T_m	63.1-67.5	74.2-78.4
T_c	71.0-79.0	81.0-85.0
Heat of cooking (J/g)	1405.0-1563.0	1432.0-1501.0

[a]Starch:water 1:4 (dry basis).



3. Representative differential scanning calorimetry thermograms of rice starches. Flour Milling and Baking Research Association, Chorleywood, UK, and IRRI, 1982.

starch, starch prepared by pronase (alkaline protease) treatment of milled rice of IR480-5-9 and IR5 were also run on DSC. The pronase-prepared starches had higher enthalpy values than DoBS-prepared starch (Fig. 3). Addition of lysolecithin to the rice starch resulted in enthalpy endotherm at 105° C (Fig. 3), suggesting that the rice starch-lipid complex did not involve lysolecithin, but probably free fatty acids, which have been reported to form an amylose complex that melts at about 95° C.

A comparison of the lipids soluble in cold water- and hot water-saturated butanol (WSB) from rice starch prepared by DoBS and pronase treatments of milled rice showed generally higher levels for pronase-prepared starch. Lipids soluble in cold WSB ranged from 0.20 to 0.94%, and 0.04-0.71% in hot WSB (total 0.24-1.65%) for pronase-prepared starch. Nonwaxy starches had more lipids than waxy starches; intermediate-amylose rices also tended to have the highest lipid content. For DoBS-prepared starches from the same eight samples, cold WSB lipids ranged from 0.03 to 0.44% and hot WSB lipids, from 0.06 to 0.43% (total 0.10 to 0.82%). Method of preparation had little effect on photometric GT and alkali viscogram gelatinization molarity of the starches.

Genetic evaluation and utilization (GEU) program

Disease resistance

Plant Pathology Department

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  - IR1545-339 **49**

A NEW STRAIN OF RICE GRASSY STUNT VIRUS

A new strain of grassy stunt virus designated RGSV 2 was identified in the Philippines. Aside from causing tungro-like symptoms in the field, RGSV 2 differs from RGSV 1 in its pathogenicity to rice varieties. *Oryza nivara*, which is very resistant to RGSV 1, is susceptible to RGSV 2 (Table 1). Consequently, IR varieties with *O. nivara* genes for resistance to RGSV 1 tested in the greenhouse were all susceptible to RGSV 2 (Table 2). Non-IR varieties, which are resistant to ragged stunt (RRSV) and tungro (RTV), were also susceptible to the new strain (Table 3). Screening for RGSV 2 resistance is continuing.

Table 1. Reaction of *Oryza nivara* to RGSV 1 and RGSV 2. IRRI, 1982.

Trial	Infection (%)			
	RGSV 1		RGSV 2	
I[a]	0.0	(0/10)	100.0	(14/14)
II[a]	0.0	(0/11)	82.0	(9/11)
III[b]	2.4	(2/84)	93.5	(29/31)

[a]Inoculated at 3 wk of age using 15-20 insects/seedling.
[b]Inoculated using the mass screening method for RGSV.

MULTIPLE DISEASE RESISTANCE

Ninety GEU elite lines and IR varieties were evaluated for reaction to 13 rice diseases (Table 4). Some lines were highly resistant to from one to four diseases. IR25865-124-3-3 was susceptible only to helminthosporium leaf spot (HLS); IR18348-36-3-3, IR19661-131-1-3-1-3, IR21820-154-3-2-2-3, IR25572-87-3-3, IR25588-7-3-1, and IR25863-8-2-3 were susceptible only to blast and HLS.

IR13427-40-2-3-3-3 was susceptible to HLS and RTV, IR19728-9-3-2-3-3 to blast and leaf scald, and IR19743-46-2-3-3-2 to HLS and narrow brown leaf spot.

Eighty GEU elite lines and IR-named varieties were evaluated for reaction to bakanae, leaf scald, and stem rot. The seed-soaking method of inoculation was used for bakanae. Reaction was evaluated on the basis of percentage seedling infection. Of the entries tested, 23.8% were resistant, 61.3% intermediate, and 15.0% susceptible. IR8, IR43, IR52, IR8073-65-6-1, and IR8192-200-3-3-1-1 showed resistant reactions. IR42, IR5420-1-1-2, IR9764-45-2-2, IR15496-219-2-3-2, and IR19762-2-3-3 showed susceptible reaction.

Seventy-seven entries from GEU elite lines were

Table 2. Reaction of IR varieties to RGSV 1 and RGSV 2. IRRI, 1982.

Variety	RGSV 1[a]		RGSV 2[b]	
	No. infected / No. inoculated	Infection (%)	No. infected / No. inoculated	Infection (%)
IR28	127/380	33.4	72/83	86.8
IR29	48/183	26.2	66/73	90.4
IR30	81/309	26.2	64/77	83.1
IR32	156/548	28.5	78/87	89.7
IR34	101/489	20.7	59/65	90.8
IR36	1546/4467	34.6	87/97	89.7
IR38	73/367	19.9	65/75	86.7
IR40	57/308	18.5	49/58	84.5
IR42	1363/4225	32.3	183/191	95.8
IR43	37/203	18.2	53/64	82.8
IR44	72/388	18.6	81/94	86.2
IR45	16/175	9.1	82/85	96.5
IR46	114/587	19.4	78/87	89.7
IR48	35/342	10.2	67/77	87.0
IR50	91/560	16.3	81/92	88.0
IR52	27/264	10.2	69/75	92.0
IR54	3/41	7.3	69/72	95.8

[a]Combined data for RGSV screening for 1980 and 1981. [b]Total of two trials (two replications/trial).

Table 3. Reaction of RRSV and RTV-resistant varieties to RGSV 2. IRRI, 1982.

Accession no.	Variety	Plants inoculated (no.) / Plants infected (no.)	Infection (%)
RRSV-resistant variety			
11052	Ptb 18	135/145	93.1
12072	Murungakayan 101 B	132/155	85.2
16195	Hathili	133/166	80.1
15224	Balaratawee	128/199	64.3
15219	Mawee	202/241	83.8
15200	Hathili	164/199	82.4
12075	Hondarawala 502	15/22	68.2
RTV-resistant variety			
	Pankhari 203	134/138	97.1
	Habiganj DW8	83/85	97.6
	Gam Pai	43/43	100.0
	Kataribhog	25/25	100.0

Table 4. Disease reactions of GEU elite lines and IR varieties. IRRI, 1982.

	Disease[a] reaction[b]												
	BL	LS	StR	BK	ShB	HLS	ShR	NBLS	BLB	BLS	RTV	GSV	RSV
IR8	S	S	I	R	I	I	I	I	S	I	S	–	S
IR20	S	R	I	R-S	I	I	I	S	I	I	S	–	S
IR36	S	S	I	R-I	I	S	I-S	R-I	I	R	S	R	S
IR42	S	I	I	R-S	I	S	I-S	R-I	I	I	S	R	S
IR43	S	R	I	R	S	S	S	I	I	R	S	–	S
IR46	S	R	I	R-I	I	S	S	I	S	I	S	R	S
IR50	S	S	I	I-S	I	S	S	I	S	S	I	R	S
IR52	S	S	I	R	I	I	S	I	I	I	I	R	S
IR54	S	I	I	R-I	I	S	I-S	I-S	I	I	I	R	I
IR56	R	I	I	I	I	S	S	R	S	I	S	R	S
Peta	S	I	I	I	I	–	S	R	S	–	I	–	S
IR3839-1	S	S	I	I	I	S	I-S	I	I	R	S	R	S
IR3858-6	S	S	I	R-I	I	S	I	R	S	–	S	–	S
IR3880-29	S	S	S	–	I	S	S	R	S	R	S	R	I
IR5420-1-1-2	S	S	S	R-S	I	S	I-S	R-I	I	–	S	R	S
IR5440-1-1-3	S	S	I	I	I	S	S	R	S	–	S	I	S
IR5873-20-1	–	–	–	–	–	–	–	–	–	–	–	–	–
IR5929-12-3	I	S	I	S	I	S	I-S	R-S	I	R	I	R	S
IR5931-110-1	R	R	I	S	I	S	S	I	S	I	S	R	S
IR6023-10-1-1	R-I	R	I	I	I	S	I-S	R-I	S	R	S	R	I-S
IR6115-1-1-1	R-S	–	–	R-I	I	S	I-S	R-S	S	R	S	R	S
IR7835-28-2-3	R	–	–	–	I	S	S	R	S	I	S	R	S
IR8192-200-3-3-1-1	S	R	I	R	I	S	I	I	S	–	I	–	S
IR8455-78-1-3-3	S	–	–	–	I	S	S	I	S	I	I	R	I
IR9129-209-2-2-2-3	S	I	–	I	I	S	I	I	I	–	S	–	S
IR9217-58-2-2	S	R	–	R	I	S	I	I	S	I	I	I	I
IR9729-67-3	S	R	–	R-S	I	S	I-S	I	I	R	I	R	I-S
IR9752-71-3-2	I-S	R	–	R-I	I	S	R-S	I	I	R	I	R	I-S
IR10011-16-3	R	–	–	–	I	R-S	I-S	R-I	I	I	S	–	S
IR10068-11-1	R	–	–	R-S	I	S	S	I	S	R	–	–	–
IR10068-18-2	I	–	–	I	I	S	S	R	S	I	–	–	–
IR13146-41-3	S	I	S	R-I	I	S	S	I	I	I	–	–	–
IR13149-3-2-2	S	I	–	R-I	I	S	I	I	I	I	–	–	–
IR13149-19-1	S	R	–	R-S	I	S	S	I	S	I	–	–	–
IR13149-23-2	S	S	–	R	I	S	S	I	S	I	S	I	S

Continued on next page

Table 4 continued

	Disease[a] reaction[b]												
	BL	LS	StR	BK	ShB	HLS	ShR	NBLS	BLB	BLS	RTV	GSV	RSV
IR13149-71-3-2	S	S	I	R-I	I	S	I	S	I	I	S	R	I
IR13240-82-2-3-2-3-1	S	S	–	R-I	I	S	I	I	I	–	S	–	I
IR13365-253-3-2	S	I	I	R	I	S	I	I	I	I	S	I	I
IR13423-10-2-3	S	S	–	R-I	I	S	I	I	–	–	S	–	S
IR13423-17-1-2-1	S	I	–	R-I	I	S	I	I	I	–	S	–	I
IR13426-19-2	S	R	I	R-I	I	S	I	I	I	I	S	I	I
IR13427-40-2-3-3-3-3	R	R	–	I	I	S	I	R	I	–	S	–	R
IR13429-109-2-2-1	I	I	–	I	I	S	I	I	S	–	S	–	R
IR13429-299-2-1-3-1	S	R	I	R-I	I	S	R-S	I	I	R	S	I	I
IR13525-43-2-3-1-3-2	S	R	S	R-I	I	S	I	I	I	I	S	R	I
IR13540-56-3-2-1	S	S	S	–	I	I-S	I	I	I	R	I-S	R	R-S
IR14632-22-3	S	S	S	R-I	I	S	S	R	I	S	S	I	–
IR14753-120-3	S	I	I	R-I	I	S	I	S	I	I	S	R	I
IR15314-30-3-1-3	S	I	–	R-S	I	S	S	I	I	–	I	–	R
IR15314-43-2-3-3	S	I	I	R-I	I	S	I-S	I	I	I	S	R	S-I
IR14791-163-1-3	S	–	I	–	I	S	I	I	I	I	S	R	I
IR17488-2-3-2	R	S	–	R-I	I	S	S	I	I	–	S	–	S
IR17494-32-1-1-3-2	S	S	I	R-I	I	S	I-S	I-S	I	I	S	R	I
IR18348-36-3-3	S	–	I	R	I	S	I	I	R	I	I	R	I
IR18349-53-1-3-1-3	S	–	–	R	I	S	S	I	I	–	S	–	I
IR19058-107-1	S	–	I	–	I	S	I-S	R	I	I	S	R	I
IR19660-131-3-3-3-3	S	R	S	R-I	I	S	I	S	I	–	S	–	I
IR19661-131-1-3-1-3	S-I	R	I	R-I	I	S	R-I	I	I	I	I	R	I
IR19661-364-1-2-3	S	S	I	R-I	I	S	I	I	I	–	I	–	I
IR19670-263-3-2-2-1	S	R	–	–	I	S	I-S	I-S	I	I	S	R	I
IR19672-140-2-3-2-2	S	R	S	R-S	I	S	R-I	I	R-S	I	I-S	I	I
IR19672-155-2-1-1-3	S	–	–	R-S	I	S	I	I-S	I	I	S	R	I
IR19728-9-3-2-3-3	S	S	–	R	I	I	I	R	I	–	I	–	I
IR19729-5-1-1-3-2	R	I	S	R-I	I	S	I	I	I	–	I	–	S
IR19735-5-2-3-2-1	R-I	R	I	R-I	I	S	I-S	I	I	I	I-S	R	S-I
IR19743-25-2-2-3-1	S	I	I	R-I	I	S	I	I	I	I	I	R	I-S
IR19743-40-3-3-2-3	S	I	R	R	I	S	I-S	I-S	I	I	I-S	R	I
IR19743-46-2-3-3-2	S	S	I	R-I	I	S	I-S	I-S	I	I	I-S	I	I
IR19746-28-2-2-3	I	I	I	R-I	I	S	I	S	–	–	I	–	I
IR21015-80-3-3-1-2	I	R	I	R	I	S	R-S	I	I	I	S	R	I
IR21820-154-3-2-2-3	S	R	I	R	I	S	I	I	I	I	I	R	I
IR21848-65-3-2	S	R	I	R-I	I	S	I	I	S	I	S	R	I
IR21912-131-3-3-2	S	I	I	R-I	I	S	I	R-I	I	R	S	R	I
IR22082-41-2	S	R	S	R	I	I-S	R-S	I	I	R	I-S	R	I
IR24632-60-3-3-2	S	–	–	I	I	S	I	I	–	–	S	–	I
IR25560-132-2-3	S	R	S	R-I	I	S	I	I	I	I	S	R	I
IR25572-87-3-3	S	I	I	R	I	S	I	I	I	I	I	I	I
IR25588-7-3-1	S	I	I	I	I	S	I	I	I	I	I	R	I
IR25588-32-2	S	R	S	I	I	S	I	I	–	–	I	–	I
IR25621-94-3-2	S	I	S	–	I	S	I	I	I	I	S	R	I
IR25621-135-1-1	S	I	S	I	I	S	I	R	S	I	S	R	I
IR25863-8-2-3	S	I	I	R	I	S	I	R	I	I	I	R	I
IR25865-124-3-3	R	I	I	R-I	I	S	I	I	I	I	I	R	I
IR25882-32-1-3	S	I	I	I	I	S	S	I	I	I	I	R	S
IR25901-9-2-3	S	I	I	R	I	S	S	I	I	I	I	R	I
IR25916-15-3-2	S	I	I	I	I	S	S	I	I	I	I	R	I
IR25922-39-3-2	S	I	I	I	I	S	R	R	S	I	I	I	S
IR25924-51-2-3	S	R	I	R	I	S	I	R	S	–	I	R	I
IR25924-92-1-3	S	I	I	R	I	S	I	I	S	I	I	R	I
IR28128-45-2	S	R	I	I	I	S	S	I	I	R	S	R	I

[a]BL = blast, LS = leaf scald, StR = stem rot, BK = bakanae, ShB = sheath blight, HLS = helminthosporium leaf spot, ShR = sheath rot, NBLS = narrow brown leaf spot, BLB = bacterial leaf blight, BLS = bacterial leaf spot, RTV = rice tungro virus, GSV = grassy stunt virus, RSV = ragged stunt virus. [b]R = resistant, I = intermediate, S = susceptible.

evaluated for reaction to leaf scald during the 1981 wet season. The clipping method was used for inoculation in the field. Of the entries evaluated, 35.1% were resistant, 37.7% intermediate, and 27.3% susceptible. IR13146-4-3, IR8192-200-3-3-1-1, IR5853-18-2, IR5854-73-3, IR4422-143-2-1, and IR4722-245-1-1 showed resistant reaction. IR36, Bahagia, IR8111-6-2, Pattambi 1751, BG35-2, and BR168-213-23 showed susceptible reaction.

SCREENING OF GERMPLASM AND BREEDING MATERIALS

Blast. A total of 84,565 entries from different sources were tested in the IRRI blast nurseries in 1982 (Table 5).

Sheath blight. Of 4,126 entries screened against sheath blight during the 1982 DS and WS, 95.25% showed moderate reaction (Table 6). About 50% of the germplasm entries were infected by virus and excluded from the tests.

Bacterial diseases. A total of 69,229 rice entries were screened, tested, and evaluated for resistance to bacterial blight for the 1982 DS and WS (Table 7). Strains of PXO 61 of pathotype I and PXO 86 of pathotype II of *Xanthomonas campestris* pv. *oryzae* were used in the screening program to determine the specific reactions.

Virus diseases. In a search for sources of resistance to virus diseases, 11,301 entries were tested for RTV resistance, 5,226 for RGSV 1 resistance, and 6,740 for RRSV resistance in the greenhouse by the mass screening method. Only 0.2% of the entries were resistant to RTV and 9% to RRSV. Seventy-six percent of the entries tested against RGSV 1 were rated resistant, 21% intermediate, and 3% susceptible; most of the IR varieties and lines were resistant.

In the field 94% of 73,595 entries from the pedigree nursery were rated resistant to RTV on the 1980 Standard Evaluation System for Rice (SES).

SOURCES OF DISEASE RESISTANCE

Sources of rice blast resistance. Rice resistant to blast was identified from exotic and local sources in Nepal. One hundred twenty-two exotic lines and varieties and 703 local accessions collected from 23 districts, representing two major ecosystems (hill and plain), were tested in blast nurseries at Khumaltar, Palung, and Parwanipur in 1981; only local accessions were tested at Parwanipur. Entries were

Table 5. Summary of blast screening. IRRI, 1982.

Source of entries	Entries (no.)			Total
	Resistant (0-2)[a]	Moderate (3-4)[a]	Susceptible (5-9)[a]	
Elite breeding lines[b]	13	13	85	111
Germplasm bank	24	26	285	335
Pedigree nursery lines	8 438	10 106	61 484	80 028
Hybridization block	156	35	358	549
Observational yield trial[b]	27	43	1 105	1 175
Replicated yield trial[b]	23	46	765	834
Korean lines	43	11	152	206
Taiwan materials	105	14	73	192
International nurseries				
IRBN	73	35	273	381
IRON	30	12	304	346
IRLRON	10	2	105	117
IURON	9	24	144	117
IRLRYN	4	1	25	30
IRYN-VE	1	0	27	28
IRYN-E	0	0	28	28
IRYN-M	3	1	24	28
Total	8 959	10 369	65 237	84 565
Percentage	10.6	12.26	77.14	100

[a]1980 SES scale. [b]Tested two to three times.

Table 6. Summary of sheath blight resistance tests. IRRI 1982.

Source	Entries (no.)	Entries (no.) rated[a]					
		R	MR	M	MS	S	VS
Elite breeding lines	116	0	2	112	2	0	0
Replicated yield trial	875	0	7	793	56	16	3
Observational yield trial	499	0	6	488	5	0	0
Hybridization block	577	0	21	521	23	5	7
Germplasm bank	1381	0	4	1375	2	0	0
Hybrid rice	189	0	0	154	27	7	1
International nurseries							
IRYN-VE	27	0	0	27	0	0	0
IRYN-E	22	0	0	22	0	0	0
IRYN-M	15	0	0	15	0	0	0
IRLRYN	24	0	0	24	0	0	0
IRLRON	91	0	0	90	1	0	0
IURON	110	0	0	110	0	0	0
IRON	200	0	0	199	1	0	0
Total	4126	0	40	3930	117	28	11
Percentage	—	0	0.97	95.25	2.83	0.68	0.27

[a]R = resistant, MR = moderately resistant, M = moderate, MS = moderately susceptible, S = susceptible, VS = very susceptible.

Table 7. Screening summary of breeding materials for bacterial blight resistance, IRRI, 1982.

Source	Total entries tested	Race	Entries rated[a]										
			R		MR		MS		S		R/S		
			No.	%	No.	%	No.	%	No.	%	No.	%	NT
Hybridization block[b]	587	I	242	41.2	53	9.0	123	21.0	150	25.6	10	1.7	9
	587	II	116	19.8	56	9.5	216	36.8	184	31.3	6	1.0	9
Replicated yield trial[b]	272	I	755	86.6	78	8.9	7	0.8	19	2.2	13	1.5	—
	872	II	272	31.2	102	11.7	227	26.0	266	30.5	5	0.5	—
Observational yield[c] trial	1 896	I	1108	58.4	86	4.5	293	25.5	348	18.4	61	3.2	—
Pedigree nurseries[c]	25 357	I	21 511	84.8					1 684	6.6	1 162	8.5	—
Elite lines[c]	117	I	2	1.7	25	21.4	50	42.7	37	31.6	—		3
	117	II	1	.9	9	7.7	34	29.1	72	61.5	—		1
	117	III	1	.9	12	10.3	33	37.6	59	30.4	—		1
	117	IV	9	7.7	20	17.1		55.6	23	19.7	—		—
Total	30 639		24 017		441		1 059		2 842		2 257		23

[a]R-resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, R/S = segregating, NT = dead plants. [b]Inoculated with PXO 61 and PXO 86 strains. [c]Inoculated with PXO 61 only.

scored using the 1980 SES.

Among the entries from exotic sources, those rated resistant were found to have derived the resistance from Tetep, Pankhari 203, Dawn, Carreon, Tadukan, Zenith, *Oryza nivara*, and Sigadis. Several entries derived from one of these sources or their combinations were also found to have stable resistance. For the local accessions, 79.2% of the entries from the hill regions were resistant; only 56.8% of the entries from the plain were resistant. The higher frequency of resistant entries among hill accessions possibly indicates there has been greater selection pressure for blast resistance in the hill environment.

Resistance to rice viruses. Several sources of resistance to rice virus diseases were identified. Habiganj DW8, ARC 6064, Tjempo Kijik, ARC 11554, Jamal Bhog, and 72 B showed consistently low percentages of RTV infection. Varieties with

outstanding resistance to RRSV were ARC 5757, ARC 5780, ARC 5838, and ARC 6650. IR9861-25-1-1, IR10232-17-2, IR18353-33-3-3-1, IR19087-22-2-2, and IR19231-133-1-1-2 were also resistant.

A perennial rice, *Oryza sativa* × *O. rufipogon* (Acc. No. 104315), was highly resistant to RGSV 1. Twenty-two tillers of a perennial rice, *Oryza sativa* × *O. rufipogon*, were planted in pots, covered with mylar cages, and inoculated individually by 25 RGSV 1 viruliferous insects for 3 d. The inoculated plants were maintained in the greenhouse and observed for disease symptoms. Virus-recovery tests using BPH were conducted at 1, 2, 4, and 6 mo after inoculation for three trials.

To recover the virus from the perennial rice 5,605 TN1 seedlings were inoculated using 2,871 insects. No positive transmission of RGSV 1 was observed. *Oryza sativa* × *O. rufipogon* could be a good source of RGSV 1 resistance. Seedlings of the perennial rice are now being used in trials to confirm this result.

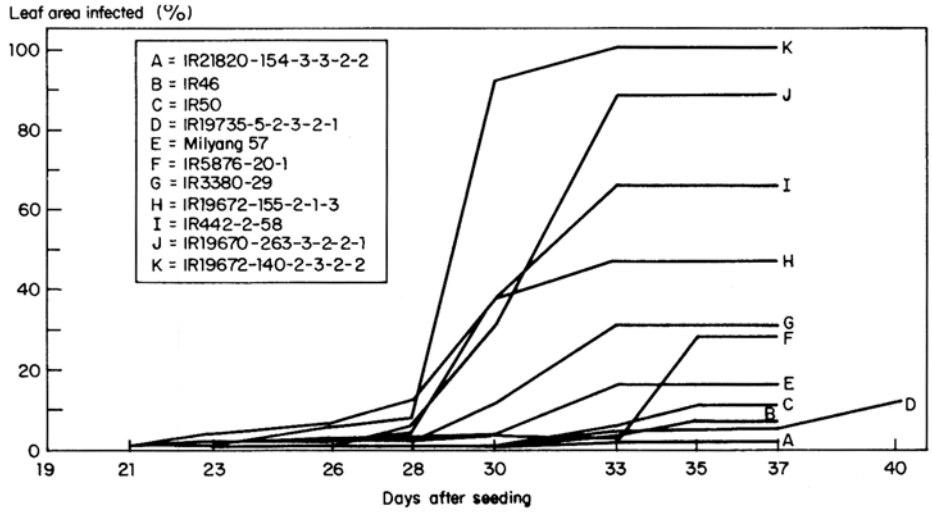
EVALUATION FOR RESISTANCE

Fungal diseases. *Functional differentials for rice blast in Nepal.* The lack of a system for describing the types of host resistance to blast races is a major problem in Nepal because of the wide variability of the pathogen *Pyricularia oryzae*. The present set of international, Philippine, and Japanese differentials seems insufficient to describe the types of host resistance functioning in the region. To develop a set of functional differentials, tests patterned after that of Ikehashi (1979) were set. The international, Philippine, and Japanese set of differential varieties and 50 other lines and varieties were tested at Khumaltar, Palung, and Parwanipur in Nepal. Scoring was patterned after the 1980 SES.

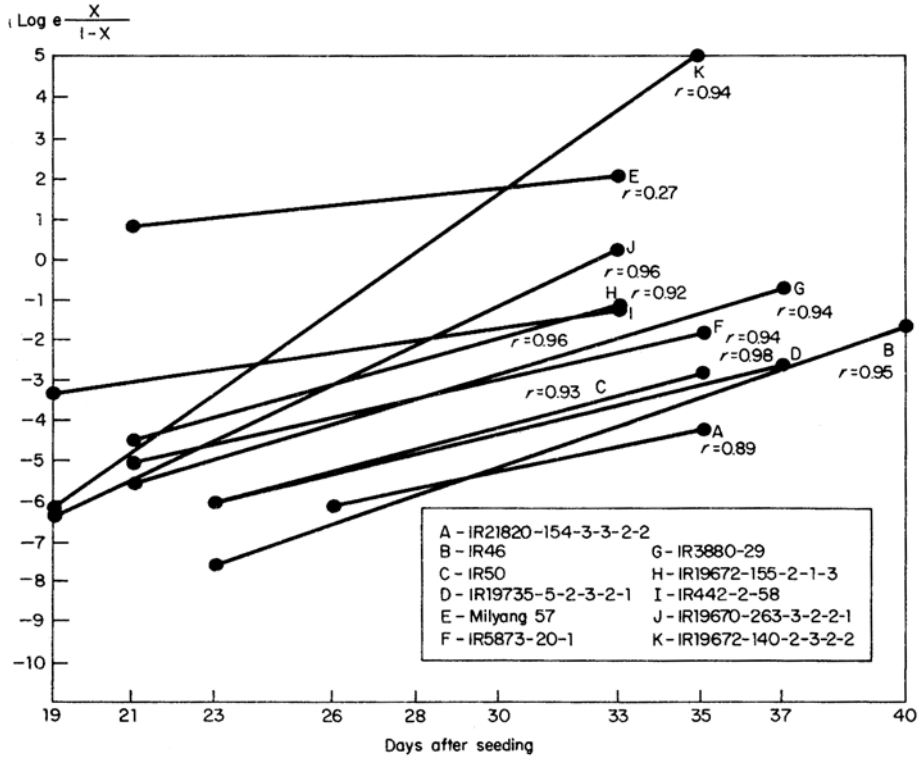
All entries were classified into seven resistance types based on primary data (Khumaltar, Palung, and Parwanipur, 1981) and into several subtypes based on secondary data (Khumaltar and Parwanipur 1977-79). From these results, a set of functional differentials — IR1416-128-5-8, IR3273-289-2-1473, Peta, Columbia II, IR34, Khao-tah-haeng 17, Wagwag, Usen, Co 25, Caloro, CI 8985, Aichi-asahi, Shin 2, Kataktara DA2, and Fanny — is being proposed. A tentative system of designating field races of *P. oryzae* in Nepal was also suggested.

Apparent blast infection rates. Apparent blast infection rates were determined in 1-m^2 microplots in the blast nursery among 80 GEU elite breeding lines and varieties. Lesion counting started 2 WAS and continued at 2- to 3-d intervals. Apparent infection rates were measured using the Van der Plank formula.

Blast development and rates of increase differed among the varieties and elite breeding lines (Fig. 1, 2). Marked differences in disease severity were observed as the experiment progressed. IR46, IR50, and IR21820-254-3-3-2-2 developed leaf blast infection very slowly; IR19672-155-2-1-3 and



1. Disease progress curves of selected cultivars. IRRI, 1982.

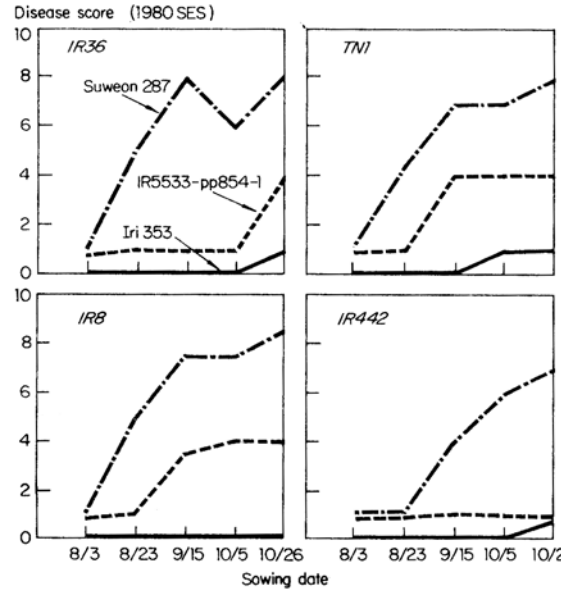


2. Rate of blast infection (logits) of selected cultivars. IRRI, 1982.

IR442-2-58 had intermediate rates, and the disease increased rapidly on IR19670-263-3-2-2-1 and IR19672-140-2-3-2-2. The observed slow blasting in some of the varieties is not necessarily an inherent property of the variety, but could be due to a lack of compatible races from the inoculum donor rows. For example, IR50 showed much higher rates of infection in other experiments. Further experiments using known compatible races under conditions where only autoinfection occurs should resolve this difficulty.

Blast inoculum donor varieties. The three blast-resistant varieties IR5533-PP854-1, Suweon 287, and Iri 353 when sown every 20 d using different inoculum-donor varieties showed different resistant reactions. The disease incidence differed among donors (Fig. 3).

In another experiment, IR36, TN1, IR8, IR442, and their combinations were evaluated as inoculum donors. Combinations of donors performed better than single donors, presumably because they trap a greater diversity of races from the pathogen population.



3. Effect of different spreaders on the blast fungus disease scores of three rice cultivars. Santo Tomas, Batangas, Philippines, 1982.

Effect of varietal mixtures on blast. To study the effect of varietal mixtures on leaf and neck blast incidence, IR54, IR1905-81-3-1, IR442-2-58, and a mixture of all three were compared. The mixtures showed equal or lower blast incidence compared with the single varieties. The random varietal mixture proved more effective than row-by-row mixtures.

Effect of leaf angle on blast development. The leaf angles of blast-susceptible IR8 were modified artificially to 45°, 90°, and 135°. Wires were attached to the highest fully extended leaves for leaf blast measurements and to the flag leaves for neck blast measurements. The plants were grown in a greenhouse and exposed to natural inoculum in the blast nursery for 7 d at the maximum tillering and heading stages. Leaves at 90° showed the most leaf blast and flag leaves at 45° showed more neck blast. Leaves at 135° showed the least blast. This shows that drooping leaves may decrease leaf and neck blast incidence.

Neck blast resistance. Fifty-nine Korean varieties and elite lines were planted at 2-wk intervals for 2 mo to synchronize flowering periods. During heading time, two isolates of *Pyricularia oryzae* (I-2017 and I-750778) were separately inoculated on different tillers of each variety and line planted in the same pot. Plants were inoculated by injecting spore suspensions when panicles were about one-third to one-half exserted. Partial and complete neck rot infections were recorded.

Neck infection ranged from 0 to 57% for isolate I-2017 and from 0 to 100% for isolate I-750778. Twenty-three varieties and lines were highly resistant (0% infection) to I-2017 and 29 were highly resistant to isolate I-750778. Fukuhikari, Cholweon 34, Suweon 305, Suweon 310, Baegunchal-byeo, Iri 355, and Milyang 59 were resistant to both isolates. Suweon 304 was susceptible (57%) to I-2017 but highly resistant (0%) to I-750778. Milyang 54 was highly susceptible (100%) to I-750778, but highly resistant (0%) to I-2017. These results indicate variety by isolate interaction.

Differential reactions of japonica and indica rices to sheath rot. Twelve varieties and lines each of japonica and indica rices were grown randomly in concrete beds in the screenhouse where many diseased plants were maintained as inoculum sources. To further ensure good infection, 20 plants from each variety were injected at the booting stage with a spore suspension of isolate S-8101. At 30 DAI, reactions were scored using a 0 (no symptoms)-4 (total sheath rot) scale.

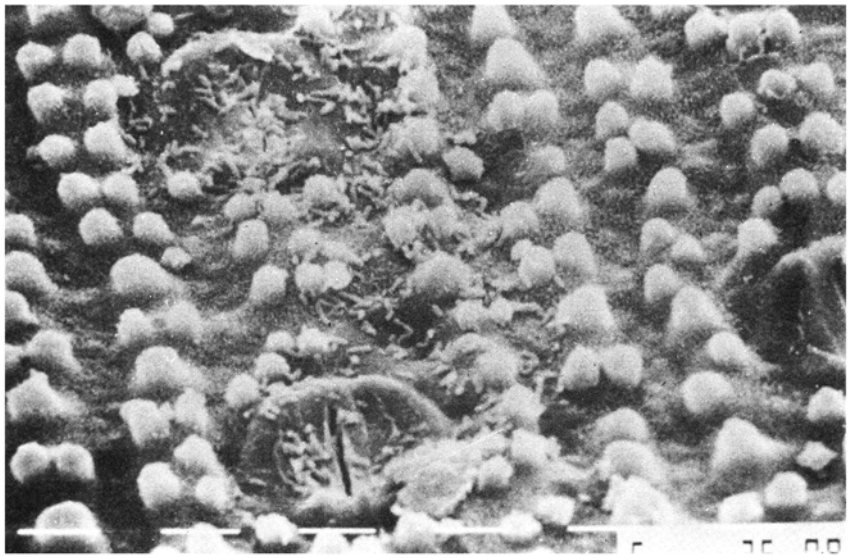
Disease reaction varied mainly within varieties rather than within rice type. Each type had a wide range of disease indices differing within varieties. At the same disease pressure, the disease indices ranged from 24.1% to 88.3% in the japonica rices and from 25.7% to 87.5% in indica rices.

Bacterial blight. *Scanning electron microscopy on rice leaf inoculated with* Xanthomonas campestris *pv.* oryzae. A gross scanning of the rice leaf surface at 1 h after spray inoculation of bacterial cells showed bacteria on the leaf surface. The bacteria were found at sites away from or around the water pores (Fig. 4). No marked difference in the number of the bacterial cells was noted on compatible host-strain combinations TN1 vs PXO 61, TN1 vs PXO 86, and Cas 209 vs PXO 61 or incompatible combinations TN1 vs BB918, Cas 209 vs PX 101, and Cas 209 vs PXO 86. Cas 209 is resistant to PXO 86; BB918 has lost its virulence. The bacterial cells were rod-shaped. There were signs of bacterial cell division on all host-strain combinations.

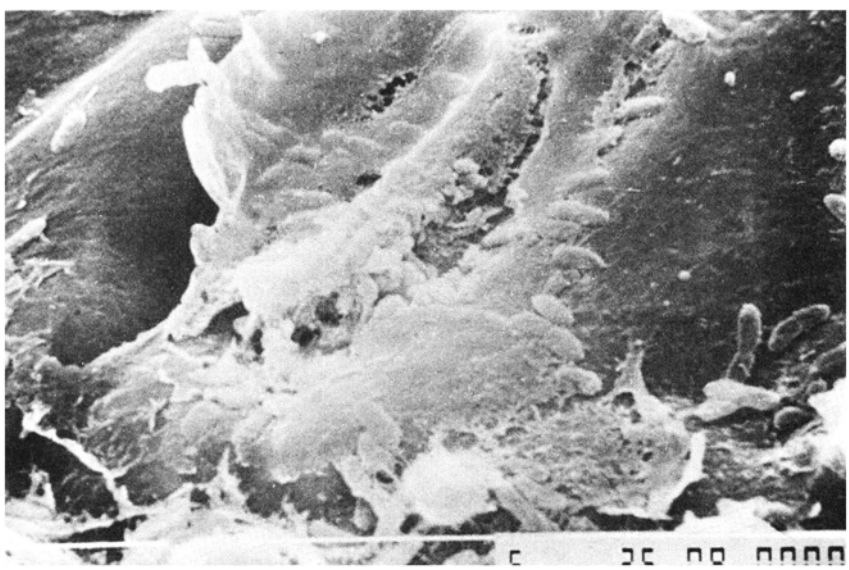
A thin layer of substance formed on the water pores of TN1 vs PXO 101 and Cas 209 vs PXO 101 combinations. The bacterial cells appeared embedded (Fig. 5). At 24 HAI, the exudate appeared secreted from water pores and completely sealed-off the openings in Cas 209 vs PXO 101. Bacteria numbers did not increase as they did at 1 HAI. There was no evidence of exudation from water pores in Cas 209 vs PXO 86 until 48 HAI. The water pores in compatible combinations remained open throughout. Cell numbers of PXO 61 increased on the water pores of Cas 209 and TN1 at 24 HAI. Many bacterial cells actively divided, massed around, and entered the water pore openings (Fig. 6).

The results indicate the immobilization of the bacterial cells of avirulent strains and site-specificity of bacterial multiplication on the rice leaf surface.

Virus diseases. *Resistance of some IR varieties to tungro virus complex and its vector.* The resistance of IR36, IR42, IR50, IR54, and IR56 to RTV and its vector, the green leafhopper (GLH), was determined by mass screening and test tube inoculation.



4. Bacterial cells of *Xanthomonas campestries* pv. *oryzae* were found around the water pores at 24 h after spray-inoculation on rice leaves. IRRI, 1982.

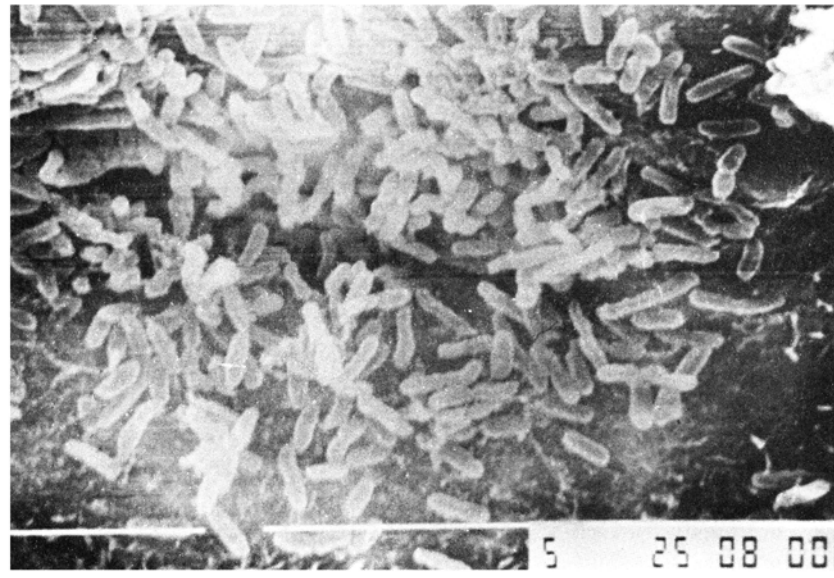


5. Bacterial cells appear embedded in exudates from water pores of Cas 209 leaf 24 h after spray-inoculation of *Xanthomonas campestris* pv. *oryzae* PXO 101, a non-pathogenic strain. IRRI, 1982.

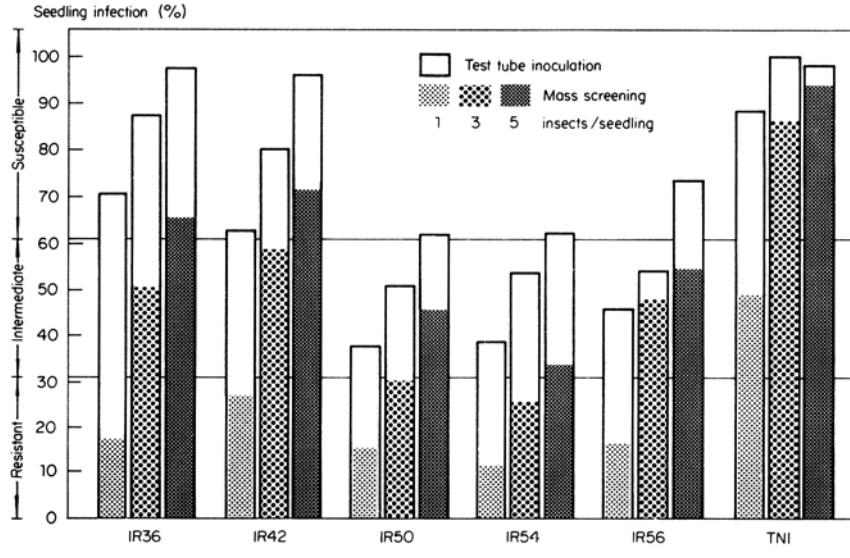
In mass screening, the five varieties and TN1 as a susceptible check were inoculated in a cage, with one, three, and five GLH per seedling. The percentage of seedlings infected increased as the number of insects per seedling was increased (Fig. 7). In all cases TN1 had the highest infection, followed by IR42, IR36, IR46, and IR50. IR54 had the lowest seedling infection (34% at five insects/seedling), which, however, was not significantly different from that of IR50 or IR56.

IR36 and IR42 moved from resistant to susceptible as the number of insects per seedling was increased (Table 8). IR50, IR54, and IR56 changed from resistant to intermediate.

In test tube inoculation using one, three, and five insects per seedling, the percentage of infected seedlings increased as the number of insects per seedling increased (Fig. 7). At one insect per seedling, IR36, IR42, and TN1 were susceptible and IR50, IR54, and IR56 were intermediate. The fairly high infection percentage for the test tube inoculation may be due to forced feeding in



6. Multiplication of a virulent strain PXO 61 of *Xanthomonas campestris* pv. *oryzae* on the water pores of Cas 209 leaf. IRRI, 1982.



7. Percentage of seeding infection of some RTV-resistant IR varieties inoculated by different numbers of RTV-viruliferous GLH per seedling following the mass screening and test tube methods of inoculation. IRRI, 1982.

confinement. The results indicate RTV resistance instability of some IR varieties. In the field, the degree of resistance decreases with the increase in disease and insect pressure or population.

In the test tube, significant differences in seedling infection were observed among the varieties, but not among increasing hours of inoculation access time (Table 9).

Significant differences in the life-span of RTV-viruliferous GLH were obtained among susceptible TN1 and IR50, IR54, and IR56 (Table 10). Similarly, GLH mortality was high (>60%) when the insects were confined on the three varieties. No difference in life-span was detected between male and female GLH. RTV infection was lower on varieties where GLH life-spans were shorter and mortality was higher.

Tungro virus complex in resistant IR varieties. Rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV) are associated with the RTV complex. RTBV alone causes mild infection, and RTSV alone causes almost symp-

Table 8. Reaction of selected IR varieties inoculated by mass screening method with one, three, and five GLH per seedling.[a] IRRI, 1982.

Variety	Reaction of variety inoculated with		
	1 GLH	3 GLH	5 GLH
IR36	R	I	S
IR42	R	I	S
IR50	R	I	I
IR54	R	R	I
IR56	R	I	I
TN1	I	S	S

[a]Based on the scale for RTV mass screening: resistant (R) = 0-30%, intermediate (I) = 31-60%, susceptible (S) = 61-100%.

Table 9. Seedling infection of selected IR varieties inoculated with RTV-viruliferous GLH in test tubes at various inoculation access times. IRRI, 1982.

Variety	Seedling infection (%) at inoculation access of				Mean
	4 h	8 h	24 h	48 h	
IR36	62.5	68.2	56.1	56.7	60.9 b
IR42	56.3	54.2	55.8	62.0	57.1 b
IR50	26.6	36.2	30.8	25.4	29.7 d
IR54	36.8	30.0	33.9	32.2	33.2 cd
IR56	36.6	43.5	40.0	39.2	39.8 c
TN1	73.0	78.2	82.4	81.5	78.8 a
Mean	48.6 a	51.7 a	49.8 a	49.5 a	

[a]Separation of Duncan's multiple range test.

Table 10. Life-span of male and female RTV-viruliferous GLH on some IR varieties. IRRI, 1982.

Variety	Life-span (d)		Mean
	Male	Female	
IR36	6.6	6.3	6.5 b
IR42	6.1	6.2	6.2 b
IR50	3.7	4.4	4.0 c
IR54	3.3	4.4	3.9 c
IR56	4.3	5.1	4.7 c
TN1	8.5	8.4	8.5 a

tomless infection. However, the presence of both viruses in the rice plant causes severe infection. When the plant is infected with RTBV alone, the vector insect cannot recover the virus from the plant.

RTBV and RTSV presence in RTV-infected IR36, IR42, IR50, IR54, and IR56 plants were determined by the latex agglutination test using virus antisera and the virus recovery test using the vector GLH.

Six-day-old seedlings in test tubes were inoculated with one GLH. The insects were kept in the test tubes for 24 h. Plant sap was obtained from the second or third youngest leaf 30, 45, and 60 DAI and tested for reaction to the RTBV and RTSV antisera by the latex agglutination test. Regardless of time after inoculation, all plants from the susceptible control TN1 reacted to RTBV and RTSV together. However, 57.1% of the IR42 plants, 41.7% of the IR56 plants, and 26.7% of the IR36 plants reacted to the two viruses together and the rest to RTBV alone. All IR50 and IR54 plants reacted to RTBV alone.

The recovery of the RTV complex using the vector GLH was attempted. The virus was successfully recovered from plants infected with both RTBV and RTSV. However, no positive transmission was obtained from 1,408 seedlings inoculated by 326 insects that were given 4-d acquisition on diseased plants with RTBV alone, regardless of the variety. This indicates that, although the plants used in the virus recovery tests are infected, they will not serve as virus sources for spread of the disease.

IR50, IR54, and IR56 went from resistant to intermediate in mass screening as insects per seedling were increased from one to five. RTV-inoculated IR50 and IR54 were infected with RTBV alone; whereas inoculated IR56 was infected with RTBV and RTSV together. Because plants infected with RTBV alone can not be a virus source for further transmission, IR56 could be broken down by RTV when the GLH population is high, while IR50 and IR54 might be more resistant.

Rice tungro virus complex in non-IR varieties. Fifteen rice varieties differing in reaction to RTV and its GLH vector were inoculated by the mass screening method in the greenhouse. Infected plants were then selected 50-60 DAI and tested for the presence of RTBV and RTSV by the latex agglutination test using virus antisera. RTBV and RTSV were generally observed together in varieties susceptible to both GLH and RTV. However, only RTBV was generally observed in varieties highly resistant to both the vector and the virus.

1982 rice tungro virus collaborative project.

Studies on the resistance of 10 rice varieties to RTV and its vector were continued at IRRI. When the average GLH life-span was used to indicate the degree of varietal resistance to the vector, IR34, Latisail, Gam Pai 33-12-15, and Pankhari 203 were found to be more resistant than TN1, Habiganj DW8, Kataribhog, Ambemohar 159, Ptb 18, and IR26.

On the basis of RTV transmission and seedling infection, Habiganj DW8, Gam Pai 30-12-15 and Pankhari 203 appeared more resistant to the virus than the other varieties. The varietal reactions are categorized in Table 11.

PATHOGEN VARIATION

Races of *Pyricularia oryzae*. One hundred and four monosporial isolates periodically isolated from infected leaves of different varieties and lines in the blast nursery were separately inoculated on the Philippine, international, and Japanese differentials.

The 14 Philippine differential varieties identified 49 races in 11 race groups. The prevalent races belonged to the PD race group, which is composed of 28 races (Table 12). Race PA-1, which corresponds to races IA-1 and race number 777, was the most virulent race detected.

Nine race groups were identified by the international differential varieties (Table 13). The most prevalent races were IH-1, IG-1, and IB-45. Races IA-109 and IA-110, the most prevalent in 1968-69 studies on races in the blast nursery, were not detected in the present study — indicating a shift over time. Twenty isolates did not infect any of the eight international varieties, although they are capable of producing symptoms on varieties of the other two differential sets. This suggests the insufficiency of the international differential varieties to differentiate races.

Nine new Japanese differentials with known R-genes as criteria for differentiating the races, identified 42 pathogenic races (Table 14). Races 03, 403, and 447 appeared prevalent. Some races have three, four, and five isolates. One or two isolates were identified in other races. Race 777 was the most virulent. It overcame the resistance of all the differential varieties with known R-genes.

Variability of *Helminthosporium oryzae*, **the brown spot fungus.** More than 100 isolates of *Helminthosporium oryzae* derived from single-spore cultures were collected from various places in the Philippines. A series of pathogenecity tests

Table 11. Varietal reaction to RTV and its vector GLH. IRRI, 1982.

Variety	Reaction to[a]	
	GLH	RTV
Ambemohar 159	S	I
Gam Pai 30-12-15	I	I
Habiganj DW8	S	R
IR26	I	S
IR34	R	I
Kataribhog	S	S
Latisail	R	I
Pankhari 203	I	I
Ptb 18	I	I
TN1	S	S

[a]R = resistant, I = intermediate, S = susceptible.

Table 12. Pathogenic races of *Pyricularia oryzae* **identified by Philippine differential varieties.[a] IRRI, 1982.**

Race	Isolate no.	Philippine differential varieties													
		A	B	C	D	E	F	G	H	I	J	K	L	M	N
PA-1	1	S	S	S	S	S	S	S	S	S	S	S	S	S	S
PA-513	1	S	R	R	R	R	R	R	R	R	R	R	S	R	R
PA-865	1	S	R	R	S	R	R	S	S	S	S	S	R	S	R
PB-289	1	R	S	R	S	S	R	S	S	S	S	S	R	R	R
PB-663	1	R	S	R	S	R	R	S	R	S	R	R	S	R	R
PC-1	1	R	R	R	S	S	S	S	S	S	S	S	S	S	S
PC-41	1	R	R	S	S	S	R	S	R	S	S	S	R	R	R
PC-117	1	R	R	S	R	R	R	S	R	S	S	R	R	R	R
PD-1	2	R	R	R	S	R	R	R	R	R	R	R	R	R	R
PD-9	1	R	R	R	S	S	R	S	R	S	S	S	R	R	R
PD-19	5	R	R	R	S	R	R	S	R	S	R	R	R	R	R

Continued on next page

Table 12 continued

Race	Isolate no.	Philippine differential varieties													
		A	B	C	D	E	F	G	H	I	J	K	L	M	N
PD-5	3	R	R	R	S	S	R	S	R	S	S	R	R	R	R
PD-37	14	R	R	R	S	R	R	S	R	S	S	R	R	R	R
PD-53	3	R	R	R	S	R	R	S	R	S	S	R	R	R	R
PD-31	1	R	R	R	S	R	R	R	R	S	R	R	R	R	R
PD-33	2	R	R	R	S	S	R	S	S	S	S	S	R	R	R
PD-73	14	R	R	R	S	R	R	S	R	S	R	S	R	R	R
PD-75	4	R	R	R	S	R	R	S	R	S	R	S	R	R	R
PD-49	1	R	R	R	S	R	R	S	S	S	S	R	R	R	R
PD-97	3	R	R	R	S	R	R	S	S	S	S	S	R	R	R
PD-105	14	R	R	R	S	R	R	S	R	S	S	S	R	R	R
PD-135	1	R	R	R	S	R	R	S	S	S	R	R	S	R	R
PD-145	19	R	R	R	S	R	S	S	R	S	S	S	S	R	R
PD-147	14	R	R	R	S	R	R	S	R	S	S	R	S	R	S
PD-151	1	R	R	R	S	R	R	S	R	S	R	R	S	R	R
PD-129	4	R	R	R	S	R	S	S	S	S	S	S	S	R	R
PD-199	1	R	R	R	S	R	R	S	S	S	R	R	S	R	R
PD-209	3	R	R	R	S	R	R	S	R	R	S	R	S	R	R
PD-211	6	R	R	R	S	R	R	S	R	S	S	R	S	R	R
PD-213	1	R	R	R	S	R	R	S	R	S	R	S	S	R	R
PD-335	1	R	R	R	S	R	S	R	R	S	R	S	R	S	R
PD-579	2	R	R	R	S	R	S	S	R	S	S	S	S	R	S
PD-587	1	R	R	R	S	R	R	S	R	S	S	R	S	R	S
PD-839	1	R	R	R	S	R	R	S	R	S	S	S	R	R	S
PD-247	1	R	R	R	S	R	R	R	R	S	S	S	S	R	R
PD-269	1	R	R	R	S	R	R	S	R	S	S	S	S	R	R
PE-15	1	R	R	R	R	S	R	R	R	S	R	R	R	R	R
PF-3	1	R	R	R	R	R	S	S	R	S	R	R	R	R	R
PG-1	4	R	R	R	R	R	R	S	R	R	R	R	R	R	R
PG-5	3	R	R	R	R	R	R	S	S	R	R	R	R	R	R
PG-7	1	R	R	R	R	R	R	S	R	R	S	R	R	R	R
PG-19	1	R	R	R	R	R	R	S	R	S	S	R	S	R	R
PG-31	1	R	R	R	R	R	R	S	R	R	R	R	S	R	R
PI-1	15	R	R	R	R	R	R	R	R	R	R	R	R	R	R
PI-7	1	R	R	R	R	R	R	R	R	S	R	R	S	R	R
PI-3	1	R	R	R	R	R	R	R	R	S	R	S	R	R	R
PJ-3	1	R	R	R	R	R	R	R	R	R	S	R	S	R	R
PK-1	1	R	R	R	R	R	R	R	R	R	R	S	R	R	R
PL-1	2	R	R	R	R	R	R	R	R	R	R	R	S	R	R

*A = Kataktara DA-2, B = CI-5309, C = Chokoto, D = Co 25, E = Wagwag, F = Pai-kan-tao, G = Peta, H = Raminad Str. 3, I = Taichung, J = CI-8985 (Lacrosse), K = Sha-tiao-tsao, L = Khao-tah-haeng, M = Carreon, N = Tetep.

were conducted to reduce the more than 100 varieties and lines being screened. After further testing, a set of differential varieties may be chosen from this group.

GENETICS AND INHERITANCE OF DISEASE RESISTANCE

Inheritance of resistance to blast. The inheritance of resistance to common blast races was studied in several crosses. In most cases, resistance was controlled by one dominant or two duplicate dominant genes, but the variety Ta-poo-cho-z had one dominant and one recessive gene for resistance (Table 15). The number of resistant genes depended on the isolates used. For example, IR1905-81-3-1 had two genes for resistance to isolates IK81-3 and 43 but one gene for resistance to isolates PO6-6 and IR81-25. Also, IR3273-289-2-1473 had two genes for resistance to isolates IK81-3 and 43, whereas its donor parent Pankhari 203 had only one gene.

The relationships of resistance genes to different races was studied in several crosses. In general, resistance to different races was controlled by different genes because the recombinants obtained

Table 13. Pathogenic races of *Pyricularia oryzae* identified by international differential varieties.[a] IRRI, 1982.

Race	Isolate no.	International differential varieties							
		A	B	C	D	E	F	G	H
IA-1	2	S	S	S	S	S	S	S	S
IA-13	2	S	S	S	S	R	R	S	S
IA-25	1	S	R	R	R	R	R	S	S
IA-45	3	S	S	R	S	R	R	S	S
IA-57	1	S	S	R	R	R	S	S	S
IA-61	4	S	S	R	R	R	R	S	S
IA-63	3	S	S	R	R	R	R	R	S
IA-125	1	S	R	R	R	R	R	S	S
IA-127	2	S	R	R	R	R	R	R	S
IB-6	1	R	S	R	R	R	R	S	S
IB-13	3	R	S	S	S	R	R	S	S
IB-45	17	R	S	R	S	R	R	S	S
IB-47	7	R	S	R	S	R	R	R	S
IB-61	3	R	S	R	R	R	R	S	S
IB-62	1	R	S	R	R	R	R	R	S
IB-63	7	R	S	R	R	R	R	R	S
IB-64	2	R	S	R	R	R	R	R	R
IC-15	1	R	R	S	S	R	R	R	S
ID-13	5	R	R	R	S	R	R	R	S
ID-14	1	R	R	R	S	R	R	R	R
ID-15	5	R	R	R	S	R	R	R	S
ID-16	2	R	R	R	S	R	R	R	R
IE-1	1	R	R	R	R	S	S	S	S
IE-5	1	R	R	R	R	S	R	S	S
IF-4	1	R	R	R	R	R	S	R	R
IG-1	26	R	R	R	R	R	R	S	S
IG-2	5	R	R	R	R	R	R	S	R
IH-1	44	R	R	R	R	R	R	R	S
II-1	20	R	R	R	R	R	R	R	R

[a]A = Raminad Str. 3. B = Zenith, C = NP-125, D = Usen, E = Dular, F = Kanto 51, G = Shao-tiao-tsao(s), H = Caloro.

were resistant to one race and susceptible to others. Several resistance genes were linked, but resistance to isolate PO6-6 in Tetep, IR1905-81-3-1, and IR9669-PP836-1 was independent from resistance to other isolates.

Tests for allelism of resistance genes are summarized in Table 16. In several crosses, a few susceptible recombinants were recovered, indicating that the two parents may have different genes for resistance. An F_3 test will be conducted to confirm this conclusion. The relationships for Tetep, Dawn, Carreon, Ta-poo-cho-z, and Pankhari 203 are in Figure 8. It is not clear if the genes from Ta-poo-cho-z for resistance to the different races are identical because very few recombinations were recovered. It seems that the dominant gene for resistance to race PO6-6 in Ta-poo-cho-z must be different from the gene for resistance to race

Table 14. Pathogenic races of *Pyricularia oryzae* identified by new Japanese differentials.[a] IRRI, 1982.

Race	Isolate no.	Japanese differential varieties								
		A	B	C	D	E	F	G	H	I
00	4	R	R	R	R	R	R	R	R	R
01	3	S	R	R	R	R	R	R	R	R
02	4	R	S	R	R	R	R	R	R	R
03	12	S	S	R	R	R	R	R	R	R
04	1	R	R	S	R	R	R	R	R	R
05	1	S	R	S	R	R	R	R	R	R
06	2	R	S	S	R	R	R	R	R	R
07	3	S	S	S	R	R	R	R	R	R
11	1	S	R	R	S	R	R	R	R	R
44	1	R	R	S	R	R	S	R	R	R
47	2	S	S	S	R	R	S	R	R	R
100	2	R	R	R	R	R	R	S	R	R
101	1	S	R	R	R	R	R	S	R	R
104	1	R	R	S	R	R	R	S	R	R
107	1	S	S	S	R	R	R	S	R	R
110	1	R	R	R	S	R	R	S	R	R
200	1	R	R	R	R	R	R	R	S	R
201	2	S	R	R	R	R	R	R	S	R
202	5	R	S	R	R	R	R	R	S	R
204	1	R	R	S	R	R	R	R	S	R
205	1	S	R	S	R	R	R	R	S	R
227	1	S	S	S	R	S	R	R	S	R
243	2	S	S	R	R	R	S	R	S	R
300	3	R	R	R	R	R	R	R	S	R
303	1	S	S	R	R	R	R	S	S	R
403	12	S	S	R	R	R	R	R	R	S
407	5	S	S	S	R	R	R	R	R	S
413	3	S	S	R	S	R	R	R	R	S
443	1	S	S	R	R	R	S	R	R	S
447	8	S	S	S	R	R	S	R	R	S
501	1	S	R	R	R	R	R	S	R	S
503	1	S	S	R	R	R	R	S	R	S
601	4	S	R	R	R	R	R	R	S	S
603	1	S	S	R	R	R	R	R	S	S
605	2	S	R	S	R	R	R	R	S	S
640	1	R	R	R	R	R	S	R	S	S
645	1	S	R	S	R	R	S	R	S	S
702	1	R	S	R	R	R	R	S	S	S
703	2	S	S	R	R	R	R	S	S	S
707	1	S	S	S	R	R	R	S	S	S
773	1	S	S	R	S	S	S	S	S	S
777	1	S	S	S	S	S	S	S	S	S
42	104	(Total)								

[a]A = Shin 2 (Pi-k^s), B = Aichi-Asahi, (Pi-A), C = Ishikare Shiroke, (Pi-i), D = Kanto 51 (Pi-k), E = Tsuyuake (Pi-m), F = Fukunishiki (Pi-Z), G = Yashino Mochi (Pi-ta), H = Pi No. 4 (Pi-ta^z), I = Toride 1 (Pi-Z^t).

IK81-3 because the Carreon gene is allelic in the case of isolate IK81-3. This indicates that at least eight resistance genes are present in these five varieties.

Moderate resistance. Two moderately resistant varieties, Dourado Precose and OS6, were crossed

Table 15. Number of resistance genes to the different blast races in some resistant varieties, IRRI, 1982.

Variety	Resistance genes[a] (no.) to race[b]							
	IA-61 (IK81-3)	IB-47 (PO6-6)	IC-27 (IK81-25)	IH-1 (43)	IH-1 (IK81-12)	IH-1 (IK81-26)	IH-1 (43-1)	II-1 (41)
IR1905-81-3-1	2D	1D	1D	2D	2D	2D	1D	1D
IR3273-289-2-1473	2D	1D	1D	2D	–	–	–	–
IR5533-PP854-1	–	2D	–	2D	–	–	–	–
IR9669-PP836-1	–	2D	–	2D	–	–	–	–
Tetep	2D	1D	1D	2D	–	–	–	–
Carreon	–	1D	2R	1D	–	–	–	–
Ta-Poo-Cho-z	1D+1R	1D+1R	1D+1R	1D+1R	–	–	–	–
Pankhari 203	1D	1D	–	1D	–	–	–	–
Dawn	–	2D	–	2D	–	–	–	–
Ram Tulasi	3D	–	–	3D	–	–	–	–

[a]D = Dominant gene, R = Recessive gene. [b]Isolate names are in parentheses.

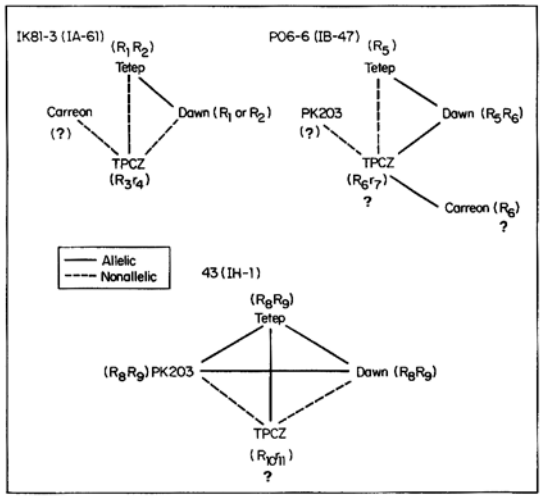
Table 16. Linkage relationships between leaf blast resistance to different isolates in the F_3 of the cross 55061/IR1905-81-3-1. IRRI, 1982.

Relationship	F_3 lines[a] (no.)				Expected ratio	Chi-square	Linkage
	R+RS / R+RS	R+RS / S	S / R+RS	S / S			
PO6-6 and 43	142	12	40	6	45:3:15:1	1.252	Independent
PO6-6 and IK81-12	144	10	40	6	45:3:15:1	2.011	Independent
PO6-6 and IK81-26	142	12	38	8	45:3:15:1	3.626	Independent
PO6-6 and IK81-25	128	26	39	7	9:3:3:1	0.074	Independent
PO6-6 and IR81-3	145	9	38	8	45:3:15:1	6.112	Independent
43 and IK81-12	178	4	6	12	225:15:15:1	95.4*	Linked
43 and IK81-26	177	5	3	15	225:15:15:1	118.2**	Linked
43 and IK81-25	165	17	2	16	45:15:3:1	74.3**	Linked
43 and IK81-3	178	4	5	13	225:15:15:1	105.5**	Linked
IK81-12 and IK81-26	179	5	1	15	225:15:15:1	135.5**	Linked
IK81-12 and IK81-25	163	21	4	12	45:15:3:1	44.1**	Linked
IK81-12 and IK81-3	180	4	3	13	225:15:15:1	114.8**	Linked
IK81012 and IK81-25	164	16	4	16	45:15:3:1	65.0**	Linked
IK81-26 and IK81-3	178	2	5	15	225:15:15:1	126.4**	Linked
IK81-25 and IK81-3	164	3	19	14	45:3:15:1	59.6**	Linked

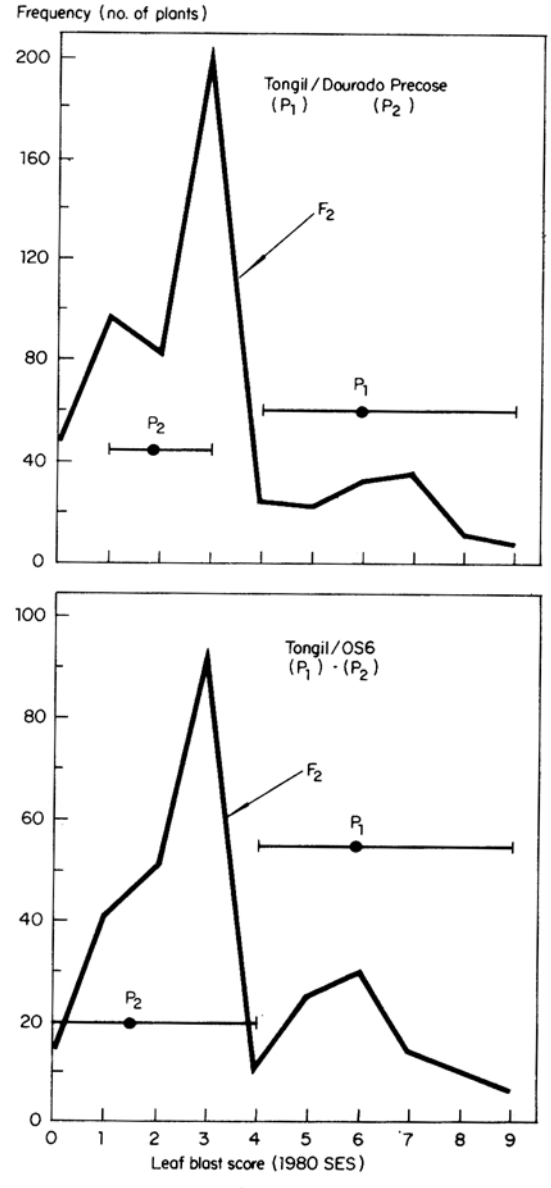
[a]R = resistant, RS = plants resistant to some races but susceptible to others, and S = susceptible.

to both a susceptible variety, Tongil, and a resistant variety, Milyang 54. The F_2 populations were tested for resistance to isolate 43 (race IH-1) and rated on the SES 0-9 scale. In the crosses, Tongil/Dourado Precose and Tongil/OS6, the F_2 populations showed a bimodal distribution, but the peak of the resistant groups did not correspond to the average of the moderately resistant parents (Fig. 9). In the crosses Milyang 54/Dourado Precose and Milyang 54/OS6, the F_2 populations also did not show a normal distribution (Fig. 10). Some susceptible isolates were recovered in both crosses. The data indicate that both Dourado Precose and OS6 possess single dominant genes for moderate resistance with some additional modifier genes.

Inheritance of resistance to *Cercospora oryzae* narrow brown spot. F_1 and F_2 populations of nine cross combinations from four resistant varieties (IR8, Bluerose, Zenith, and Delitus) and three susceptible cultivars (IR26, IR4227 and IR9093-211-6) were used in the study. The F_1, F_2, and the parents were grown in the greenhouse in galvanized iron trays with fertile soil. The seedlings were



8. Allelic relationships of genes for leaf blast resistance to three isolates (races). IRRI, 1982.



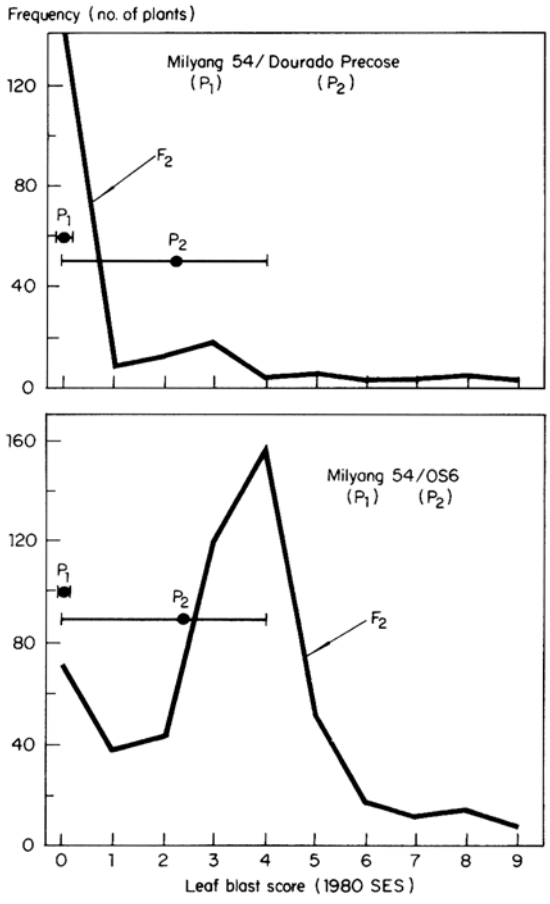
9. Frequency distribution of leaf blast score to isolate 43(IH-1) in the F_2 of the cross Tongil/Dourado Precose and Tongil/OS6. IRRI, 1982.

grown to the 5-to 6-leaf stage and then inoculated by spraying with a spore suspension of I-58 of *C. oryzae*. Reactions of inoculated seedlings were recorded 21 DAI.

Crosses between resistant and susceptible parents and between resistant parents yielded resistant F_1 progeny — suggesting that resistance is dominant over susceptibility (Table 17). F_2 populations of crosses between resistant and susceptible segregated into a simple Mendelian 3:1 ratio of resistant to susceptible plants, indicating that resistance to the disease is governed by a dominant gene. F_2 progenies of crosses between resistant parents gave a 15:1 ratio of resistant to susceptible plants, indicating the presence of duplicate genes in the resistant varieties.

Bacterial blight. *Variety Cas 209.* Previously, Cas 209 (IRRI Accession 15793) was found resistant to race 2 but susceptible to races 1, 3, and 4, of *Xanthomonas campestris* pv. *oryzae* in the Philippines. Analysis of F_1, F_2, and backcross populations from the crosses of Cas 209 with susceptible cultivars revealed that Cas 209's resistance was controlled by a single dominant gene. Tests for linkage relationships indicated that this newly identified dominant gene was linked with *Xa-4* with a recombination value of 27.4%, but was independent of *xa-5* (Table 18). This new gene for bacterial blight resistance was designated as *Xa-10*.

IR1545-339. Four race groups of the rice bacterial blight pathogen have been identified in the Philippines. To date, resistance genes *Xa-4, xa-5, Xa-6, Xa-7, xa-8,* and *xa-9* are all detected on reaction to race 1. Further studies indicated that the F_1 and F_2 populations of TN1/IR1545 showed susceptibility to PXO 61 of race 1, PXO 86 of race 2, and PXO 79 of race 3, suggesting that the resistance of IR1545 to the three strains is recessive. The F_2 segregation yielded a good fit to indicate



10. Frequency distribution of the leaf blast score to isolate 43(1H-1) in the F_2 of the cross Milyang 54/Dourado Precose and Milyang 54/OS6. IRRI, 1982.

that the resistance of IR1545 to the three strains could be controlled by an identical single recessive gene.

Compared with TN1, IR1545-339 was moderately susceptible to PXO 61 of race 4. To characterize the reactions of IR1545 and TN1 to PXO 61 and PXO 71, lesion development was observed from 6 to 24 DAI. The lesion length on IR1545 was considerably shorter than that on TN1 at any time after inoculation. The PXO 71 lesion developed exponentially on TN1 but it became stationary 18 DAI on IR1545. To linearize all the disease progress curves, the Gompertz model was applied and tested (Fig. 11). Distinct difference was observed between the lesion development caused by PXO 71 on TN1 and that on IR1545. The F_2 plants of TN1/IR1545 were susceptible to PXO 71, similar to TN1 plants. The F_2 segregation showed a wide range of variation. The pattern, however, deviated from a normal distribution ($P < 0.005$) and appeared to possess two modes, one corresponding to the reaction of IR1545, the other to that of TN1 (Fig. 12). This suggested that the moderate susceptibility of IR1545 to PXO 71 was characteristic of the line, and the mode of gene action was recessive, and appeared to be under monogenic control. It was observed that plants with *xa-5* were greatly skewed toward lower susceptibility. A normal distribution appeared to correspond to that of IR1545. Plants with *xa-5* in the heterozygous state and those without *xa-5* were greatly skewed toward higher susceptibility and corresponded to those of TN1. To confirm the genic relationship, the F_2 plants were further classified into nine classes (Table 19). The mean lesion length for the group of plants with *xa-5* was significantly lower than that for the group without *xa-5*. The two characters were closely linked together ($P < 0.005$). Both groups showed a wide variation and several plants overlapped between

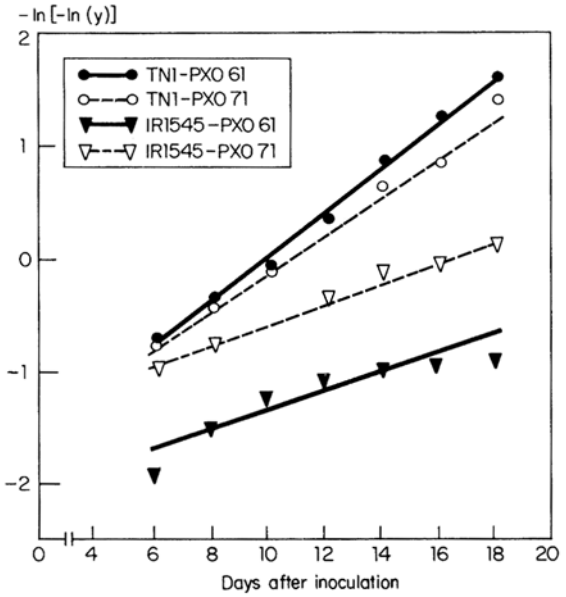
Table 17. F_2 segregations of different rice combinations in response to isolate I-58 of *Cercospora oryzae*. IRRI, 1982.

Cross combination	Observed				Ratio	Chi-square	P
	F_1	R	S	Total			
IR8(R)/IR9093-211-6(S)	48R	188	47	235	3:1	3.13	10-5.0
IR8(R)/IR26(S)	16R	181	53	234	3:1	0.68	50-30
IR4227(S)/IR8(R)	38R	139	45	184	3:1	.03	90-80
Delitus(R)/IR9093-211-6(S)	65R	147	37	184	3:1	2.347	20-10
Zenith(R)/IR9093-211-6(S)	5R	158	49	207	3:1	0.195	70-50
Zenith(R)/IR26(S)	33R	120	44	164	3:1	0.296	70-50
Bluerose(R)/IR4227(S)	5R	123	41	164	3:1	.00016	99-100
Delitus(R)/IR8(R)	92R	203	15	218	15:1	0.148	70-50
Bluerose(R)/Delitus(R)	7R	225	20	245	15:1	1.5306	30-20

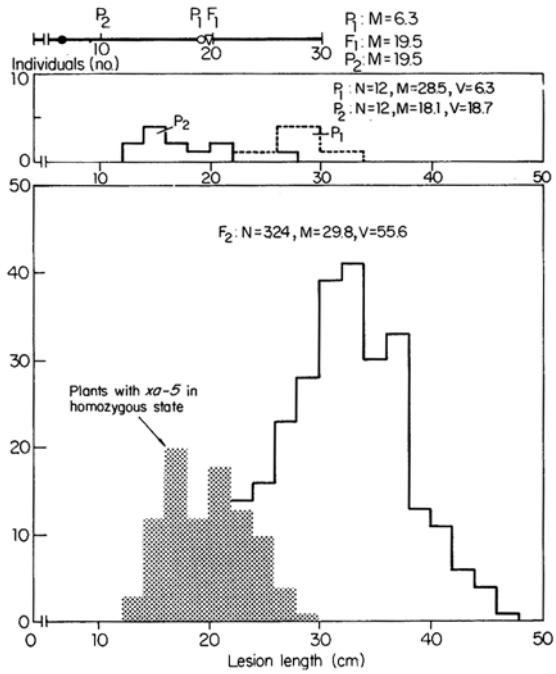
Table 18. Reactions to bacterial strains PXO 86 and PXO 61 of F_1 and F_2 populations from the crosses of Cas 209 with IR20 and IR1545. IRRI, 1982.

Cross combination	F_1[a]	Reaction pattern in F_2					Mean square	P	Recombination value(%)
		RR	RS	SR	SS	Total			
IR20/Cas 209	RR	132 (140.57)	71 (62.67)	62 (62.67)	6[b] (5.07[c])	271	1.802	0.75-0.05	27.4±5.6
IR1545/Cas 209	SMR	65 (70.25)	0 (0.00)	163 (158.06)	53[b] (52.69[d])	281	0.548	0.90-0.75	

[a]R = resistant, MR = moderately resistant, S = susceptible; for combined capital letters, the first letter stands for reaction to PXO 61; the second, to PXO 86. [b]Observed segregation. [c]Calculated based on recombination value of 27.4%. [d]Calculated on the basis of 4:0:9:3 ratio.



11. Bacterial blight lesion development caused by PXO 61 and PXO 71 on TN1 and IR1545-339. Values are transformed with Gompertz equation ($-ln(-ln(y))$: y = disease proportion (mean lesion length/mean leaf length). Each value is the average of 20 observations. IRRI, 1982.



12. Reactions of parental and F_1 plants, and frequency distribution for disease scores of parental and F_2 population from the cross of TN1 (P_1)/IR1545-339 (P_2) to PXO 71. M = mean lesion length (cm), N = number of individuals, V = variance. IRRI, 1982.

the two groups. However, no plants showed high susceptibility in the group *xa-5*, nor low susceptibility in the group without *xa-5*. In addition, the variation within each group appeared similar to that of corresponding parents. The results suggested that the moderate susceptibility might be governed by *xa-5*, or at least by one or more recessive genes closely linked to the *xa-5* locus.

Two sets of F_3 families from TN1/IR1545 were tested against PXO 86 and PXO 71. Data on F_3 segregation against PXO 86, avirulent to IR1545, confirmed the genic control of *xa-5* on resistance. The other set of F_3 families were inoculated with PXO 71. According to the results of PXO 86, the F_3 families were divided into three groups. Group 1 included the families with *xa-5* in the homozygous state; Group 2, those with *xa-5* in heterozygous state; and Group 3, those lacking *xa-5*. Group 1 was skewed toward the lower susceptible end; and group 3, toward the hgher susceptible end — similar to that in the F_2 population. Analysis of variance for lesion length showed a significant

Table 19. Relationship between the groups with and without *xa-5*[a], for the reaction scores to PXO 71 in F_2 population from the cross TN1/IR1545-339. IRRI, 1982.

Group	1	2	3	4	5	6	7	8	9	Total	Mean lesion length (cm)
	12-16	16-20	20-24	24-28	28-32	32-36	36-40	40-44	44-48		
xa-5	15 (4.4)[a]	32 (9.3)	31 (9.3)	14 (11.3)	1 (19.4)	0 (20.6)	0 (13.4)	0 (4.9)	0 (1.5)	94	20.3
without *xa-5*	0 (10.6)	0 (22.7)	1 (22.7)	25 (27.7)	66 (47.6)	71 (50.4)	46 (32.6)	17 (12.1)	5 (3.5)	230	33.7
Total	15	32	32	39	67	71	46	17	5	324	

[a]Calculation of the expected values, in parentheses, was based on the observed ratio of 94:320. $X^2 = 268.95$, d. f. = 8, $P<0.005$, $t = 25.1$, $P<0.001$.

Table 20. Analysis of variance for lesion length caused by PXO 71 in 65 F_3 lines from the cross of TN1 (P_1)/ IR1545-339 (P_2) and parental lines. IRRI, 1982.

Source of variance	Degrees of freedom	Mean square	F
Total	1281		
Among lines	66	269.3988	23.55
P_1 vs P_2	1	685.5706	59.94**
$P_1 + P_2$ vs F_3 lines	1	0.0762	<1
Among F_3 lines	64	267.1037	23.35**
Among groups[a]	2	3567.9678	22.21**
Lines within groups	62	160.6242	
P_2 vs Group I	1	4.3301	<1
P_1 vs Group II	1	25.2020	2.20[ns]
Plants within lines	1215	11.4378	

[a]Tested against lines within groups.

difference among the three groups and no significant difference between group 1 and IR1545 and between group 2 and TN1 (Table 20). The results supported the conclusion drawn from the F_2 population. The lesion development was slower in families with *xa-5*. This may further suggest that the moderate susceptibility to lesion development caused by PXO 71 in IR1545 was due to the effect of the same gene *xa-5*.

Trisomic analysis of *xa-5* was done by crossing IR1545-339 with Triplo 7, Triplo 8, Triplo 9, and Triplo 12. When the F_2 population from a trisomic F_1 was classified into disomic and trisomic fractions by morphological characteristics, the segregation gave a good fit to the theoretical trisomic segregation ratio calculated by assuming random complete chromatid assortment. The results revealed that *xa-5*, a recessive gene for resistance to PXO 86 in IR545, is located on the extra chromosome of Triplo 5 (Table 21). Triplo 5 corresponds to the L-type of trisomics with japonica genetic backgrounds. The extra chromosome of L-type of trisomics was chromosome 2 followed by Nishimura's designation. The conclusion is that *xa-5* is located on chromosome 2.

Table 21. Trisomic segregation of *xa-5* for resistance to PXO 86 in F_2 populations from the cross IR1545-339/Triplo 5. IRRI, 1982.

Cross	Fraction of population	Observed number		Total	Mean square for		
		+	*xa-5*		3:1	8:1	44:1
Triplo 5/IR1545[a]	2X	70	8	78	9.043*	0.058	–
	2X + 1	35	2	37	7.577*	–	1.725
	Total	105	10	115	16.304*	–	–
Triplo 5/IR1545[b]	2X	125	42	167	0.002	–	–

[a]F_2 population from a trisomic F_1 plant. [b]F_2 population from a disomic F_1 plant.

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

Evaluation of the germplasm collection (*Entomology and Plant Breeding*). Most IRRI screening work involves the evaluation of breeding lines. However, the germplasm collection is also screened for resistance to eight rice insects (Table 1). Resistance to the brown planthopper (BPH) *Nilaparvata lugens*, whitebacked planthopper (WBPH) *Sogatella furcifera*, green leafhopper (GLH) *Nephotettix virescens*, and the zigzag leafhopper (ZLH) *Recilia dorsalis* is studied on seedlings in seedboxes in the greenhouse. Screening for resistance to the yellow and striped stem borers is carried out in the screenhouse or in "hot spots" in the field. Resistance to rice whorl maggot (RWM) *Hydrellia philippina* is evaluated in the field, and resistance to leaf folder in the greenhouse. Of the approximately 60,000 accessions in the IRRI germplasm collection, many have been screened against the BPH, WBPH, and GLH. In 1982, almost 300 additional varieties were identified as resistant to these insects. Methods are currently being developed for screening rices for resistance to thrips *Baliothrips biformis* and rice stink bug *Leptocorisa oratorius*.

Sources of green leafhopper resistance in IR varieties (*Entomology*). Most of the varieties used as parents in the breeding of IR5 to IR54 were evaluated in the greenhouse to determine their level of GLH resistance. Of the varieties tested, eight had high levels of GLH resistance (Table 2). Several of the IR varieties have two or more of these resistant varieties as parents in their pedigree. TKM6 also has a gene for BPH resistance and is moderately resistant to stem borers and leaf folders.

Table 1. Number of germplasm accessions screened and selected for resistance at IRRI through 1982.

Insect	Accessions		
	Tested (no.)	Resistant	
		no.	%
Brown planthopper			
biotype 1	30 790	281	0.91
biotype 2	8 922	126	1.41
biotype 3	10 711	148	1.38
Whitebacked planthopper	46 488	391	0.84
Green leafhopper	47 944	1 196	2.50
Zigzag leafhopper	2 370	36	1.52
Yellow stem borer	19 961	25	0.13
Striped stem borer	ca 15 000	18	0.12
Whorl maggot	15 787	1	0.01
Leaf folder	9 838	85	0.86

NATURE OF RESISTANCE

Entomology Department

Tolerance for the brown planthopper. Tolerance may be one of several strategies for coping with the BPH biotype problem. Tolerant rice cultivars are likely to offer little or no selective advantage to the pest to develop a new BPH biotype. When biotype selection is detected and the first line of defense provided by major genes is removed, the tolerance mechanism, as a second line of defense, will continue to function. This would buy time between the breakdown of the variety possessing both specific resistance and tolerance and the release of a new variety.

Tolerance is the ability of a variety to grow and produce grain or to repair injury despite the presence of an insect population that would destroy a susceptible variety. Seedbox screening techniques have been developed to identify tolerant and moderately resistant rice varieties. The commonly used seedling screening test was modified in that older plants (10-12 d) were used at the time of infestation, plants were infested with fewer insects (four or five first-instar nymphs per seedling), and the F_1 progeny rather than the initial infestation caused the plant damage. Varieties, such as IR46, Kencana, Triveni, and Utri Rajapan, with a damage

Table 2. Parents of IR varieties having GLH resistance. IRRI, 1982.

Variety	Accession no.	Damage rating[a]
BPI 121	15762	3
Gam Pai	00831	3
Latisail	08340	3
Ptb 18	06105	1
Ptb 21	06113	3
Peta	00035	3
Sigadis	00611	3
TKM 6	00237	3
IR29 (R check)	–	1
TN1 (S check)	–	9

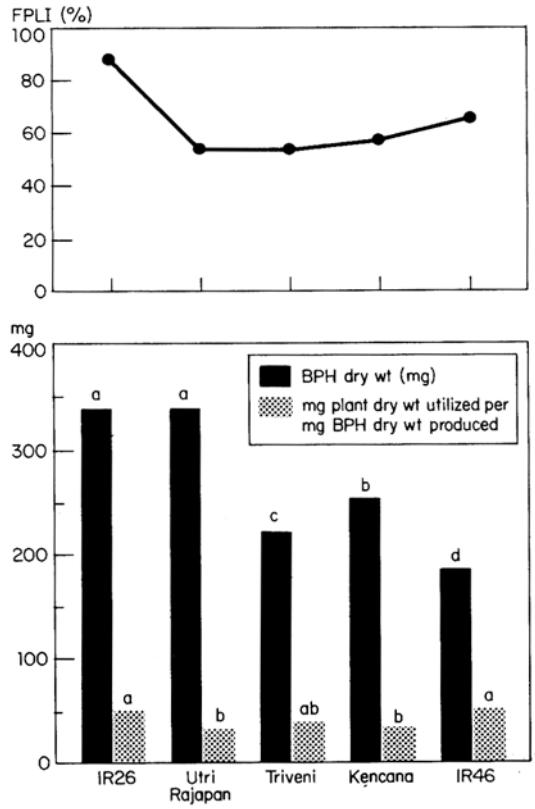
[a] 1980 SES.

rating of 3-6 in the common seedbox screening test, were used in assessing the level of antibiosis or tolerance, or both, to BPH biotype 2. IR26 was the susceptible check.

Tolerance tests. Plant tolerance was measured using the formula:

$$\text{Functional plant loss index (FPLI)} = 1 - \left[\frac{\text{dry weight of infested plants}}{\text{dry weight of uninfested plants}}\right]\left[1 - \frac{\text{damage score}}{9}\right]$$

The insect dry weight, produced through the reproduction of BPH feeding on the varieties, was measured as an indicator of the antibiosis level. The FPLI was highest in IR26 at all levels of BPH infestation, whereas it was significantly lower in moderately resistant varieties, indicating the presence of tolerance or lower levels of antibiosis in these varieties. The insect biomass produced was almost identical on susceptible IR26 and moderately resistant Utri Rajapan. However, the BPH dry weight was significantly less on the other moderately resistant varieties IR46, Kencana, and Triveni at all infestation levels. This indicates that the moderately resistant varieties tested, except Utri Rajapan, have both tolerance and antibiosis, the levels of which vary. The plant dry weight, in milligrams loss per milligram of BPH dry weight produced, was significantly less in Utri Rajapan (32.78) than in IR26 (51.78). The low plant loss is evidence of the high levels of tolerance in these varieties. The relationships among the FPLI, BPH dry weight, and plant weight utilized per BPH dry weight produced is illustrated in Figure 1.



1. FPLI, BPH dry weight, and plant dry weight utilized per milligram of BPH in rice varieties at 32 DI. Mean of three levels of infestation and five replications. IRRI greenhouse, 1982.

Utri Rajapan had no antibiosis, the BPH growth index on it being similar to that on IR26. However, BPH had a lower growth index on IR46, Kencana, and Triveni than on IR26, indicating the effect of moderate levels of antibiosis. Results in the relative growth rate were similar (Table 3).

The pooled regression estimate of all varieties for the FPLI on insect dry weight was significant, indicating the possible separation of varieties having the various combinations of antibiosis and tolerance (Fig. 2). The regression line and the mean of BPH dry weight ($\bar{x}$) are useful in categorizing the varieties by their resistance components. The points based on the observations on susceptible IR26 fell distinctly into the antibiosis-absent, tolerance-absent category while those on Utri Rajapan fell into the antibiosis-absent, tolerance-present category. IR46, Kencana, and Triveni points fell mostly to the left of vertical line ($\bar{x}$) indicating the presence of antibiosis and various levels of tolerance.

Further tests were conducted in the field. The BPH populations reached high levels in the field cages, providing reliable conditions for measuring levels of tolerance and antibiosis among test varieties. By 50 d after infestation (DI), the IR26 plants had a damage rating of 9 and were completely hopperburned, resulting in 100% yield reduction (Table 4). Utri Rajapan, despite a high BPH population of 815 nymphs/hill, had a low damage rating of 3 and a low 35.5% yield reduction.

Table 3. Assessment of tolerance[a] in rice varieties exposed to various BPH levels for 32 d. IRRI greenhouse, 1982.

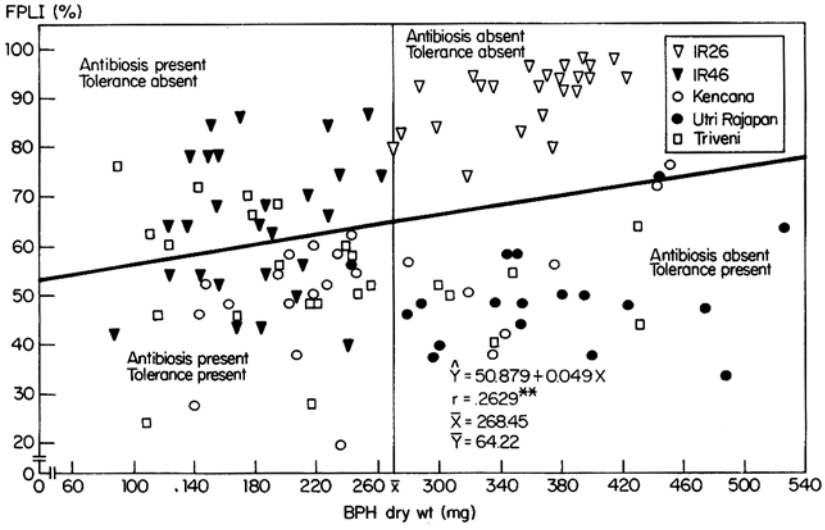
Variety	FPLI (%)	Insect dry wt (mg) produced by feeding on rice varieties	Plant dry wt (mg) utilized per mg of insect dry wt produced	Tolerance index	Insect growth index	Relative growth rate
IR26 (S)	89.7 a	337.90 a	51.78 a	—	6.06 a	0.1333 a
IR46 (MR)	64.7 b	188.92 d	52.44 a	0.56 c	5.44 c	0.1315 ab
Kencana (MR)	56.8 c	254.76 b	36.21 b	0.75 b	4.69 d	0.1285 bc
Utri Rajapan (MR)	54.9 c	339.26 a	32.78 b	1.00 c	6.03 a	0.1319 ab
Triveni (MR)	55.0 c	221.40 c	39.73 ab	0.65 bc	5.72 b	0.1261 c

[a]Av of three levels of infestation (25, 50, 100) of 1 to 2-d-old nymphs and two plant ages (35 and 48 d old).

Grain yield recovery test. Fifty-five-day-old plants were infested with various levels of newly hatched BPH nymphs. They were covered with nylon mesh cages until the first-generation population buildup at 28 DI. The insects were then removed and the plants allowed to grow and recover until grain maturity. The grain yield of infested plants was compared with that of uninfested plants. Grain yield of Utri Rajapan (81.93%), was equal to that of the resistant check IR54 and significantly higher than that of the susceptible IR26 (Table 5).

The incidence (Table 6) and recovery (Table 7) of BPH-transmitted rice ragged stunt virus (RRSV) was significantly less in Utri Rajapan than in TN1. Although Utri Rajapan is susceptible to GLH, it is moderately resistant to the tungro virus (RTV). However, disease recovery in Utri Rajapan was only 5% compared with 80% in TN1 (Table 8). This was confirmed by serological studies that indicated that both spherical (RTSV) and bacilliform (RTBV) virus particles occurred in the susceptible TN1, but only the RTBV particle occurred in moderately resistant Utri Rajapan and resistant IR29. Because both RTSV and RTBV particles are necessary for a plant to serve as a virus source, GLH cannot transmit RTV from an Utri Rajapan or IR29 plant to another rice plant. Thus, Utri Rajapan is a good source of tolerance for BPH and resistance to ragged stunt and RTV.

A brown planthopper population that feeds on IR36. After IR26 having the *Bph* 1 gene for BPH



2. Identification of components of resistance to BPH using dry weight (antibiosis factor) and FPLI (tolerance indicator) in rice varieties. IRRI greenhouse, 1982.

Table 4. Grain yield reduction in rice varieties exposed to various levels of BPH infestation in field microplots (1-m^2) cages.[a] IRRI farm, 1982 DS.

Variety	Grain yield reduction (%) when variety was exposed to		
	17 pairs BPH	35 pairs BPH	70 pairs BPH
IR26 (S)	100.00 (a) a	100.00 (a) a	100.00 (a) a
IR46 (MR)	28.88 (a) b	41.19 (a) bc	48.64 (a) bc
Kencana (MR)	19.41 (b) b	25.75 (ab) bc	55.53 (a) bc
Kalubalawee (MR)	11.16 (b) b	13.54 (b) c	50.10 (a) bc
Utri Rajapan (MR)	21.77 (a) b	19.63 (a) bc	35.48 (a) c
Moharathkundawee (MR)	31.45 (b) b	46.34 (ab) b	72.89 (a) ab
Triveni (MR)	35.89 (a) b	35.88 (a) bc	49.32 (a) bc
IR54 (R)	21.59 (a) b	26.88 (a) bc	28.99 (a) c
Mahsuri (S)	100.00 (a) a	100.00 (a) a	100.00 (a) a

[a]Each microplot of 35 hills was infested with 17, 35, and 70 pairs of 1- to 2-d-old adult BPH. Separation of means in a column (without parentheses) and means in a row (with parentheses) by Duncan's Multiple Range Test at the 5% level.

Table 5. Grain weight loss (%)[a] in S, R, and MR rice varieties exposed to various levels of BPH infestation for 28 d. IRRI greenhouse, 1982.

Variety	Grain wt loss (%) at initial infestation[b] of			Av grain wt loss of three infestation levels
	50 insects	100 insects	200 insects	
IR26 (S)	32.1 abc	49.1 cde	65.9 e	49.1 c
IR54 (R)	17.0 a	18.7 ab	24.1 abcd	19.9 a
Utri Rajapan (MR)	8.6 ab	20.7 ab	24.9 abc	18.1 a
IR46 (MR)	26.2 abcd	35.1 abcd	42.9 bcde	34.7 b
Triveni (MR)	25.8 abcd	38.1 bcd	53.1 de	39.0 b

[a]Av of five replications. Grain wt loss = $\frac{\text{Grain wt without BPH infestation} - \text{Grain wt with BPH infestation}}{\text{Grain wt without BPH infestation}} \times 100$. [b]Each pot of two 50-d-old plants was infested with 1st-instar nymphs.

Table 6. RRSV-diseased plants at 60 DI in susceptible (S) and moderately resistant (MR) rice varieties exposed to various levels of RRSV-viruliferous BPH for 24 h.[a] IRRI greenhouse, 1982.

Variety	RRSV-diseased plants (%) at initial infestation[b] of		
	1 insect	5 insects	10 insects
TN1 (S)	15	45	64
Utri Rajapan (MR)	0	15	20
Difference	15 ns	30**	44**

[a]Av of four replications. [b]Each pot of one 10-d-old plant was infested with 4th-instar nymphs.

Table 7. Recovery of RRSV disease for 3 subsequent days from S and MR 60-d-old rice plants infested with 10 RRSV-viruliferous BPH. IRRI, 1982.

Recovery period	Recovery of RRSV (%) from	
	TN1 (S)	Utri Rajapan (MR)
1st day	10.66 b	1.06 a
2nd day	10.84 b	1.54 a
3rd day	18.30 a	1.71 a
Variety mean	13.27	1.44

resistance was planted for about 2 yr in Indonesia, Philippines, and Vietnam, it became susceptible because the planthopper population shifted to biotype 2, which could feed on and destroy it. IR36 with the *bph* 2 gene conferring resistance to biotype 2 replaced IR26 and has been successfully planted on more than 10 million ha. IR36 has been planted for 6 yr in some areas.

In 1982 reports from Mindanao in the southern Philippines indicated that IR36 was being damaged by BPH. Hoppers collected from IR36 in Minda-

Table 8. Recovery of RTV disease from S, MR, and, R 25-d-old rice plants infested with seven RTV-viruliferous GLH, and the frequency of bacciliform (RTBV) and spherical (RTSV) particles from infected leaf samples. IRRI, 1982.

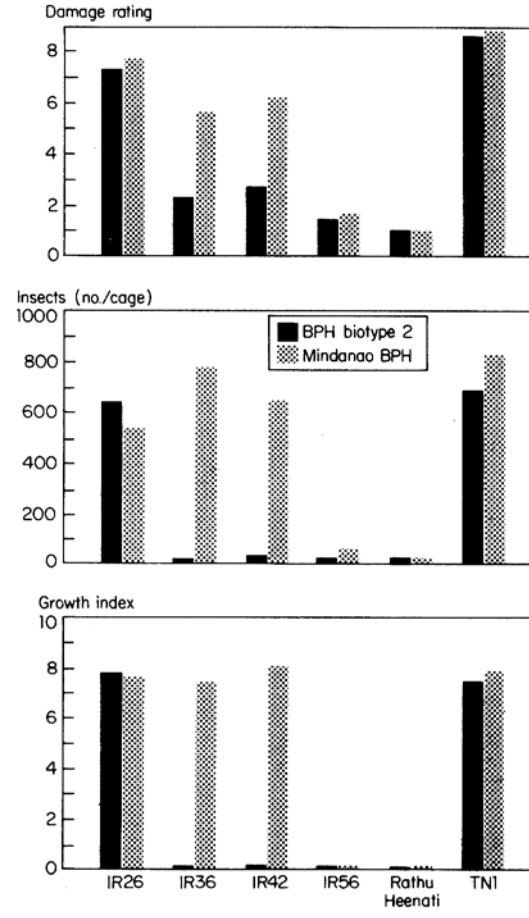
Variety	Recovery (%) of RTV	Occurrence of virus particles (%)	
		RTBV	RTSV
TN1 (S)	80	100	80
Utri Rajapan (MR)	5	93	0
IR29 (R)	5	53	0

nao were compared with biotype-2 hoppers cultured in the greenhouse. As expected, biotype 2 was able to damage IR26, but not IR36 and IR42, which have the *bph*-2 gene, nor IR56 and Rathu Heenati, which have the *Bph* 3 gene for resistance (Fig. 3). The Mindanao biotype, however, was able to feed on and damage and multiply on IR26, IR36, and IR42 indicating that the population is probably a new biotype.

Because a shift in biotype was expected after the planting of IR36 for several years, varieties resistant to biotype 3 had been identified and used as donors in the breeding of resistant varieties. IR56 is one such variety, and several tons of seed have been shipped to areas where this new biotype is reportedly destroying IR36.

Brown planthopper resistance in wild rice. Of the 343 wild rice accessions screened for BPH resistance, 149 were resistant to biotype 1, 125 to biotype 2, and 128 to biotype 3. Many were resistant to all three biotypes. These varieties may offer new gene sources for BPH resistance.

In 1981-82, the mechanisms of BPH resistance in selected wild rices were studied. In the modified seedbox screening test, several accessions were resistant to the three biotypes (Table 9). Several were from countries other than India and Sri Lanka, the major sources of resistance in *O. sativa*. The hoppers were not able to reproduce and multiply on the resistant accessions (Table 10). The low population growth on the resistant varieties may have been due to the lack of feeding as indicated by the amount of honeydew excreted (Table 11). The low amount of blue spots produced by the reaction of honeydew on bromocresol green-treated filter paper indicated low feeding on



3. Plant damage, insect population, and growth index of Mindanao BPH and BPH biotype 2 on selected varieties. IR26 has the *Bph* 1 gene, IR36 and IR42 the *bph* 2 gene, and IR56 and Rathu Heenati the *Bph* 3 gene for BPH resistance. TN1 has no gene and is susceptible. IRRI, 1982.

the phloem, the source of nutrients. BPH on the susceptible varieties, however, produced copious amounts of blue spots and few pale-colored spots, indicating higher levels of phloem feeding than xylem feeding. This result suggests the presence in the phloem of some factors that prevent feeding on resistant accessions.

The low feeding activity on the resistant accessions resulted in shorter life-spans of the females — and low egg production (Table 12). Egg hatching was also lower and the location of egg deposition was higher on the leaf sheath in resistant accessions than in the susceptible accessions.

Multiple resistance of Chinese rice varieties. The search for varieties having moderate BPH resis-

Table 9. Screening of wild rice varieties for BPH resistance by the modified seedbox screening test. IRRI, 1981-82.

Name	Variety		Damage grade[a]		
	Acc. no.	Origin	Biotype 1	Biotype 2	Biotype 3
		Test 1			
O. perennis	100844	Madagascar	9.0	9.0	8.3
O. punctata	100954	Japan	1.7	1.0	2.3
O. punctata	101409	Ghana	2.3	3.0	3.0
O. punctata	100937	China	1.7	2.3	1.0
O. minuta	101081	Philippines	1.0	1.7	1.0
O. rufipogon	100184	Cuba	9.0	8.3	8.3
O. rufipogon	100910	Thailand	5.0	4.3	4.2
O. latifolia	100914	Mexico	2.3	3.0	3.0
O. latifolia	100956	India	2.3	3.0	3.0
O. latifolia	100964	Guatemala	3.0	3.0	3.0
O. latifolia	100962	Guatemala	1.7	3.0	3.0
O. nivara	102165	India	3.0	3.0	3.0
O. officinalis	101155	Malaysia	1.0	1.0	1.0
TN1	–	–	9.0	9.0	9.0
IR26	–	–	3.0	8.3	3.0
ASD 7	–	–	3.0	3.3	8.3
		Test 2			
O. punctata	100892	India	3.0	3.0	6.3
O. minuta	100887	India	2.3	5.0	5.7
O. latifolia	100168	Costa Rica	3.0	3.7	2.3
O. latifolia	100172	Guatemala	1.0	3.0	3.7
O. latifolia	100895	USA	1.0	3.0	5.0
O. latifolia	100965	Costa Rica	1.7	4.3	3.7
O. latifolia	100966	Panama	1.0	3.0	5.0
O. latifolia	102481	Nicaragua	1.7	3.0	1.7
O. nivara	101970	India	5.0	7.7	6.3
O. nivara	102185	India	3.0	3.0	1.7
O. nivara	101973	India	3.7	5.0	6.3
O. nivara	101979	India	9.0	9.0	9.0
O. nivara	102467	Bangladesh	9.0	9.0	9.0
O. nivara	100197	Burma	9.0	9.0	9.0
O. officinalis	101414	India	1.0	1.0	1.0
O. barthii	101243	Mali Rep.	3.0	7.7	4.3
O. longistaminata	100930	Sudan	9.0	9.0	9.0
O. nivara × *rufipogon*	101966	–	7.7	8.3	6.3
O. sativa f. spontanea	100901	India	5.0	7.7	8.3
O. sativa f. spontanea	100902	Japan	8.3	9.0	8.3
O. sativa f. spontanea	100920	Malaysia	8.3	9.0	9.0
O. sativa f. spontanea	100942	India	8.3	7.7	9.0
O. sativa f. spontanea	100943	India	8.3	7.7	9.0
TN1	–	–	9.0	9.0	9.0
ASD 7	–	–	3.0	3.5	9.0
IR26	–	–	3.7	8.3	3.0

[a]Av of three replications, based on the 1980 SES: 1 = little or no damage; 9 = all plants dead; 1.0-3.9 = R; 4.0-5.9 = MR; 6.0-7.9 = S; 8.0-9.0 = HS.

tance continued. It is expected that these varieties will have a general or horizontal type of resistance that would provide control for all biotypes. Although varieties with high resistance (specific or vertical resistance) are primarily from India and Sri Lanka, varieties with moderate resistance from other countries have been identified in the IRRI screening program.

Two Chinese varieties, Pao-Hsun No. 2 and Pao-Tai-Ai, were found to have moderate resistance to the three biotypes at IRRI (Fig. 4). They were resistant not only to BPH but also to GLH, and moderately susceptible or moderately resistant to several other insects (Table 13). Both had low levels of resistance to RGSV possibly because of their resistance to BPH, its vector.

Table 10. Population growth of BPH biotype 2 on wild rice varieties.[a] IRRI, 1981.

Variety		Damage rating	Insects[a] (no./cage)					
Name	Acc. no.		3rd instar	4th instar	5th instar	Adult	Total	Ratio[b]
O. perennis	100844	S	102.2 abc	212.4 a	216.8 a	35.4 a	566.8 a	30.8
O. rufipogon (Cuba)	100184	S	36.2 bcd	62.0 a	199.8 a	27.8 a	325.8 a	17.7
O. punctata	100954	R	5.6 d	10.8 b	2.0 d	0.0 b	18.4 c	1.0
O. latifolia	100962	R	34.0 bc	43.4 a	13.6 c	0.2 b	91.2 bc	5.0
O. rufipogon (Thailand)	100910	MR	104.8 ab	158.6 a	281.2 a	20.6 a	565.2 a	30.7
TN1	–	S	49.2 cd	163.6 a	312.4 a	18.6 a	543.8 a	29.6
ASD 7	–	R	79.6 b	133.0 a	22.4 c	1.6 b	236.6 b	12.9
IR26	–	S	218.2 a	222.2 a	160.4 ab	18.2 a	619.0 a	33.6

[a]Three pairs (female and male) of 3-d-old adults of BPH biotype 2 reared on 30 d-old IR26 seedlings were released in each cage of potted plants. Av of five replications. [b]Figures are ratios of total insects on a given variety to the lowest total insect population, 18.4 on *O. punctata*.

Table 11. Honey excretion of BPH biotype 2 on wild rice varieties.[a] IRRI, 1981.

Varieties		Damage rating	Honeydew area (mm^2)		
Name	Acc. no.		Blue color	Pale color	Total
O. perennis	100844	S	852.0 a	7.8 c	859.8 a
O. rufipogon	100184	S	638.6 ab	12.6 bc	651.2 ab
O. punctata	100954	R	6.2 c	47.6 ab	53.8 c
O. latifolia	100962	R	50.0 c	27.6 abc	77.6 c
O. rufipogon	100910	MR	152.0 c	65.2 a	217.2 c
O. nivara	102165	R	100.6 c	27.4 abc	128.0 c
TN1	–	S	735.6 ab	12.2 bc	747.8 ab
ASD 7	–	R	146.8 c	44.2 abc	191.0 c
IR26	–	S	514.2 b	25.0 bc	539.2 b

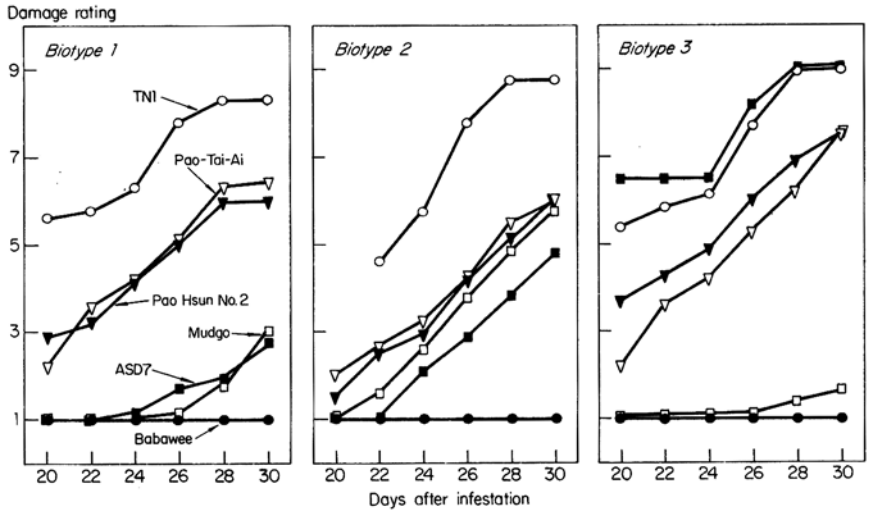
[a]Average of five replications.

Table 12. Life-span, fecundity, egg hatchability, and location of egg deposition by BPH biotype-2 females on wild rice varieties.[a] IRRI, 1982.

Variety		Damage rating	Female life-span (d)		Eggs laid per female (no.)	Egg hatching (%)	Location of egg deposition[b] (mm)
Name	Acc. no.		Range	Mean			
O. punctata	100954	R	4-9	5.8 c	28 c	55.37 c	198.2[c]a **
O. latifolia	100962	R	9-21	14.9 b	169 bc	74.53 bc	149.5 b**
O. rufipogon	100910	MR	10-31	18.3 ab	401 a	81.64 ab	43.1 c
O. perennis	100844	S	13-33	23.2 a	421 a	79.67 ab	32.8 c
IR26	–	S	9-27	17.3 ab	359 a	94.24 a	24.5 c
ASD 7	–	R	4-26	13.1 b	222 ab	98.07 a	35.9 c

[a]Av of 10 replications on 30-d-old seedlings. [b]Distance from the base of plant to the location where the lowest egg was laid. [c]Some egg masses were laid in the leaf near the midrib.

The moderately resistant accessions *O. rufipogon* (Acc. 100910) and *O. nivara* (Acc. 101973) showed BPH tolerance. The BPH survived on them and supported populations equal to those on the susceptible varieties (Fig. 5). However, plant damage as indicated by the FPLI was significantly lower on the moderately resistant accessions. Also, the plant weight loss in milligrams per milligram of insect produced was lowest on the moderately resistant accessions. This indicates that the insects

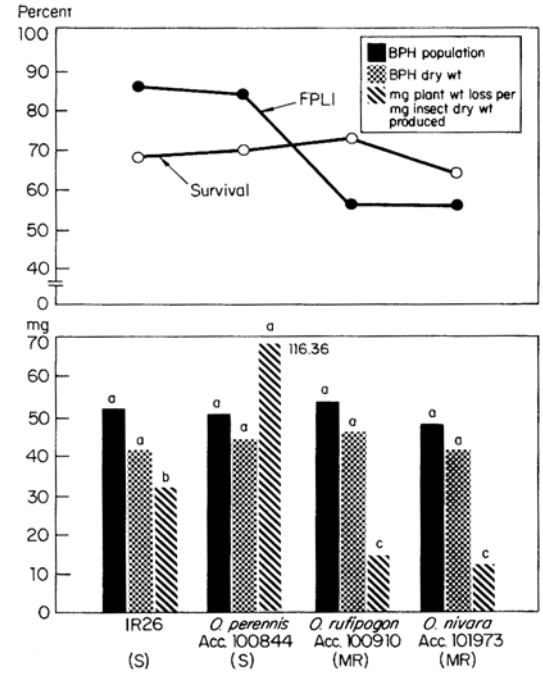


4. Reaction of selected varieties to the three BPH biotypes using the modified seedbox screening test. IRRI, 1982.

Table 13. Reaction of two Chinese rice varieties to various rice insects and diseases. IRRI greenhouse and screenhouse, 1981.

Rice insect or disease	Reaction	
	Pao Hsun #2	Pao Tai-Ai
BPH	MR	MR
WBPH	MS	MS
YSB	MS	MS
SSB	S	S
GLH	R	R
Leaf folder	MR	MR
RCW	MS	MS
BLB	S	S
RTV	S	S
RRSV	S	S
RGSV	MS	MS

obtained for its growth sufficient nutrients from the plant, but that the plant was not damaged. The susceptible varieties, on the other hand, provided a large amount of plant nutrients to support hopper growth. It appears that the sap of the moderately resistant varieties is much more nutritious than that of the susceptible varieties and that only a small amount, which causes little plant weight loss, is required to sustain the insect population. This is a characteristic of tolerant varieties such as Utri Rajapan. Because tolerant varieties exert no selection pressure for biotype development, they may be important sources for the breeding program.



5. FPLI, insect dry weight, population, plant weight loss, and survival of BPH biotype 2 on selected wild rice varieties. IRRI, 1982.

Minor genes for whitebacked planthopper resistance. Plant breeders have identified four major genes for resistance to the WBPH, a pest whose importance is increasing in Asia. Three tests were

conducted to determine whether the level of resistance differed among varieties with the same major gene, *Wbph* 1 or *Wbph* 2. Varieties were compared on the basis of the damage rating of seedlings in the seedbox test and WBPH survival and population growth — all of which varied significantly (Table 14, 15).

The results indicate that the varieties have minor genes that modify the effect of the major gene and play an important role in determining the level of WBPH resistance. It is expected that these minor genes would slow the rate of biotype selection.

Green leafhopper feeding and tungro virus transmission. In contrast to the BPH, the GLH feeds on and excretes honeydew on resistant rice varieties. However, the insects survive only for a few days. Previous studies have shown that the leafhoppers feed on xylem sap of resistant varieties and on phloem sap of susceptible ones. The insects cannot survive on the xylem sap because it lacks nutrients. Studies in 1982 showed similar feeding activity, as indicated by honeydew excretion, on susceptible, moderately resistant, and resistant varieties (Table 16). Analysis of the pH of honeydew excreted on filter paper indicated that the spots were acidic, acidic + basic, or basic. Acidic spots indicate xylem and basic spots phloem feeding. As the level of resistance increased, the amount of xylem feeding increased — reaching 90% in resistant IR29. The percentage of RTV infection was related to the degree of phloem feeding; it ranged from 99 in IR22 (susceptible) to 14 in IR29 (resistant). RTV infection in the moderately resistant varieties was intermediate. This indicates that the mechanism for resistance occurs in the phloem. When the leafhoppers cannot feed on the phloem and are forced to feed on the xylem, the RTV particles, which are injected, do not cause RTV symptoms.

Tungro virus transmission by green leafhopper biotypes. Since the release of IR8, GLH-resistant varieties have been widely grown throughout Asia. Resistant varieties have been instrumental in controlling GLH-vectored RTV. In 1982 greenhouse studies were conducted to determine whether GLH biotypes that developed and reproduced on resistant varieties could be selected and whether the

Table 14. Damage rating, nymphal survival, and population growth of the WBPH on varieties with the *Wbph* 1 gene for resistance. IRRI, 1982.

Variety	1980 SES Damage rating (9 DI)	Survival[a] (%)	Population growth[b] (per 5 females)
N 22	6.3	83 cd	247 def
N32	6.3	84 bcd	350 bcdef
Latighawar	4.3	81 cd	330 bcdef
Sonpattar 45	3.0	86 bcd	289 bcdef
Bansphul	3.7	84 bcd	333 bcdef
P 580	5.0	87 bcd	313 bcdef
Senawee	4.3	88 bcd	106 g
W 128	5.0	88 bcd	387 abcdef
SM 2-34	3.7	79 d	195 f
Sufaida 172	3.7	78 d	375 abcdef
Tirisurkh 251	5.0	94 abc	309 bcdef
Jhinuwa	5.0	84 bcd	340 bcdef
Sathra 205	4.3	87 bcd	384 abcdef
Sukhwel	7.0	80 d	316 bcdef
Muskhan	2.3	88 bcd	261 cdef
Zirijowaian 245	3.7	80 d	284 bcdef
Siahnakidar 195	4.3	83 cd	246 def
CI 6037-4	3.0	79 d	283 bcdef
S 39 JK 10	5.0	81 cd	353 abcdef
MP 97	3.0	84 cd	335 bcdef
76 S	4.3	79 d	270 cdef
18	7.0	88 bcd	285 cdef
39	5.0	95 ab	545 ab
78	6.3	87 bcd	463 abcd
24 A	5.7	84 bcd	234 ef
180	5.7	89 abcd	457 abcd
213 B	3.7	88 bcd	435 abcde
267	3.7	86 bcd	489 abc
293	3.7	91 abcd	251 def
IR2035-117-3 (R check)	4.3	49 e	30 h
TN1 (S check)	9.0	100 a	629 a

[a]Av of five replications; determined at 15 DI. [b]Av of five replications; counted at 30 DI.

Table 15. Damage rating, nymphal survival, and population growth of the WBPH on varieties with the *Wbph* 2 gene for resistance. IRRI, 1982.

Variety	Damage rating (9 DI)	Survival[a] (%)	Population growth[b] (per five females)
ARC 10239	4.3	73 cd	481.8 a
Cheriya chittari	2.3	30 f	41.8 c
Chempan	1.0	41 f	47.0 c
Sinnanayan	5.0	89 b	760.4 a
ARC 13340	9.0	91 b	639.4 a
MGL 1	5.7	86 bc	463.2 a
BAM 3	2.3	61 de	201.0 b
IR2035-117-3 (R check)	1.7	47 ef	31.8 c
TN1 (S check)	9.0	100 a	629.8 a

[a]Av of five replications; determined at 15 DI. [b]Av of five replications; counted at 30 DI.

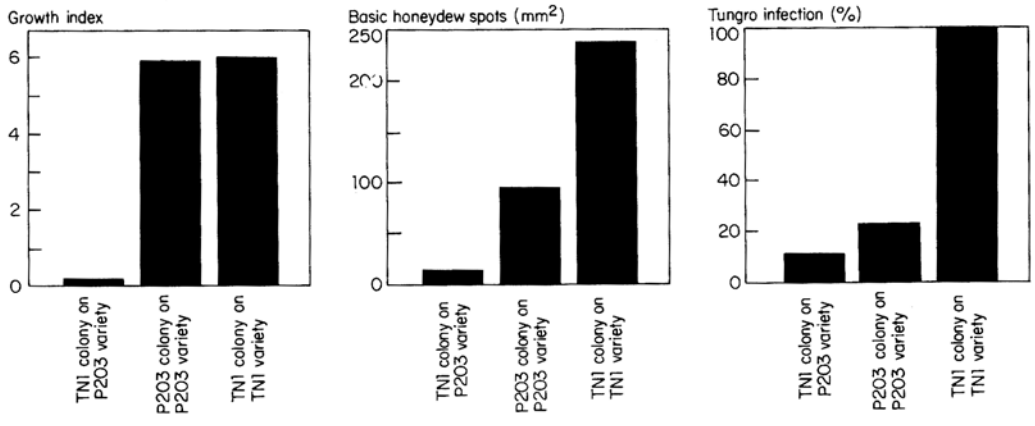
Table 16. Honeydew excretion by viruliferous GLH and RTV infection in rice varieties. IRRI, 1982.

Variety	Level of GLH resistance	Area of honeydew spots (mm^2)	Honeydew excretion (% of spots)			RTV infection (%)
			Acidic (xylem)	Acidic + basic (xylem + phloem)	Basic (phloem)	
IR22	S	228 a	0	60	40	99 a
IR8	MR	187 b	51	41	8	78 b
IR24	MR	179 b	48	43	9	71 b
IR40	MR	172 b	57	40	3	43 c
IR29	R	197 ab	90	10	0	14 c

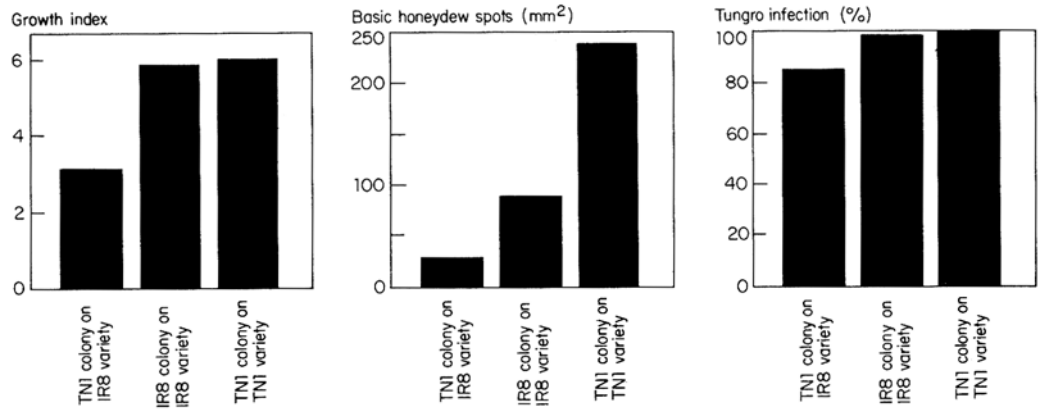
ability of the insects to transmit RTV increased with selection. Biotypes were successfully selected on Pankhari 203 with the *Glh* 1 gene for GLH resistance, IR8 with the *Glh* 3 gene, Ptb 8 with *glh* 4 gene, TAPL #796 with the *Glh* 6 gene, and Moddai Karuppan with the *Glh* 7 gene. No biotypes could be selected on ASD 7 with the *Glh* 2 and on ASD 8 with the *Glh* 5 gene.

The biotype selected on highly resistant Pankhari 203 was called the Pankhari 203 colony and the biotype on the moderately resistant IR8, the IR8 colony. Growth of the Pankhari 203 colony on Pankhari 203 and of the IR8 colony on IR8 were equal to that of the TN1 colony on TN1 (Fig. 6, 7). Ability to infest the resistant varieties with RTV also increased somewhat, but less than did insect growth. The increase was apparently related to the increased feeding on the phloem, as indicated by the area of basic honeydew spots produced when feeding over bromocresol green-treated filter paper. The results indicated that, after 19 generations of selection on the highly resistant Pankhari 203, insect growth was equal to that on a susceptible variety. The amount of phloem feeding (rather than xylem) and subsequent RTV transmission increased but lagged behind the increase in insect growth. In moderately resistant IR8, phloem feeding again lagged behind the increase in insect growth. RTV infection on Pankhari 203 increased from 14% in the TN1 colony to 23% in the Pankhari 203 colony. Continuing studies will indicate whether phloem feeding and subsequent RTV infection will continue to increase after further selection on Pankhari 203.

Leaf folder resistance. Screening of the germplasm collection for leaf folder resistance began in 1981 and about 80 moderately resistant accessions have been identified. In 1982, varieties were studied to determine why they were resistant. Adult moths, whether or not they were given a choice of varieties, preferred not to oviposit on the resistant varieties. Leaf width and egg number were highly correlated.



6. GLH growth index, area of basic honeydew spots on filter paper, and RTV infection caused by the feeding of the Pankhari 203 insect colony on Pankhari 203 and the TN1 colony on Pankhari 203 and TN1. IRRI, 1982.



7. GLH growth index, area of basic honeydew spots on filter paper, and RTV infection caused by the feeding of the IR8 insect colony on IR8 and the TN1 colony on IR8 and TN1. IRRI, 1982.

There was no difference in larval survival among the varieties. Only in two varieties was pupa weight lower than in the susceptible check. When given a choice of varieties, they least preferred the resistant varieties, on which feeding damage was lowest as indicated by the area of leaf scraping and feces weight. Resistance apparently involves the moth's nonpreference for oviposition and the larva's nonpreference for feeding as well as a reduced feeding rate.

Rice susceptibility to storage insects. In 1982, rice varieties were evaluated for resistance to storage insects for the first time. Varieties were tested against the major rice grain pests, the Angoumois grain moth (AGM) and the lesser grain borer (LGB).

Susceptibility of IR varieties. The AGM susceptibility index of 23 IR varieties was determined on the basis of the number of emerging F_1 adults (F) and the mean developmental period in days (D):

$$\text{Susceptibility index} = \frac{\text{Natural log } F}{D} \times 100$$

The susceptibility indices differed significantly among the IR varieties. IR50 was the most susceptible and IR42 and IR46, the least susceptible (Table 17). Grain weight loss due to AGM infestation was highest in IR50 and lowest in IR42 and IR46.

Effect of different grain qualities. Varieties with different chemical characteristics such as amylose content, gel consistency, and percentage of milled-rice protein were evaluated for their AGM and LGB resistance. No correlations were found.

INHERITANCE OF RESISTANCE

Plant Breeding and Entomology Departments

Whitebacked planthopper. Inheritance and allelism of genes for resistance to WBPH in 21 resistant rice varieties were studied. One-leaf-stage seedlings were artificially infested in the greenhouse with second- and third-instar WBPH nymphs. Reactions of the seedlings were recorded 7-10 DI, when the susceptible check, TN1 had already been killed.

Study of the mode of inheritance from the F_1, F_2, and F_3 populations of the crosses of test varieties with TN1 revealed single dominant genes confer resistance in S. 2204, RDS 19, Toga 378, JKW 141, Gokhue Saier, Dharia, Faram Bajari, Karmuli, Kashi Prasad, Munji 389, Lal Dhan 304 (A), Safed, 357, Lal Dhan 304 (B), Ratua 394, and Nakhi. Two independent dominant genes governed resistance in Early Sutarsar 39, C.I. 6008-1, Son 14, C.I. 6010-1, and JKW S18.

Test varieties were crossed with IR13475-7-3-2, homozygous for *Wbph* 1, and IR30659-2-165, homozygous for *Wbph* 2, to determine allelic relationships. Genetic analysis of F_1, F_2, and F_3 populations from these crosses revealed that single dominant genes in RDS 19, Toga 378, JKW 141, Gokhue Saier, Dharia, Faram Bajari, Karmuli, Kashi Prasad, Munji 389, Lal Dhan 304 (A), Safed, 357, Lal Dhan 304 (B), Ratua 394, and

Table 17. AGM susceptibility of IR varieties and grain weight loss due to AGM infestation.[a] IRRI, 1982.

Variety	Susceptibility[b] index	Grain wt loss[c] (g)
IR5	3.56 cd	0.76 cdefg
IR8	1.87 efg	0.62 efg
IR20	2.25 efg	0.50 fg
IR22	1.61 fg	0.44 g
IR24	2.76 def	0.70 defg
IR26	1.98 efg	0.46 g
IR28	1.94 efg	0.58 efg
IR29	3.86 cd	1.28 ab
IR30	5.25 b	1.38 a
IR32	2.01 efg	0.60 efg
IR34	1.80 efg	0.64 efg
IR36	3.64 cd	0.98 cd
IR38	2.88 de	0.72 defg
IR40	4.47 bc	1.06 bc
IR42	1.32 g	0.46 g
IR43	3.41 cd	0.82 cdef
IR44	2.02 efg	0.72 defg
IR45	2.92 de	0.86 cde
IR46	1.32 g	0.46 g
IR48	4.26 bc	1.34 ab
IR50	7.52 a	1.52 a
IR52	1.96 efg	0.64 efg
IR54	1.87 efg	0.64 efg

[a]Averaged over five replications. [b]Susceptibility index is significantly correlated with the loss of grain weight. r = 0.922. [c]Per 30 g weight prior to the test.

Nakhi are allelic to *Wbph* 1, but the dominant gene of S. 2204 is independent of and nonallelic to both *Wbph* 1 and *Wbph* 2. The two independent dominant genes governing resistance in C.I. 6008-1 are *Wbph* 1 and *Wbph* 2. However, resistance in Early Sutarsar 39, Son 14, C.I. 6010-1, and JKW S18, is governed by *Wbph* 1 and an unknown independent dominant gene.

Genes for insect resistance. Six genes for BPH resistance and seven for GLH resistance have been identified (Table 18). Several of these genes have been incorporated into varieties that effectively control these pests over thousands of hectares. Four genes for WBPH resistance have been identified and are being utilized in the breeding program.

BIOCHEMICAL BASIS FOR STRIPED STEM BORER RESISTANCE

Chemistry and Entomology Departments

Compound A, the oviposition deterrent to striped stem borer (SSB), identified from the volatile oil of TKM6 rice plants, was assayed in steam distillate

Table 18. Genes for insect resistance identified through 1982.

Insect	Genes identified (no.)	Designation
BPH	6	*Bph 1, bph 2, Bph 3, bph 4* plus two unnamed genes.
GLH	7	*Glh 1, Glh 2, Glh 3, glh 4, Glh 5, Glh 6, Glh 7*
WBPH	4	*Wbph 1, Wbph 2, Wbph 3, wbph 4*

of selected resistant rice samples and Rexoro (susceptible check) and nine wild rice samples. Analysis by gas chromatographic fractionation on 1.5% Carbowax 20M on Chromosorb W and verification on 3% OV17 on Chromosorb W showed that leaf, leaf sheath, stem, and grain fractions of 60-d-old plants all contained compound A. Volatile oil from the leaf blades and leaf sheaths of these rices showed various levels of compound A, but some rice plant parts with low levels still maintained the biocidal effect on first-instar SSB larvae of TKM6 (Table 19). The nine wild rices (four *O. minuta*, four *O. officinalis*, and one *O. punctata*) had no compound A in their plant volatiles, but a few were still toxic to SSB. This suggests that other compounds may also be involved in SSB resistance.

CYTOLOGICAL VARIATIONS AMONG BROWN PLANTHOPPER BIOTYPES 1, 2, AND 3

Entomology Department

Cytological studies of meiotic chromosomes of BPH biotypes 1, 2, and 3, maintained as stock cultures at IRRI for several years, revealed that meiosis I was reductional and meiosis II equational for all the components of the species' genome.

Investigations used primary spermatocytes of newly emerged brachypterous males to characterize the nuclei and chromosomes and to determine their morphometrics and behavior during the sequential stages of the first meiosis.

Salient variations in nuclear and chromosomal measurements of biotypes 1, 2, and 3 during substages of *prophase I* are shown in Table 20.

Chromosomal behavior during *metaphase I* featured clumping or clustering of highly condensed

Table 19. Compound A content and biocidal activity of volatile oil on first-instar SSB larvae on selected cultivated and wild rices. IRRI, 1982.

Rice sample or cultivar	Compound A content (mg/kg fresh wt)	Mortality of SSB larvae after 48 h[a] (%)
Rexoro	2.2	20
TKM6	8.8	75
IR1514A-E666[b]	11.8	65
IR1820-52-2-4-1[c]	1.3	65
O. minuta accession	0.0	65
O. officinalis accession	0.0	60
Control (diethyl ether)	0.0	10
LSD (5%)	0.6	27

[a]Oil from 50 g plant fresh wt/ml diethyl ether. [b]IR127-80-1/TKM6. [c]IR24/Mudgo/IR8/Peta[4]/TN1//Tetep.

and shortened autosomes at the equatorial portion of the reproductive cell and separation of the highly heterochromatic synapsed sex chromosomes from the autosomal grouping. Noteworthy variations during *metaphase I* in the three biotypes were:

- The highest number of *metaphase I* cells was detected from biotype 1 followed by biotype 3.
- Biotypes 1 and 3 revealed two types of metaphase I cells — cells with sex chromosomes isolated from autosomes and cells with both chromosome types grouped together. Biotype 2 showed only the first type.
- The average distance of the sex chromosomes from autosomal grouping was highest in biotype 2, almost twice that in biotype 1.
- More cells with combined autosomes and sex chromosomes were observed in biotype 1 than in biotype 3. Intrachiasmatic and interchiasmatic connections were higher in biotype 1 than in biotype 3 homologues.
- The sex chromosomes of the three biotypes varied in length and width. Biotype 2 had the longest chromosomes; biotype 3 the next longest. Biotype 2 had the widest girth and those of biotypes 1 and 3 had almost equal measurements.

During *anaphase I*, measurements of the chromosome clumps at the two poles of the cells indicated that the lengths and widths of chromosome groupings in biotype 2 were significantly different from those of groupings in biotype 1, but not from those in biotype 3.

At *telophase I*, the groupings of chromosomes at two opposite poles of the cells had almost equal measurements of chromosomal clumps in the three biotypes.

Chromosomal aberrations, such as loose pairings of paired homologous bivalents as well as fragmen-

Table 20. Variations[a] in nuclear and chromosomal measurements of BPH biotypes 1, 2, and 3 during *prophase I*. IRRI, 1981-82.

Prophase I substage	Measurements		
	Biotype 1	Biotype 2	Biotype 3
Leptonema			
Nuclei: *aml* and *amw*[ns]	31.74μm and 26.50μm, highest	29.90μm and 24.00μm, lowest	30.50μm and 24.75μm, intermediate
Zygonema			
Autosomes	no difference	no difference	no difference
Sex chromosome			
Pachynema			
Autosomes *rml*[ns]	11.11 mm, lowest	12.43 mm, intermediate	13.17 mm, highest
Sex chromosomes *rml*	6.50 mm, lowest	9.00 mm, highest	7.00 mm, intermediate
Diplonema			
Autosomes *aml*[b]	5.92μm, lowest	8.08μm, highest	7.08μm, intermediate
Sex chromosome *aml*	7.50μm	5.00μm	5.00μm
Diakinesis			
Chromosomes *aml*[c]	4.35μm, highest	3.77μm, intermediate	3.39μm, lowest

[a]*aml* = absolute mean length, *amw* = absolute mean width, *rml* = relative mean length. ns = not significant at 5% level by analysis of variance and Duncan's multiple range test. [b]Biotype 1 significantly different from biotypes 2 and 3; biotypes 2 and 3 not significantly different from each other at 5% level by analysis of variance and Duncan's multiple range test. [c]Biotype 1 significantly different from biotype 3 but not from biotype 2; biotype 2 not significantly different from biotype 3 at 5% level by analysis of variance and Duncan's multiple range test.

tations or chromosomal deletions, occurred more frequently among biotype-1 individuals, followed by biotype 3.

LEERSIA HEXANDRA AS A WEED HOST FOR THE BROWN PLANTHOPPER

Entomology Department

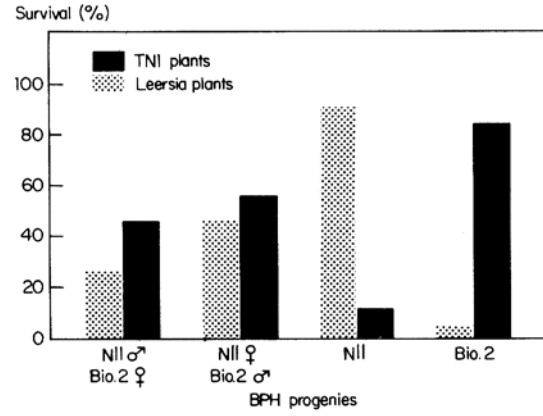
BPH has not been able to complete development and multiply on a host other than cultivated and wild rices, *Oryza* sp. Recently, high BPH populations were observed on a weed, *Leersia hexandra*, in irrigation canals at two locations on the IRRI farm. BPH were collected from the *L. hexandra* plants and greenhouse studies conducted to determine the suitability of *L. hexandra* and rice as a host. The biology of the *Leersia* BPH population was compared with that of greenhouse cultures maintained on rice.

The incubation period of the *Leersia* BPH on *Leersia* plants was 7.8 d; egg hatchability, 81.2%; longevity, 30.0 d; and fecundity, 513 eggs/female. These data compare with those of BPH biotype 1 on susceptible TN1 rice plants. However, when placed on TN1, which is susceptible to the three BPH biotypes at IRRI, and on several resistant varieties, the *Leersia* BPH fed very little and could not survive.

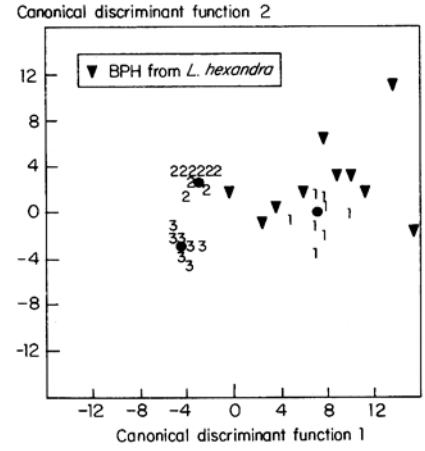
The inability of the *Leersia* BPH to feed on rice plants indicates that the population could not serve as a source of infestation in rice fields. However, it could contribute to the rice-feeding BPH gene pool through interbreeding. An experiment was conducted to determine whether interbreeding between the two populations occurs and to determine the survival of the progeny on *Leersia* and TN1.

Fifth-instar nymphs of *Leersia* BPH were individually placed in test tubes containing *Leersia* cuttings, and a greenhouse culture of BPH biotype 2 and a red form were individually placed in test tubes containing TN1 seedlings. Crosses between the *Leersia* BPH and rice BPH were made by placing insects in cages containing a closely planted mixture of *Leersia* and TN1 plants. When eggs resulting from the crosses hatched, a survival test was conducted by caging 10 newly emerged nymphs on separate potted *Leersia* or TN1 plants.

Survival of the F_1 progeny of all the crosses on both *Leersia* and TN1 (Fig. 8) was high though still



8. Survival of progenies resulting from various crosses between the *Leersia*-infecting BPH (NII) with the BPH biotype 2. IRRI, 1982.



9. Discriminant scores based on rostral, leg, and antennal characters of macropterous females of biotypes of BPH infesting a grass and rice hosts in the Philippines. The numbers indicate biotype designation; the circle indicates a group centroid. IRRI, 1982.

lower than that of the two populations on their regular hosts, i.e. *Leersia* BPH on *Leersia* plants and BPH biotype 2 on TN1. This indicates that if intermating also occurs under field conditions, the *Leersia* BPH can contribute to infestations on rice and introduce genetic variability to the BPH population, possibly slowing the biotype selection process on resistant varieties.

Morphological variations between populations of the brown planthopper infesting rice and *Leersia hexandra*. The BPH population found infesting *L. hexandra* manifested strong specificity for the weed host and individuals died if caged on rice

plants. These biological characteristics of the grass-infesting BPH population clearly differentiated it from the rice-infesting populations of BPH biotypes 1, 2, and 3 in the Philippines.

A study was conducted to determine whether sufficient morphological differences existed to justify the categorization of the grass-infesting population as a separate biotype. The rostrum, legs, and antennae of brachypterous males and females were morphologically and morphometrically evaluated and subjected to the same multiple discriminant analysis used for differentiating biotypes 1, 2, and 3. The scatter plot diagram based on computed discriminant scores of the rostral, leg, and antennal characters of macropterous females of the grass-infesting population and of macropterous females of biotypes 1, 2, and 3 showed distinct segregation (Fig. 9). The same was true for other morphs. However, the diffused cluster character of the grass-infesting population indicated it to be a less homogeneous population than either biotype 1, 2, or 3.

Genetic evaluation and utilization (GEU) program

Nutritional value

Chemistry, Plant Breeding, Agronomy, and Statistics Departments

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Plant Breeding, Agronomy, Statistics, and Chemistry Departments

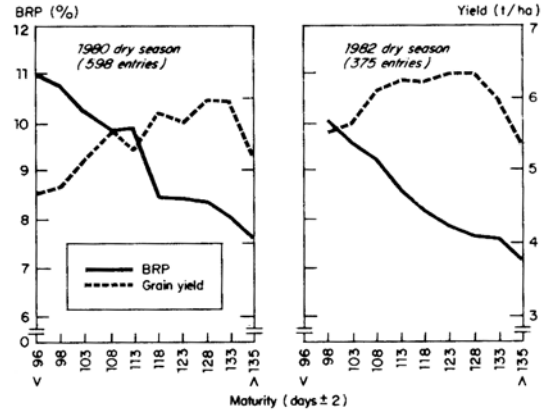
Protein-yield-duration relationships in rice (*Plant Breeding, Agronomy, Statistics, and Chemistry*). Earlier studies on traditional varieties have consistently shown that early-maturing rices tend to have higher grain protein content, but have lower yield than later-maturing varieties. A stùdy of the simple correlation coefficients between brown-rice protein (BRP) and maturity and between BRP and grain yield from replicated yield trials showed negative significant correlations (Table 1). The corresponding partial correlation coefficients were not appreciably nor consistently different. The trend for the protein-duration relationship was simple, as depicted for the 1980 and 1982 DS crops (Fig. 1). By contrast, a reversal of the trend for yield-duration, was observed at longer duration. It seems that the negative correlation between BRP and growth duration may be independent of grain yield.

IR36, a high yielding variety with short growth duration, has about a one percentage point higher BRP than other longer duration IR varieties, such as IR8 and IR42 (Table 2). A more recent promising line, IR9752-71-3-2, which yields similarly to IR36 but matures about 1 wk earlier, had a BRP as high as, and at times higher than, that of IR36. Agronomy fertilizer trials on elite breeding lines showed that the early-maturing lines retained high BRP without losing yield advantage over later-maturity varieties (Table 3). Thus, the development of high yielding early-maturing rice varieties appears to be an effective means of improving BRP.

Table 1. Simple and partial correlation coefficients between BRP and maturity and between BRP and grain yield in replicated yield trials. IRRI, 1978-1982 DS.

Data set	Entries (no.)	Correlation coefficient[a]		Partial correlation coefficient[b]	
		r_{12}	r_{13}	$r_{12.3}$	$r_{13.2}$
1978	361	−0.80**	−0.68**	−0.76**	−0.61**
1979	370	−0.54**	−0.95**	−0.88**	−0.98**
1980	369	−0.96**	−0.83**	−0.86**	−0.13**
1982	347	−0.96**	−0.31**	−0.98**	−0.72**

[a] r_{12} = r between BRP and maturity, r_{13} = r between BRP and grain yield. [b] $r_{12.3}$ = partial r between BRP and maturity, independent of grain yield; $r_{13.2}$ = partial r between BRP and grain yield, independent of maturity.



1. Relationship of BRP and grain yield with growth duration in replicated yield trials. IRRI, 1980 and 1982 DS.

High-protein yield trial (*Plant Breeding and Chemistry*). A yield trial was conducted using 39 high-protein entries from the germplasm bank. Although the entries had high BRP from 10.0 to 15.8%, their rough-rice yields ranged from 0.42 to 3.13 t/ha. Growth duration (from seeding to harvest) ranged from 97 to 105 d. BRP and yield values for four check samples were 10.8% and 3.93 t/ha for IR9752-71-3-2, 10.4% and 2.76 t/ha for IR480-5-9, 11.0% and 2.86 t/ha for IR2153-338-3, and 11.8% and 3.66 t/ha for IR36. Only Se-Hsin-dau approached the yield of the check samples (3.13 t/ha), but had a higher BRP of 13.1%. Yield and BRP were significantly negatively correlated ($r = -0.64^{**}$, $n = 45$). Varieties with more than 14% protein yielded 2 t or less.

Properties of rice mutants (*Chemistry*). Nine mutants of the Japanese variety Kinmaze obtained by treating the fertilized eggs were supplied by the Tissue Culture Laboratory and analyzed for BRP properties. All brown-rice samples had identical sodium dodecyl sulfate (SDS)-polyacrylamide gel electrophoretic patterns of 0.5% SDS − 0.6% β-mercaptoethanol extracts of rice protein showing the major subunits of rice glutelin. Confirmatory protein and lysine analyses showed 6.5-9.8% protein and 3.8-4.9 g lysine/16.8 g N in the mutants, compared with 7.4% protein and 3.7 g lysine/16.8 g N for Kinmaze. The shrunken mutant had 9.8% protein and 4.9% lysine in protein, which may have been due to poor endosperm development and the

Table 2. Yield and BRP of four rices varying in growth duration, from replicated yield trials. IRRI, 1978-1982 DS.

Variety, line	Growth duration (d)	1978	1979	1980	1982	Mean
			BRP (%)			
IR42	131	8.2	8.3	8.8	7.8	8.3
IR8	124	7.1	7.3	7.7	7.7	7.4
IR36	110	8.6	8.5	10.2	8.8	9.0
IR9752-71-3-2	104	8.8	8.6	10.2	9.2	9.2
			Yield (t/ha)			
IR42	131	6.4	6.6	6.4	6.7	6.5
IR8	124	3.4	7.2	3.4	5.4	4.8
IR36	110	6.0	6.9	5.5	6.3	6.2
IR9752-71-3-2	104	5.8	6.9	5.7	6.3	6.2

Table 3. Mean field duration, productivity, and BRP content of three varieties and two early-maturing IR lines, as affected by deep placement of N fertilizer. IRRI, 1980-1982 DS.

Variety[a]	Mean field duration (d)	0 kg N/ha		87 or 108 kg N/ha[b]	
		Grain yield (t/ha)	BRP (%)	Grain yield (t/ha)	BRP (%)
IR8	105	2.8	8.8	4.4	9.2
IR42	107	4.4	8.7	6.2	9.8
IR36	88	3.6	8.1	5.7	9.9
IR9729-67-3	84	4.7	8.2	7.1	9.5
IR9752-71-3-2	82	3.4	8.4	6.3	10.1

[a]Test rices are listed in the order of decreasing field duration. [b]Deep placement as urea supergranule. N rate was 108 kg N/ha in 1980 and 87 kg N/ha in 1981 and 1982.

resulting greater contribution of embryo and bran protein to BRP.

PROTEIN AND ENERGY UTILIZATION

Chemistry Department

Degree of milling and nutritional value. High-fiber diets have been advocated to minimize digestive tract disorders and reduce body weight. However, such a fad may not be justified in tropical Asia where diets are deficient in energy and protein. Because of its higher vitamin content, brown rice has been advocated to be more nutritious than milled rice. A study was conducted on the relative energy and protein utilization of brown and milled rices in preschool children. Completion of the energy analysis of the rice-casein (2:1 N ratio) diets showed energy absorption to be higher in the milled-rice diet than in the brown-rice diet at two levels of protein intake (Table 4). At a daily intake of 200 mg N/kg body weight, fat absorption from the milled-rice diet was better than that from the brown-rice diet. Protein absorption and retention were similar for the brown, undermilled (5% bran-polish removal from brown rice), and milled (9% bran-polish removal) rice diets. Protein utilization was poorer for the experimental diets than for the casein diets.

Because whole milk powder is more commonly used for weaning than casein, and because the earlier study on degree of milling also used whole milk, milk was used for additional studies on brown and milled rices. Mineral mixture was deleted from the diets so the calcium balance could be checked. The differences in protein utilization were still not significant (Table 4).

Nutritional value of "yellow" rice. Earlier studies have shown that "yellow" rice results from heating of unthreshed wet grains awaiting threshing through metabolism of microorganisms on the wet straw. The yellowing is readily simulated in the laboratory by heating wet grains at 60° C or higher. The effect of yellowing on the nutritive value of milled rice was studied using two samples with more than 50% yellow grains from the National Food Authority (NFA) and the IRRI Agricultural Engineering Department. The data were compared with those reported for white milled rice because check samples were not obtainable. Yellow-rice protein had slightly lower lysine content than white-rice protein but their energy contents were the same. The lower lysine content may reflect decomposition

Table 4. Protein, energy, and fat utilization in preschool children fed brown, undermilled, and milled-rice diets with casein or milk (2:1 N ratio). Nutritional Evaluation Laboratory, Food and Nutrition Research Institute, Manila, and IRRI, 1980-1982.

	Apparent value (% of intake)				
	Control diet I	Brown-rice diet	Undermilled rice diet	Milled-rice diet	Control diet II
			250 mg N/kg daily rice-casein in six children		
N absorbed	80.9 a	67.4 b	70.0 b	70.4 b	79.9 a
N retained	33.4 a	36.1 a	37.3 a	36.9 a	34.1 a
Energy absorbed	91.8 a	89.6 b	92.3 a	92.8 a	92.3 a
			200 mg N/kg daily rice-casein in five children[a]		
N absorbed	76.9 a	63.0 b	62.6 b	61.9 b	77.7 a
N retained	32.7 a	28.2 a	25.7 a	27.3 a	38.7 a
Energy absorbed	90.5 b	89.5 b	90.5 b	92.6 a	92.0 ab
Fat absorbed	94.3 ab	93.4 b	95.5 ab	97.6 a	96.1 ab
			200 mg N/kg daily rice-milk in six children		
N absorbed	74.7 a	59.7 b	–	63.3 b	73.2 a
N retained	37.7 a	27.3 a	–	28.9 a	34.2 a
Energy absorbed	90.9 ab	90.1 b	–	92.0 a	90.6 ab
Fat absorbed	94.0 b	94.3 b	–	97.1 a	95.8 b

[a]Four children only for control diets. One child less (three to four children) for fat absorption data.

Table 5. Comparison of composition and energy and N utilization in rats fed yellow milled rice from stack burning of unthreshed panicles and straw with ordinary milled rice. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1981-1982.

Property	Yellow rice		White rice (IR32, H4, and Perurutong)
	IR42 IRRI	IR36 NFA	
Protein (% N X 6.25)	7.0	8.1	8.1-9.7
Lysine (g/16 g N)	3.14	3.24	3.36-3.67
Energy content (kcal/g dry basis)	4.275	4.317	4.252-4.318
Energy content (kJ/g dry basis)	17.89	18.06	17.79-18.07
Balance data in growing rats			
Digestible energy (% of intake)	96.1	95.8	95.6-96.6
True digestibility (% of N intake)	91.8	90.8	97.5-99.2
Biological value (% of absorbed N)	68.0	69.0	65.7-68.4
NPU (% of N intake)	62.3	62.7	65.2-66.7

of protein by heat because lysine is the most sensitive amino acid to thermal treatment. Although digestible energy values were comparable, the yellow rices had slightly lower protein digestibility, which was also reflected in their net protein utilization (NPU) values (Table 5). Yellow rice is slightly inferior to white milled rice.

Effect of parboiling on nutritional value. Although parboiled rice and raw rice had been shown to have comparable NPU, the increasing popularity of pressure-parboiled rice in India led to a study on the effect of prolonged parboiling on the nutritive value of milled rice. The wet heat treatment had no effect on lysine content of protein and on energy content (Table 6). Rat feeding trials showed slightly lower digestible energy and lower protein digestibility for both the parboiled samples of IR8 rice than for its raw sample. But with the compensatory effect of biological value, both parboiled samples had the same NPU as raw rice. Thus prolonged heating, even at 1.05 kg/cm^2 (121° C) to three times the normal steaming period (60 vs 20 min), did not further deteriorate the nutritive value of the milled rice. However, pressure parboiling definitely prolongs cooking time.

Nutritional value of dehulled mungbean. Earlier studies of preschool children on weaning diets of rice and whole mungbean (1/3 of N from mungbean) showed poor energy absorption at N intakes above 200 mg/kg body wt. Because earlier studies using rice and dehulled mungbean diets gave better results, the seed coat was suspected to be the cause of poor energy absorption and increased fecal

Table 6. Effect of degree of parboiling on N and energy utilization of IR8 milled rice in growing rats. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1982.

Property	Raw milled rice (control)		Milled rice from IR8 rough rice parboiled at 1.05 kg/cm^2 for	
	IR32 (1981)	IR8 (1972)	20 min	60 min
Protein content (%)	8.3	7.7	7.2	7.4
Lysine (g/16 g N)	3.55	3.59	3.43	3.69
Energy content (kJ/g)	18.01	–	18.06	17.98
Balance data in growing rats				
Digestible energy (% of intake)	96.6	–	95.2	94.7
True digestibility (% of N intake)	98.4	96.2	89.7	88.6
Biological value (% of absorbed N)	67.5	73.1	78.1	79.5
NPU (% of N intake)	66.4	70.3	70.0	70.4

weight. Confirmatory rat feeding studies were done comparing whole raw beans with dehulled raw beans by toasting and winnowing and by mechanical dehulling of presoaked beans. Analysis showed a decrease in lysine content caused by toasting (Table 7). Mechanical dehulling more effectively reduced phenolics and neutral detergent fiber, but toasting was more efficient in deactivating the trypsin inhibitor.

The rat feeding study showed the improved energy and protein digestibility of mechanically dehulled over whole and toasted mungbean (Table 7). The biological value was higher for whole mungbean protein than for dehulled bean, although digestibility was highest for the mechanically dehulled bean. The resultant NPU was highest for whole mungbean and lowest for toasted mungbean. The poor performance of toasted bean may be due in part to thermal decomposition during toasting, as evidenced by reduced lysine content.

Nutritive value of defatted bran. Defatting of rice bran has been reported to improve the nutritive value of the defatted bran in addition to producing an edible oil if it is extracted from the bran soon after milling. Because heat stabilization to deactivate the fat-hydrolyzing enzyme (lipase) of bran also improves the nutritive value of the bran, a study was conducted on the effect of defatting with refluxing petroleum ether at $\leq 50°$ C on the properties of IR32 and IR42 bran-polish. Removal of the 12-14% fat increased the protein and phytin P content of the samples, but had no significant effect on trypsin inhibitor and neutral detergent fiber content (Table 8). Energy content, as expected, decreased on defatting because of the high caloric value of fat.

Balance data on rats showed a significant drop in digestible energy with defatting, but no change in protein utilization (Table 8). Thus, defatting per se

Table 7. Effect of processing of green mungbean on energy and N utilization in growing rats. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1982.

Property	Whole mungbean	Toasted winnowed mungbean	Dehulled mungbean flour (FNRI)
Crude protein (% N X 6.25)	22.3	25.6	22.6
Lysine (g/16 g N)	6.87	6.03	6.95
Cystine + methionine (g/16 g N)	2.10	2.16	2.02
Phenolics (% as catechin)	0.98	0.31	0.13
Neutral detergent fiber (%)	7.5	6.1	2.0
Trypsin inhibitor activity (% inhibition/mg sample)	38.5 a	7.8 c	21.8 b
Energy content (kcal/g dry basis)	4.485	4.485	4.548
Energy content (kJ/g dry basis)	18.77	18.77	19.03
Balance data in rats			
Digestible energy (% of intake)	82.4 c	85.5 b	93.0 a
True digestibility (% of N intake)	85.2 b	85.3 b	95.2 a
Biological value (% of absorbed N)	62.2 a	52.1 b	53.1 b
NPU (% of N intake)	53.0 a	44.4 c	50.5 b

Table 8. Effect of defatting with refluxing petroleum ether at 50°C on composition and energy and N utilization of IR32 and IR42 rice bran-polish in rats. National Institute of Animal Science, Copenhagen, Demark, and IRRI, 1982.

Property	IR32 bran-polish[a]		IR42 bran-polish[a]	
	Whole	Defatted	Whole	Defatted
Crude protein (% N X 6.25)	13.2	15.1	13.9	15.7
Lysine (g/16 g N)	4.4 a	4.1 b	4.6 a	4.5 a
Crude fat (%)	15.4	1.4	13.5	1.0
Trypsin inhibitor activity (% inhibition/mg sample)	11.0 a	7.7 a	11.3 a	7.8 a
Phytin P (%)	0.66	0.70	1.36	1.48
Neutral detergent fiber (%)	10.5 a	11.2 a	11.1 a	11.2 a
Energy content (kcal/g dry basis)	4.846	4.428	4.886	4.270
Energy content (kJ/g dry basis)	20.28	18.53	20.44	17.87
Balance data in growing rats				
Digestible energy (% of intake)	79.1 b	76.9 c	80.2 a	78.4 b
True digestibility (% of N intake)	85.9 bc	84.7 c	88.1 a	87.0 ab
Biological value (% of absorbed N)	81.1 a	82.2 a	81.9 a	81.8 a
NPU (% of N intake)	69.7 b	69.6 b	72.1 a	71.1 a

[a]Separation of means in a raw by Duncan's multiple range test at the 5% level.

Table 9. Comparative nutrient and energy composition of rice hull and rice straw of IR rices. IRRI, 1982.

Nutrient content	Rice hull		Rice straw[a]	
	IR29	IR32	IR36	IR42
Protein (% N X 6.25)	1.9	1.8	8.6	4.6
Lysine (g/16 g N)	4.4	3.9	5.4	5.5
Crude fiber (%)	36.0	38.3	29.9	30.0
Neutral detergent fiber (%)	89.3	83.9	60.2	58.0
Acid detergent fiber (%)	78.4	80.5	57.7	53.9
Hemicellulose (%)	5.9	3.4	2.5	4.1
Cellulose (%)	36.5	40.6	32.5	29.6
Lignin (%)	16.0	15.4	10.3	5.5
Silica (%)	25.9	24.5	14.9	18.8
Energy content (kcal/g)	3.07	3.12	3.35	3.16
Energy content (J/g)	12.9	13.1	14.0	13.2

[a]Energy and fiber composition data from University of the Philippines at Los Baños.

Table 10. Protein content and lysine content protein of freeze-dried azolla samples. IRRI, 1982.

Azolla sample	Protein content (%)	Lysine (g/16 g N)
A. caroliniana Wild (green)	15.2	5.5
A. caroliniana Wild (red)	14.6	5.6
A. pinnata R. Brown	15.6	4.6
A. pinnata var. pinnata	23.1	5.1
A. filiculoides	22.9	5.2
A. microphylla	33.5	5.4
A. microphylla	22.0	5.4
A. nilotia	20.3	5.5

has no effect on protein utilization of bran-polish, but reduces energy content of the product. The thermal (drying) treatment of bran-polish prior to defatting probably causes the beneficial denaturation of the antinutrition factors, trypsin inhibitor and hemagglutinin, but does not affect the phytate and dietary fiber level of the product.

Nutritive value of rice straw and hull. In view of the interest in rice biomass utilization, comparative protein content and amino acid analysis of rice straw and rice hull was done. Rice hull had lower nutritive value than rice straw on the basis of lower protein content and higher level of undigestible nutrients — crude fiber, cellulose, lignin, and silica (Table 9). Straw protein also was richer than hull protein in lysine, the first limiting essential amino acid.

Si content of the hull of 23 IR varieties from the 1982 DS crop replicated yield trial ranged from 6.19 to 11.3% wet basis and 6.81 to 12.4% dry basis. Mean values were 9.20% wet basis and 10.11% dry basis. Similar wide variation in Si content was observed on straw samples of IR varieties analyzed at University of the Philippines at Los Baños.

Nutritive value of azolla (*with Soil Microbiology*). Samples of water-washed azolla species were obtained from the Soil Microbiology Department, freeze-dried, and analyzed for protein content and amino acid composition. The freeze-dried samples varied in protein (% N X 6.25) content from 14.6 to 33.5% (Table 10). All samples, except *A. pinnata*

R. Brown, were in good amino acid balance and adequate in all essential amino acids. The analysis indicated that the protein of azolla would make it a good nutritive feed for fish in rice fields and for poultry.

Genetic evaluation and utilization (GEU) program

Drought tolerance

Agronomy, Plant Breeding, and Soil Chemistry Departments and International Rice Testing Program

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Agronomy and Plant Breeding Departments

Field screening, 1982 dry season (*Agronomy*). Of the 4,121 rices tested during the 1982 DS field drought screening, 2,617 were rainfed wetland materials from the pedigree nursery and observational and replicated yield trials. The rest were dryland, deepwater, and flood-tolerant germplasm bank accessions, 1981 IRTP materials, hybridization block parents, GEU elite lines, dryland rice breeding lines, rice and rice/sorghum hybrids, and preceding years' drought selections.

After being seeded on 28-29 Jan, the experimental area was sprinkler irrigated every 4-6 d for stand establishment until 6 Mar (36 DAS), after which the soil was allowed to dry. The reaction of individual rices to soil moisture tension (SMT) of 2, 5, and 10 bar was determined using the 1980 SES 0-9 scale (0 = no soil moisture stress effects, 9 = all plants apparently dead). After the scoring at 10 bar SMT, the whole experiment was sprinkler irrigated twice. For drought recovery capacity determination, the 1980 SES 1-9 scale was used (1 = 90% and above of the plants fully recovered, 9 = 0-19% of the plants fully recovered).

The checks were IRAT9 and IR20, earlier identified as drought susceptible, and IR442-2-58 and Salumpikit, drought-tolerant rices.

Twenty-six entries (Table 1) consisting of nine lines from the IRRI pedigree nursery, replicated yield trial, and hybridization block and six accessions from Thailand, five from India, two from Bangladesh, and one each from Brazil, Sri Lanka, Guinea, and Laos, performed better than Salumpikit, the better of two drought-tolerant checks. Line IR13299-96-2-2 and variety Thangone showed high tolerance for 2 and 5 bar SMT. Another 129 rices had drought tolerance and recovery scores

Table 1. Outstanding selections in field screening for drought tolerance. IRRI, 1982 DS.

Designation	Source	Drought score[a] at SMT of			Recovery score[b]
		2 bar	5 bar	10 bar	
IR5178-1-1-4		2	2	4	3
IR10068-11-1		1	2	4	3
IR11185-RRR-18-2		1	2	3	3
IR13299-96-2-2		0	1	5	3
IR13358-16-3-2-3		1	3	4	3
IR21015-196-3-1-3		2	3	4	3
IR21033-58-1-1-2-1-2		1	2	4	3
IR21033-58-1-1-2-1-3		1	3	4	1
IR21313-36-2-2		1	4	4	3
ARC 10372	India	1	2	4	3
BKN7022-6-4	Thailand	1	2	3	1
BKNFR76046-10-2-5-3	Thailand	2	3	4	3
Chamara	Bangladesh	1	3	4	3
Dourado Agulla	Brazil	1	2	4	3
DWCT156-1-B-B	Thailand	1	1	3	3
FRG 2	India	1	2	3	3
Hathili	Sri Lanka	1	3	4	3
Jao Khao	Thailand	2	2	4	3
Jhum Sonalichikon	Bangladesh	1	2	4	3
Leuang Yai 148	Thailand	1	2	4	3
Moroberekan	Guinea	1	3	4	3
NCS 130	India	2	3	4	1
NCS 166	India	1	2	4	1
RD 19	Thailand	1	3	4	1
Thangone	Laos	0	1	4	4
64-117	India	1	3	4	3
IR442-2-58 (T ck)		2	4	6	3
Salumpikit (T ck)	Philippines	1	3	5	3
IRAT 9 (S ck)	Ivory Coast	4	6	9	9
IR20 (S ck)		3	5	8	6

[a]Based on the 1980 SES 0-9 scale. [b]Based on the 1980 SES 1-9 scale.

similar to those of Salumpikit at 10 bar SMT.

Of the 26 outstanding selections, Moroberekan and RD19 had been found drought tolerant in preceding years' tests, indicating the reproducibility of the screening technique (Table 2). RD19, a modern deepwater variety from Thailand, has consistently shown better drought tolerance and recovery capability than Salumpikit. Breeding lines IR11185-RRR-18-2, IR21015-196-3-1-3, and IR21033-58-1-1-2-1-3 showed outstanding drought tolerance in the 1982 DS field screening (Table 1).

Table 2 also presents drought tolerance and recovery scores of modern dryland varieties IR43 and UPL Ri-5, and other rices that performed as well as or better than Salumpikit from 1980 to 1982.

Screening at reproductive stage (*Agronomy*). In 1981, the line source sprinker (LSS) system was used for drought screening of different rice varieties and lines at the reproductive stage. It was found to be unwieldy for such large-scale screening because of wind-irrigation uniformity and experimental design problems. A decision was made to utilize a much simpler, more direct approach.

In 1982, a labor-saving and more manageable trial (whole plot sprinkler irrigation system) gave higher quality data. Four irrigation treatments were applied in separate experiments:

Experiment 1 — 0.35 pan evaporation (E_{pan}) irrigation at flowering (7 Apr-5 May)

Experiment 2 — 0.70 E_{pan} irrigation at flowering stage (7 Apr-5 May)

Experiment 3 — preflowering stage water stress — zero irrigation for 2 wk (17 Mar-2 Apr)

Experiment 4 — irrigation to exceed 1.4 E_{pan} all season.

Each experiment, discrete and managed separately, was replicated four times with randomized complete block design (Fig. 1). There was less experimental variability in genotypic comparisons within an environment. Entry comparison across environments was treated identical to that in the LSS system.

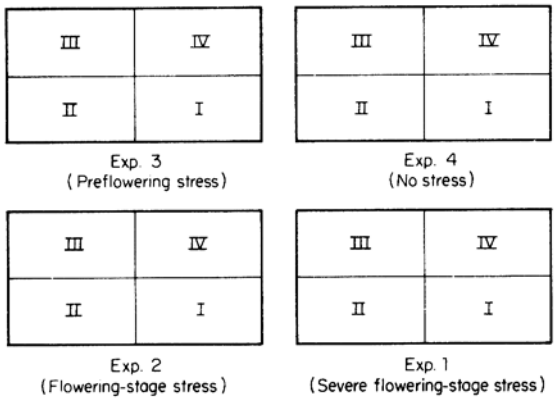
At the end of the stress period, drought tolerance and leaf rolling scores were taken at midday. Flowering dates, canopy temperature, panicle exsertion, yield, and selected yield components were taken as in 1981.

Before the data were analyzed, plots damaged by

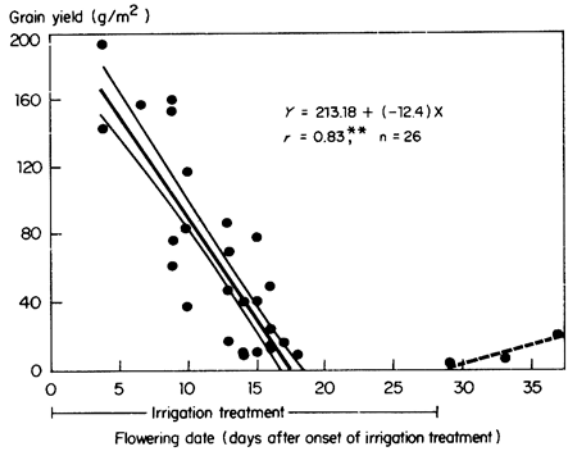
Table 2. Drought tolerance and recovery score of selected rices from field screening. IRRI, 1980-82 DS.

Designation	Origin	Score[a]								
		1980			1981			1982		
		Tolerance at SMT of		Recovery	Tolerance at SMT of		Recovery	Tolerance at SMT of		Recovery
		5 bar	10 bar		5 bar	10 bar		5 bar	10 bar	
IR43		4	7	3	4	6	4	4	6	4
IR52		4	5	3	4	5	3	3	5	3
IR8235-194		3	3	3	3	4	3	3	5	3
IR9266-124		3	3	3	4	6	3	3	5	3
BKN6986-108-2	Thailand	3	5	4	3	5	3	3	6	1
Carreon	Philippines	–	–	–	5	5	3	3	5	4
Kinandang Patong	Philippines	4	5	5	3	5	4	3	5	4
Moroberekan	Guinea	2	5	6	3	5	4	3	4	4
RD 19	Thailand	2	3	3	3	4	3	3	4	1
UPL Ri-5	Philippines	4	5	3	4	7	4	4	6	4
IR442-2-58 (T-ck)		4	6	3	5	6	3	4	6	3
Salumpikit (T ck)	Philippines	4	5	4	3	5	3	3	5	3
IRAT 9 (S-ck)	Ivory Coast	7	8	8	7	8	7	6	9	9
IR20 (S-ck)		6	8	5	6	8	5	5	8	6

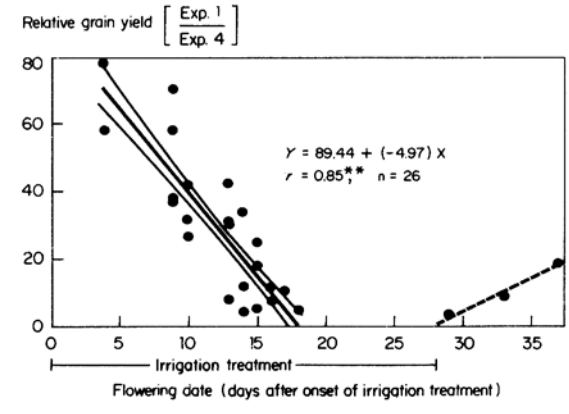
[a]1980 and 1981 data were based on the 1975 SES 1-9 scales for both the tolerance and recovery scores. The 1982 data were based on the 1980 SES scales of 0-9 for tolerance to drought and 1-9 for recovery.



1. Field layout of the reproductive-stage drought tolerance trial with 32 entries conducted during the 1982 DS. A uniform whole-plot irrigation was used on each experiment.



2. Relationship between grain yield and flowering date with regression analysis of genotypic performance. 1982 DS.



3. Relationship between relative grain yield and flowering date with regression analysis of genotypic performance. 1982 DS.

pests or those that escaped drought due to early flowering were discarded. Five yield-related variables (grain yield, relative grain yield, percentage of fertility, panicle exsertion, flowering delay) were regressed against flowering date (number of days to flowering after the onset of irrigation treatment). Each variable was found to be highly correlated with flowering date (Fig. 2-6). Grain yield and percentage fertility, which were regressed against canopy temperature, also showed significant correlation (Fig. 7, 8). Based on the regression results, indices for each yield-related variable were computed using the formula:

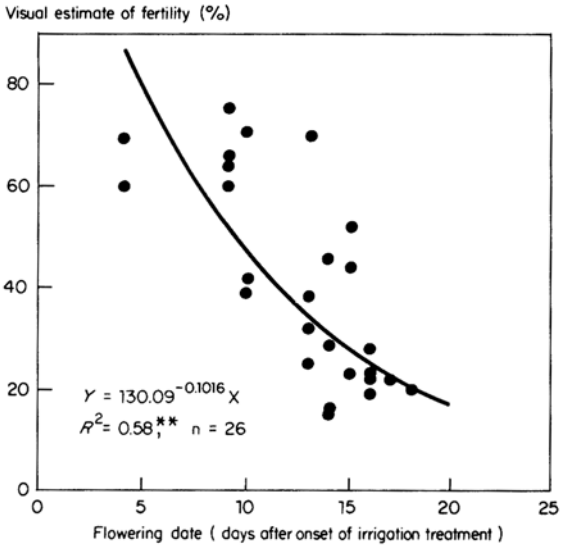
$$\text{Drought index} = \frac{Y - \hat{Y}}{SE_{\hat{Y}}}$$

where:

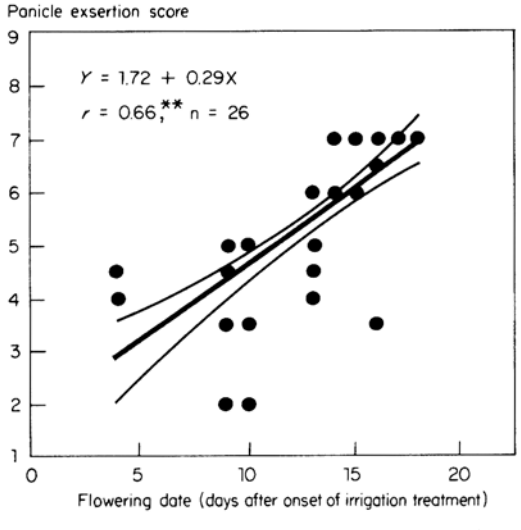
Y = actual yield
$\hat{Y}$ = predicted yield
$SE_{\hat{Y}}$ = standard error of $\hat{Y}$.

A correlation matrix on the indices of the five yield-related variables showed that only grain yield, relative grain yield, and fertility percentage were correlated. The range of index values for relative grain yield and fertility percentage was adjusted to grain yield. This gave equal weight to each of the indices when totaled. The results were compared with the nonadjusted indices and the sum of the numerical ranks of entries. There was little change in the genotype ranking. Because the three methods of summing up the indices gave the same results, using the unadjusted indices or the numerical ranks of each entry was less complicated and more useful. Table 3 shows the genotype rankings based on the sum of the numerical rank of each entry. By either technique, relative grain yield gave the highest correlation with the sum of the indices.

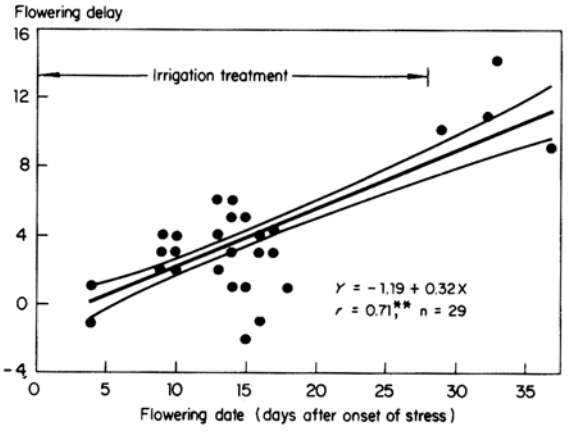
The results suggest that the best data to take for the 1983 drought screening at the reproductive stage (hundreds of lines and varieties) are grain yields of both the stress and the control treatments. Relative grain yield can be computed. Fertility percentage and canopy temperature may be helpful, especially when yield data become unreliable



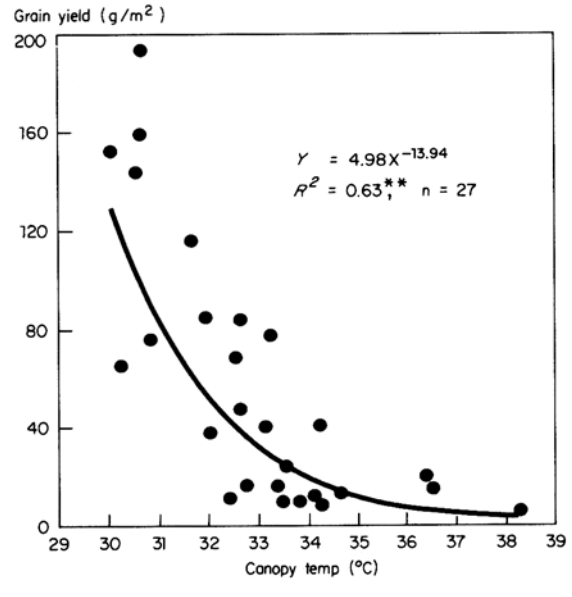
4. Relationship between percent fertility and flowering date with regression analysis of genotypic performance. 1982 DS.



5. Relationship between panicle exsertion and flowering date with regression analysis of genotypic performance. 1982 DS.



6. Relationship between flowering delay and flowering date with regression analysis of genotypic performance. 1982 DS.

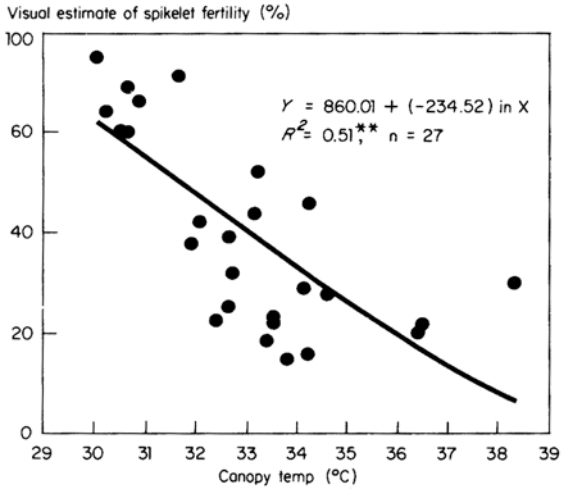


7. Relationship between grain yield and canopy temperature with regression analysis of genotypic performance. 1982 DS.

because of typhoon lodging, diseases, insects, rats, birds, and other problems that may occur after the irrigation treatment has started or when full irrigation is restored in the grain-filling and maturing stages.

Field screening under rainfed-wetland culture (*Plant Breeding*). In the simulated rainfed-wetland experiment of the DS, 752 breeding lines and varieties were scored at the vegetative stage. The drought reactions ranged from 1 to 7 on a 1-9 decimal scale (Table 4). Because of soil heterogeneity, the drought reaction of the susceptible check variety IR20 varied from plot to plot. Inspite of such varied reactions of the check variety, 18.6% of the test entries distinctly showed a high level of drought resistance at the vegetative stage, scoring from 1 to 2.

At the reproductive stage, the decimal scores ranged from 1 to 9 (Table 4). Of the 183 entries, 24% had high scores of 1 to 3. Khao Lo, a tradi-



8. Relationship between spikelet fertility and canopy temperature with regression analysis of genotypic performance. 1982 DS.

Table 3. Genotype rankings based on the sum of the numerical rank of each entry. 1982 DS.

Genotype	RI_1[a]	RI_2[b]	RI_3[c]	Σ	Mean	Overall rank
IR8234-174-3	1	5	2	8	2.7	1
IR9575 Sel.	6	1	1	8	2.7	1
IR52 #1	3	2	4	9	3.0	3
IR9782-111-2-1-2	2	4	9	15	5.0	4
UPL-Ri-5	4	6	10	20	6.7	5
C1064-5	5	12	3	20	6.7	5
IR9752-71-3-2	13	3	4	20	6.7	5
IR9669 Sel.	9	11	6	26	8.7	8
IR52 #2	7	10	12	29	9.7	9
IR8103-120-3	10	8	12	30	10.0	10
IR9995-1-1-1	7	9	21	37	12.3	11
IR43	11	14	16	41	13.7	12
IR5982-7-6-1	14	16	11	41	13.7	12
Salumpikit	15	15	14	44	14.7	14
IR5624-110-2	12	12	20	44	14.7	14
IR6023-10-1-1	20	19	7	46	15.3	16
IR3880-10	17	7	23	47	15.7	17
K. Patong	22	18	8	48	16.0	18
IR3646-8-1-2	16	20	21	57	19.0	19
IR36 #1	18	17	23	58	19.3	20
IR3839-1	19	22	18	59	19.7	21
IET 1444	21	24	14	59	19.7	21
IR20	25	26	16	67	22.3	23
IR7790-18-1-2	26	23	18	67	22.3	23
IR6115-1-1-1	23	21	26	70	23.3	25
IR36 #2	24	25	25	74	24.7	26

[a] I_1 = grain yield. [b] I_2 = relative grain yield index. [c] I_3 = percent fertility index.

tional dryland variety of Laos, and IRAT 142 of West Africa both had a score of 2. This was consistent with the drought reaction observed in previous screenings in dryland culture. KDML65G_1U-45, a mutant selection from Thailand, scored 1, and Sailboro 426 (Acc. 29407) from Bangladesh scored 3. The susceptible check IR20 remained stunted and bore no panicles.

Generally, most of the test entries showing high levels of drought resistance at both the vegetative and reproductive stages were selected from the dryland breeding nurseries or from the GEU nurseries; they have either a dryland breeding line in the parentage or a drought-resistant parent.

A major constraint on screening for field resistance to drought in wetland culture was the seepage of water from neighboring irrigated fields, especially when the plants were under stress.

Field screening under dryland culture (*Plant Breeding*). Screening of the germplasm of *Oryza sativa, Oryza glaberrima,* and the breeding lines selected from the dryland nurseries of IRRI and those of Indonesia, IRAT, and IITA continued. Of 1,615 entries scored at the vegetative stage, 38.9% had scores of 1 to 3 (Table 5). These cultivars showed a wide range of reactions at the vegetative and reproductive stages.

Of 649 accessions and breeding lines evaluated at the reproductive stage, 2.8% scored 1 to 3. Among them were Dular (Acc. 3688) from India, BMT53R3536 (Acc. 1863) from USA, and Dahanala 2014 (Acc. 3469) from Sri Lanka. IRAT144 and IRAT133, which flowered 80 DAS, scored 3 and 4, respectively. Eight *sativa* cultivars, three breeding lines, and five *Oryza glaberrima* strains scored 4 at the reproductive stage. These varieties and lines are early maturing and most likely have the escape mechanism. More refined tests are needed to determine the drought resistance mechanisms involved.

Another 900 accessions included in the screening nursery were not scored because of the soil heterogeneity in the test site.

FIELD EVALUATION OF RAINFED RICES

Agronomy and Plant Breeding Departments and IRTP

Dryland rice yield trial, 1982 wet season (*Agronomy*). During the 1982 WS, dryland rice yield trials with 49 entries were conducted at IRRI; in two farmers' fields at Cuenca and Santo Tomas,

Table 4. Drought reaction of breeding lines and varieties grown in rainfed-wetland culture. IRRI, 1982 DS.

Source	Entries tested (no.)	Reaction[a]								
		1	2	3	4	5	6	7	8	9
					Vegetative phase					
Breeding lines from wetland nurseries	171	–	2	17	20	53	55	24	–	–
Breeding lines from dryland nurseries	157	1	32	59	24	37	4	–	–	–
Hybridization block entries	250	9	48	72	17	52	28	24	–	–
Rainfed-wetland collaborative entries	41		11	21	6	3	–	–	–	–
International Rainfed-Lowland Rice Observational Nursery entries	134	1	36	47	24	19	6	1	–	–
					Reproductive phase					
Breeding lines from wetland nurseries	43	–	–	–	–	4	–	7	1	31
Breeding lines from dryland nurseries	8	–	–	3	–	5	–	–	–	–
Hybridization block entries	80	1	7	22	2	25	–	13	–	10
Rainfed-wetland collaborative entries	13	1	2	6	–	2	–	2	–	–
International Rainfed-Lowland Rice Observational Nursery entries	39	–	1	1	–	10	–	20	–	7

[a]Based on Loresto and Chang (1981) [IRRN 6(2):9-10].

Table 5. Drought reactions of germplasm bank accessions and breeding lines in dryland culture. IRRI, 1982.

Source	Entries tested (no.)	Reaction[a]								
		1	2	3	4	5	6	7	8	9
					Vegetative stage					
Germplasm bank accessions	834	–	1	145	94	332	221	41	–	–
Breeding lines from dryland nurseries	364	92	109	86	47	24	6	–	–	–
Breeding lines from Indonesia	22	4	5	10	1	2	–	–	–	–
Breeding lines from IRAT	41	13	13	6	4	5	–	–	–	–
TOX lines from IITA	120	45	55	10	6	4	–	–	–	–
Oryza glaberrima strains	244	3	14	17	29	66	47	51	6	11
					Reproductive stage					
Germplasm bank accessions	298	1	–	3	8	17	17	44	2	206
Breeding lines from dryland nurseries	6	–	–	–	1	–	2	1	–	2

Continued on next page

Table 5 continued

Source	Entries tested (no.)	Reaction[a]								
		1	2	3	4	5	6	7	8	9
Breeding lines from Indonesia	4	–	–	–	–	–	–	–	–	4
Breeding lines from IRAT	19	–	–	1	2	1	2	1	–	12
TOX lines from IITA	37	–	–	–	–	2	3	7	3	22
Oryza glaberrima strains	285	2	–	11	5	21	11	46	6	183

[a]Based on the decimal scale of Loresto and Chang (1981) [IRRN 6(2):9-10].

Batangas; and in two Philippine Bureau of Plant Industry experiment stations at Ilagan, Isabela, and La Granja, Negros Occidental. Most of the entries were selections from the 1981 and earlier field drought screening tests.

In addition, preliminary yield tests with 16 entries composed of phenotypically acceptable drought selections were conducted at IRRI and the two Batangas sites.

At Santo Tomas, the first (31 May) seeding received relatively adequate soil moisture during the June-September crop season (Fig. 9). At Cuenca, too much rain before seedling emergence resulted in poor germination of the 49 entries in the first (28 May) seeding. The second seeding in Santo Tomas (1 Jul) and Cuenca (8 Jul), both seedings at IRRI (8 Jun and 13 Aug), and the only seedings in Ilagan (4 Jun) and La Granja (8 Jun), encountered moderate to high soil moisture stress (Fig. 9, 10). On 9 Sep, Typhoon Ruping brought 24-h rainfalls of 171 mm at IRRI, 181 mm at Santo Tomas, 270 mm at Cuenca. A dry spell that immediately followed the typhoon caused SMT at 10- and 20-cm soil depths to rise beyond 30 cbar 1 wk later and to remain high into early November (Fig. 9). In Cuenca, SMT remained low at the 20-cm depth in late September, but it went beyond 30 cbar for 1 and 2 wk at the 10-cm depth in late October to early November.

Grain yield data were obtained from the 28 May and 8 Jul seedings at Cuenca, the first (31 May) seeding at Santo Tomas, and the only (8 Jun) seeding at La Granja (Table 6). Dry spells caused complete sterility at the other sites and dates.

Drought reactions during the vegetative stage were recorded in Cuenca, La Granja, and Ilagan (Table 7). Soil moisture stress prolonged growth duration by 9 d in IR19728-9-3-2 and by 21 d in IR9814-11-3. The dry spells greatly depressed plant height, as shown by a comparison of the mean plant height column with the Santo Tomas (31 May) seeding plant height column in Table 7.

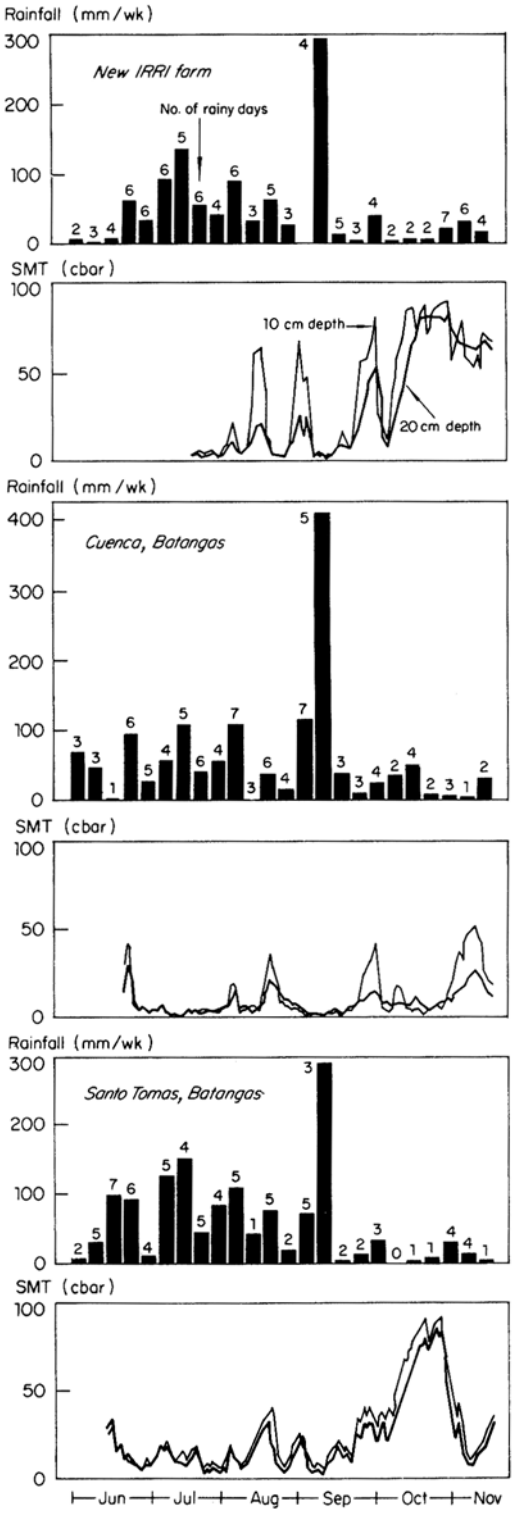
IR9782-111-2-1-2 produced the highest yields in Santo Tomas (4.4 t/ha) and in Cuenca (3.5 t/ha) and was the only line with a mean yield higher than 3 t/ha and 0.5 t/ha higher than that of the better yielding check, IR43 (Table 6). It matured 10 d earlier and showed greater vegetative growth drought tolerance than IR43 and UPL Ri-5 (Table 7). Its semidwarf stature, however, renders it unacceptable to dryland rice farmers whose main problem is weed management.

The better entries in the preliminary yield test, except IR3839-1, which was favorably 10 d earlier, and IR18189-42-2-3, which was 10 d later, were similar to IR43 and UPL Ri-5 in grain yield and growth duration (Table 8). Their plant height and other phenotypic expressions promise better weed competitiveness than those of IR43.

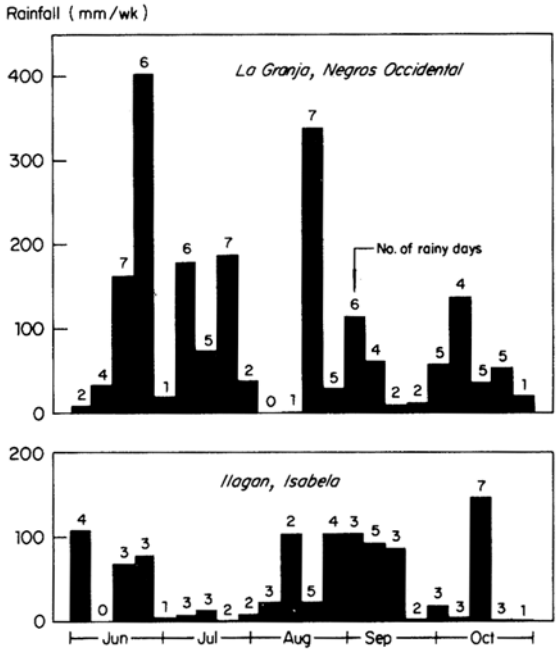
The prominent disease was brown spot in Santo Tomas and sheath blight in Cuenca (Table 7).

The results confirm the importance of uniform rainfall distribution for successful dryland rice production. In Cuenca, rice should not be deep seeded (the practice is seeding 5 cm on dry soil) when successive rainy days are expected.

Integrated performance trials for rainfed-shallow drought-prone environments (*Agronomy, Plant Breeding, and IRTP*). Identification of rices with traits for adaptation to drought-prone shallow rainfed conditions continued at three sites in the Philippines. Testing in rainfed sites outside of IRRI has been conducted since 1979. The 1982 combined trial of 75 entries was composed of



9. Weekly rainfall distribution and resulting SMT at new IRRI farm and Batangas sites. 1982 WS.



10. Weekly rainfall in Ilagan, Isabela, and La Granja, Negros Occidental, Philippines. 1982 WS.

advanced lines from the IRRI breeding program, several lines from Thailand, and the entries from the 1982 International Rainfed Lowland Rice Yield Nursery (IRLRYN).

Conditions at the three sites presented a wide range of stress environments. Liloan, Cebu, which has a marginal wetland rice environment with low rainfall of variable frequency in most years, had a prolonged drought during the 1982 WS, which delayed planting until August. Rainfall during the growing season was inadequate to maintain standing water except for limited periods during the vegetative phase (Fig. 11). By the onset of flowering, the subsurface water table was falling, and the field had no impounded water throughout the reproductive phase. The low soil matric potentials that were induced (Fig. 11) resulted in severe moisture stress, reducing the average grain yield for the trial to 1.2 t/ha. The earlier maturing genotypes were not as severely affected by moisture stress as the late-maturing types (Fig. 12). A significant negative linear relationship was observed between days to flowering and grain yield.

Drought tolerance scores were taken using the 1980 SES 0-9 scale during a severe drought period at the panicle initiation stage. Final yield was

Table 6. Yield of selected rices in a yield test in dryland condition at three locations in the Philippines. 1982 WS.

Designation	Yield (t/ha)				
	Cuenca		Santo Tomas	La Granja	Mean
	28 May	8 Jul	31 May	8 Jun	
Early maturing					
IR9782-111-2-1-2	2.3	3.5[a]	4.4[a]	3.1	3.32
IR9101-37-1	2.1	2.7	3.7	2.8	2.82
IR19728-9-3-2	1.7	2.6	4.1	2.9	2.82
IR7790-18-1-2	2.3	2.1	4.0	2.8	2.80
IR9209-262-1-3-1	2.1	2.1	3.8	3.0	2.75
IR9814-11-3	2.3	3.0	3.9	1.8	2.75
IR5931-110-1	2.0	2.7	3.7	2.2	2.65
IR19743-25-2-2	1.8	2.9	3.2	2.6	2.62
IR8608-3-2-2-3	1.9	2.4	4.1	2.1	2.62
IR19735-5-2-3-2-1	1.4	2.5	2.0	3.5[a]	2.35
Late maturing					
IR9560-2-6-3-1	3.0[a]	2.3	3.9	2.5	2.92
IR13149-23-2	2.5	–	3.7	2.6	2.90
IR43 (yield check)	2.8	2.4	4.0	2.0	2.80
B44b-50-2-2-5-1-1	2.7	–	2.8	2.8	2.77
IR9995-96-2	2.2	3.3	3.2	1.6	2.58
UPL Ri-5 (yield check)	2.6	2.3	2.6	2.7	2.55
Drought checks					
IR442-2-58 (T)	2.0	1.9	1.8	2.3	2.00
Salumpikit (T)	2.8	1.6	1.6	1.6	1.90
IR20 (S)	1.7	1.9	2.8	1.3	1.92
IRAT 9 (S)	1.2	2.1	3.0	2.6	2.22
Test mean	1.96	2.23	3.01	2.08	2.32

[a]Highest yield within site or date.

Table 7. Mean yield at three locations and other agronomic characteristics in four locations of selected rices in a yield test in dryland condition in the Philippines. 1982 WS.

Designation	Yield (t/ha)	Heading range (DAS)	Plant height (cm)		Panicles (no./m^2)	Drought reaction[a]			Important diseases[b]
			Santo Tomas, seeded 31 May	Mean		Cuenca	La Granja	Ilagan	
Early maturing									
IR9782-111-2-1-2	3.3	83-99	82	71	368	3	3	2	BS
IR9101-37-1	2.8	78-90	89	79	307	3	3	2	BS, LSm
IR19728-9-3-2	2.8	72-81	89	75	285	3	2	3	–
IR7790-18-1-2	2.8	83-105	94	83	294	3	2	5	BS, LSm
IR9209-262-1-3-1	2.8	78-99	82	72	304	3	3	5	BS, ShB
IR9814-11-3	2.8	84-103	90	82	278	5	2	2	ShB
IR5931-110-1	2.6	85-102	106	89	281	3	4	3	–
IR19743-25-2-2	2.6	72-84	76	71	334	3	2	3	BS, ShB
IR8608-3-2-2-3	2.6	81-99	89	74	311	3	2	2	BS, LSm
IR19735-5-2-3-2-1	2.4	74-84	80	68	338	3	3	3	BS, FSm, LSm, ShB
Late maturing									
IR9560-2-6-3-1	2.9	100-113	88	76	285	3	2	2	BS, LSm
IR13149-23-2	2.9	100-118	85	75	270	3	3	3	ShB
IR43 (yield check)	2.8	93-111	87	77	273	3	2	4	LSm, ShB
B44b-50-2-2-5-1-1	2.8	104-118	95	88	199	4	2	3	–
IR9995-96-2	2.6	95-116	90	82	294	3	2	2	LSm

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Table 7 continued

Designation	Yield (t/ha)	Heading range (DAS)	Plant height (cm)		Panicles (no./m²)	Drought reaction[a]			Important diseases[b]
			Santo Tomas seeded 31 May	Mean		Cuenca	La Granja	Ilagan	
UPL Ri-5 (yield check)	2.6	94-110	117	100	241	3	4	3	–
Drought checks									
IR442-2-58 (T)	2.0	96-110	91	84	260	3	2	4	Bl, ShB
Salumpikit (T)	1.9	87-102	137	124	266	3	1	2	LSm, ShB
IR20 (S)	1.9	93-112	93	79	262	7	4	5	BS, LSm
IRAT 9 (S)	2.2	84-99	86	77	298	3	1	6	ShB

[a]1980 SES 0-9 scale for drought tolerance. [b]Disease reaction of higher than 5 using 1980 SES 0-9 scale where 0 = no disease incidence and 9 = severe infection. Bl = blast, BS = brown spot, FSm = false smut, LSm = leaf smut, ShB = sheath blight.

Table 8. Performance in a preliminary yield test of phenotypically acceptable drought-tolerant rices, Cuenca and Santo Tomas, Batangas. 1982 WS.

Designation	Grain yield (t/ha)			Heading (DAS)		Phenotypic acceptability[b]	Plant height (cm)	Panicles (no./m²)	Important diseases[c]
	Cuenca	Santo Tomas	Mean	Cuenca	Santo Tomas	Cuenca	Mean	Mean	
IR43 (check)	3.8[a]	4.0[a]	3.9[a]	106	96	5	84	235	ShB
IR18189-42-2-3	4.3[a]	3.3[a]	3.8[a]	117	106	3	106	270	–
IR3839-1	3.3	3.9[a]	3.6[a]	96	84	4	96	259	–
UPL Ri-5	4.1[a]	2.9[a]	3.5[a]	105	95	3	109	183	–
IR18599-68-2-1	3.7	3.2[a]	3.4[a]	107	96	4	89	293	ShB
IR21442-44-3	3.6	2.9[a]	3.2[a]	102	89	4	93	277	ShB
Kinandang Patong (local ckeck)	2.9	2.0	2.4	99	91	6	142	155	FSm
Mean	3.25	2.70	2.98						

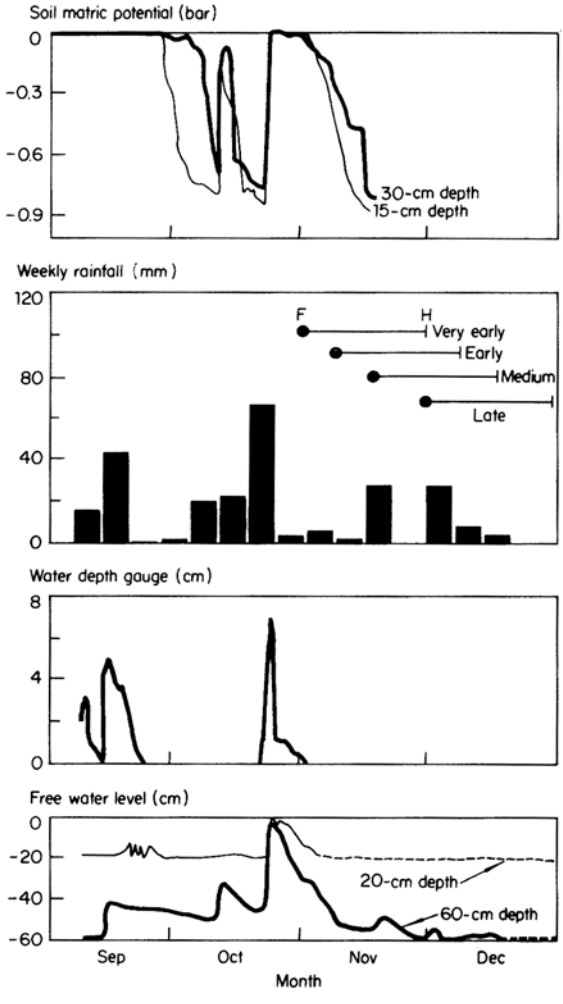
[a]Better than Kinandang Patong at P = 0.05 by Duncan's Multiple range test. [b]Based on the 1980 SES 1-9 scale where 1 = excellent, 9 = not acceptable. [c]Disease reaction higher than 5 where 0 = no disease incidence, 9 = severe infection. ShB = sheath blight, FSm = false smut.

highly and negatively correlated with the drought scores (Fig. 13). Scores ranged from 1 to 8 and grain yields varied from less than 0.5 t to more than 2.5 t/ha.

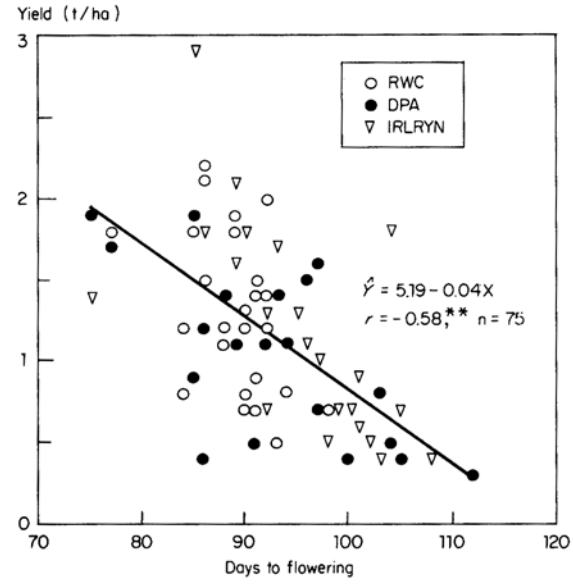
The IRRI trial was planted on a well-drained location on the new IRRI farm. The field retained impounded water until the flowering stage of the early maturing lines, except for brief periods (Fig. 14). The reproductive phase was characterized by a declining water table and gradual reductions in soil matric potential, accelerating in intensity during the grain-filling period. Yields were generally affected by the moisture stress conditions, but the average yields (2.1 t/ha) were higher than in Cebu.

Hydrological conditions at the Guimba site in central Luzon, 300 km north of IRRI, were very favorable (Fig. 15). Rainfall was uniformly distributed throughout the growing season. Although the fields retained no standing water late in the season, the water table level stayed at or near the surface until harvest was nearly completed. Soil matric potentials remained near zero all season. With these conditions average grain yields of 4.7 t/ha were produced, causing the site to serve as a measure of yield potential with favorable conditions. Insects and diseases were not significant problems. The water regime was the major differentiating variable among locations.

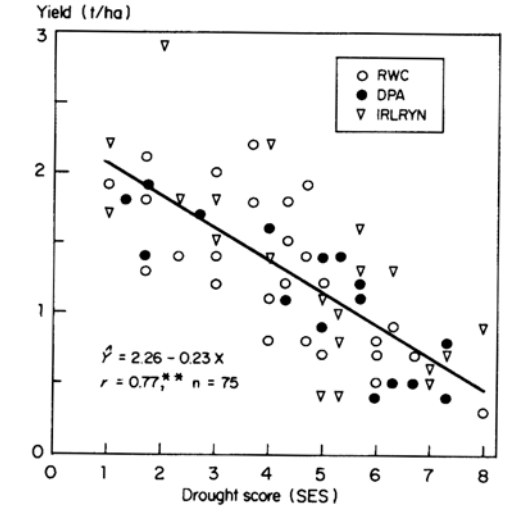
The performance of the top 13 genotypes in each of the three groups is shown in Table 9. Cebu is emphasized as the discriminating environment for performance and the cultivars are listed in their



11. Soil matric potential (15- and 30-cm depth), water level in the field (piezometer at 20 cm) and below the field (piezometer at 60 cm), field water depth, and rainfall, Liloan, Cebu, Philippines. 1982 DS.



12. Relationship between grain yield and days to flowering with regression analysis of genotypic performance. Liloan, Cebu, 1982 WS. RWC = rainfed wetland culture nursery, DPA = drought-prone area nursery.

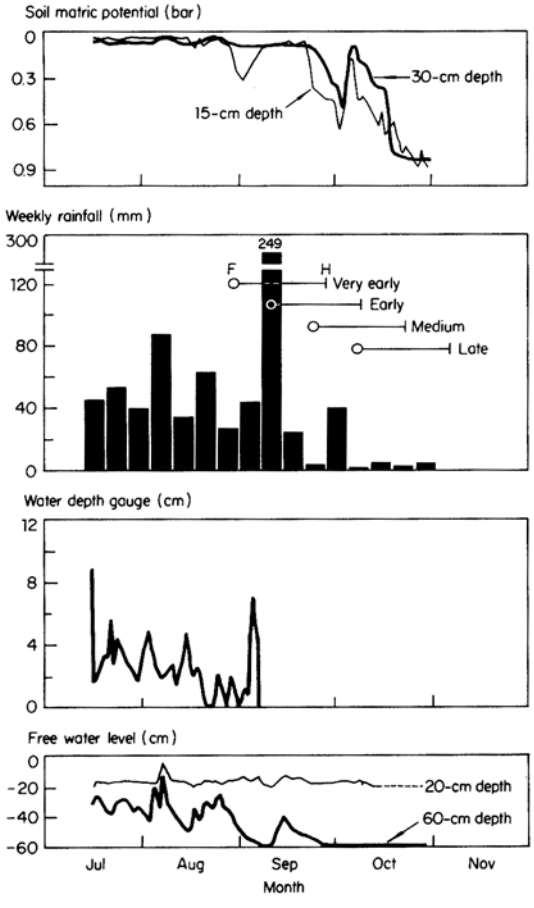


13. Relationship between grain yield and drought tolerance score at panicle initiation with regression analysis of genotypic performance. Liloan, Cebu, 1982 WS. RWC = rainfed wetland culture nursery, DPA = drought-prone area nursery.

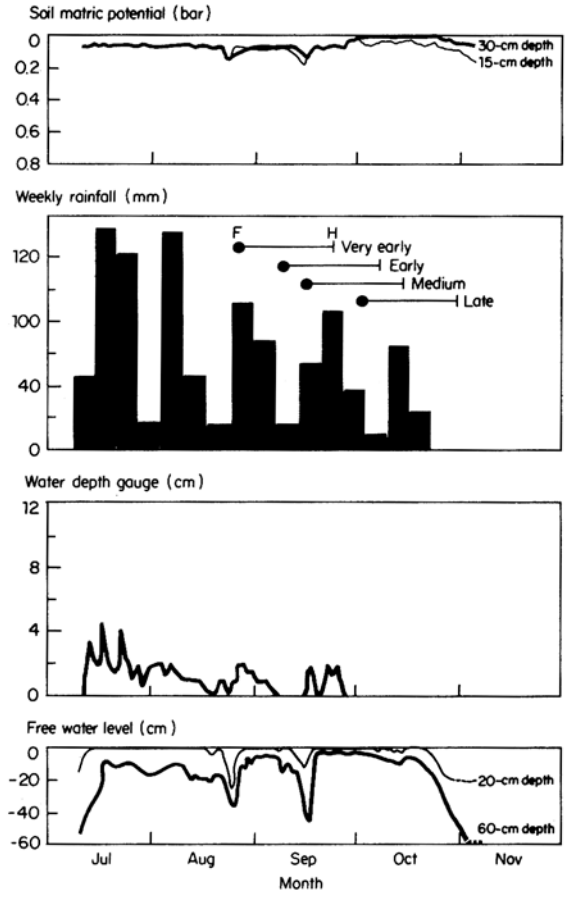
rank order because the moisture stress was most severe at that site. Statistical comparisons among the lines within each group were made using the group balanced block design.

The lines with the highest yields, or those whose yields were statistically on par with the highest in Cebu while statistically on par with the highest at IRRI and in Guimba, were considered superior for drought conditions.

The entries in group 1 tended to be the highest yielders in Cebu. However, their mean yields across all environments were considerably lower than the averages of groups 2 and 3, suggesting greater adaptation to severe stress environments but relatively lower capacity to respond in more favorable conditions. These materials tended to be taller than the entries in groups 2 and 3, and to include some lines with outstanding performance in northeastern Thailand (e.g. Khao Dawk Mali 105, Nam Sagui 19, and KDML65-GU-45-45).



14. Soil matric potential (15- and 30-cm depth), water level in field (piezometer at 20 cm) and below the field (piezometer at 60 cm), field (piezometer at 60 cm), field water depth, and rainfall, IRRI, Los Baños, Laguna, Philippines, 1982 WS.



15. Soil matric potential (15- and 30-cm soil depth), water level in field (piezometer at 20 cm) and below the field (piezometer at 60 cm), field water depth, and rainfall, Guimba, Nueva Ecija, Philippines, 1982 WS.

Table 9. Summary of grain yields and plant characters for the top 13 entries in each group of the integrated performance trial for rainfed shallow drought-prone environments. IRRI, 1982.

Designation	Yield (t/ha)			Overall				Drought score[a] (Cebu)
	Cebu	IRRI	Guimba	Mean yield (t/ha)	Rank	Plant height (cm)	Days to flowering	
Group 1. Rainfed wetland culture nursery								
IR3179-25-3-4	2.2 a	1.8 abc	4.8 abc	2.9	2	104	87	3.7
IR10110-24-1	2.1 ab	2.2 abc	3.8 bcdef	2.7	8	125	60	1.7
IR8997-4-18-1	2.0 ab	2.0 abc	4.2 abcd	2.7	6	113	94	3.0
BPI-76 N. S.	1.9 abc	1.9 abc	4.3 abcd	2.7	9	115	93	1.0
Nam Sagui 19	1.8 abcd	1.4 cd	2.4 gh	1.9	22	133	89	1.7
KDML65-GU-45-45	1.8 abcd	0.8 d	2.3 h	1.6	25	127	100	3.7
KKN7205-39-3-SKN-1-1-1	1.8 abcd	2.1 abc	4.1 abcde	2.7	10	102	92	4.3
IR5931-110-1	1.5 abcde	1.7 abcd	5.1 ab	2.8	4	101	84	4.3
IR13754-5	1.5 abcde	1.9 abc	5.4 a	2.9	3	116	93	3.0

Continued on next page

Table 9 continued

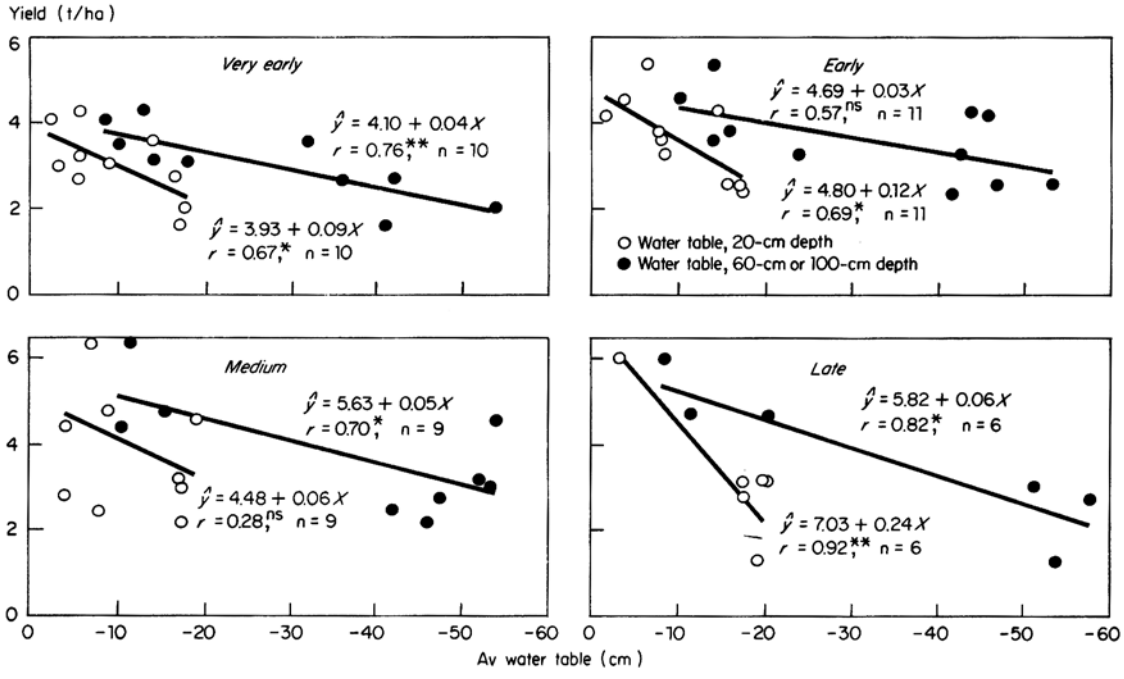
Designation	Yield (t/ha)			Overall				Drought score[a] (Cebu)
	Cebu	IRRI	Guimba	Mean yield (t/ha)	Rank	Plant height (cm)	Days to flowering	
IR11438-13	1.4 abcde	2.5 ab	5.0 abc	3.0	1	132	90	3.0
IR18848-35	1.4 abcde	1.6 bcd	4.0 abcde	2.3	15	113	99	2.3
Khao Dawk Mali 105	1.4 abcde	2.0 abc	2.5 fgh	2.0	21	133	108	4.7
IR10044-24-1-1	1.3 abcde	1.9 abc	4.7 abc	2.7	11	125	93	1.7
Group 2. Drought-prone areas nursery								
IR36	1.9 a	1.3 ef	4.4 bc	2.5	19	75	82	4.7
IR19735-5-2-3-2-1	1.8 a	1.4 ef	3.1 a	2.1	22	83	70	1.7
IR19058-107-1	1.8 a	2.0 bcdef	4.9 abc	2.9	13	87	82	1.0
IR21015-80-3-3-1-2	1.8 a	2.4 abcd	5.6 ab	3.3	5	87	84	1.3
IR13427-40-2-3-3-3-3	1.7 a	1.3 ef	3.0 d	2.0	23	78	71	2.7
BPT3291	1.6 ab	2.1 abcde	4.9 abc	2.9	14	79	99	4.0
IR5853-198-1-2	1.5 abc	2.4 abcd	5.7 ab	3.2	7	94	92	3.0
IR54	1.4 abcd	3.0 ab	6.0 a	3.5	1	92	93	1.7
IR19672-140-2-3-2-2	1.4 abcd	2.7 abc	5.3 abc	3.1	8	86	99	5.3
IR13146-13-3-3	1.4 abcd	3.2 a	5.5 ab	3.3	2	100	96	4.7
IR22082-41-2	1.3 abcd	3.2 a	5.3 ab	3.3	4	90	89	5.0
IR5629-64-3	1.2 abcd	2.8 ab	5.3 ab	3.7	10	93	87	5.0
IR19274-26-2-3-1	1.2 abcd	3.1 a	5.7 ab	3.3	3	87	89	5.7
Group 3. International Rainfed Lowland Rice Yield Nursery								
IR13429-130-2	2.9 a	1.5 cdef	4.7 cdefg	3.0	3	81	83	4.0
UPL Ri-5	2.2 ab	2.6 ab	5.6 abcd	3.4	2	113	90	1.0
R9-1-6-1-3-7-7	2.2 ab	1.9 bcdef	4.2 g	2.8	16	86	100	4.0
RD975-109-2	1.8 c	2.1 abcde	5.2 abcde	3.0	5	99	105	3.7
IR52	1.8 abc	1.8 bcdef	5.2 bcde	2.9	10	89	86	2.3
IR13427-45-3-1-2-2-2	1.8 bc	1.3 def	4.1 efg	2.4	22	74	83	3.0
UPL Ri-3	1.7 bc	2.5 abc	5.0 bcdef	3.0	4	113	93	1.0
R114-2-1-1-1	1.6 bcde	2.1 abcde	5.1 bcde	3.0	9	96	104	5.7
IR9129-192-2	1.4 bcde	1.2 ef	3.3 g	2.0	25	84	73	4.0
IR19672-54-1-3-2-1	1.3 bcde	2.3 abcd	5.2 bcde	3.0	11	92	97	5.7
IR20 (local check)	1.3 bcde	2.3 abcd	5.0 bcdef	3.0	12	89	91	6.3
IR8192-166-2-2-3	1.1 cde	2.2 abcde	5.8 abc	3.0	6	105	102	5.0
IR46	1.1 cde	3.1 a	6.7 a	4.0	1	99	93	4.3

[a]Based on 1980 SES 0-9 scale.

Many lines had outstanding performance at Guimba and mediocre performance at Cebu because of severe stress. IR46, the highest yielding line in the trial, is an example of this pattern. Entries with particularly good performance in all three environments included IR3179-25-3-4, IR11438-13, IR13754-5, IR21015-80-3-3-1-2, IR54, IR13146-13-3-3, and UPL Ri-5.

Selection by yield performance in environments with severe reproductive period moisture stress tends to favor early maturing materials. Comparisons of genotypes within their respective maturity classes are necessary to identify the best materials for a range of maturities.

Analysis of water table and grain yield (*Agronomy*). During the 1980 to 1982 WS, the effects of water table depth in 11 environments on grain yield of several elite and advanced breeding materials of the rainfed lowland yield trial for drought-prone areas were studied. Polyvinylchloride tubes (Piezometer) placed in the field to depths of 20, 60, and 100 cm served as observation wells from which water table depth was measured. The average water table depth during the yield-determining reproductive stage was calculated by adding the daily values from panicle initiation to 10 DBH individually for each maturity class — very early (<105 d), early (105 to 115 d), medium (115 to 130 d), and late (>130 d). This period encompasses the main reproductive stage events most sensitive to

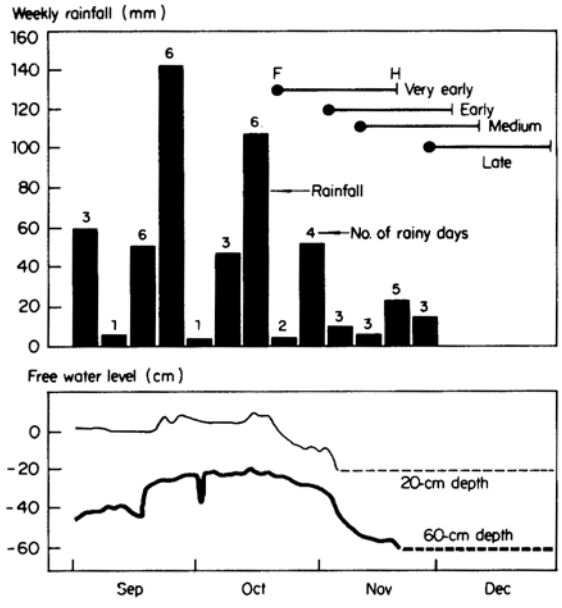


16. Relationship between grain yield of the two highest yielding entries at each location and average water table depth below the soil surface in the root zone above the hardpin (0 to 20 cm) and below the field (0 to 60 or 100 cm) soil surface. Entries were grouped by maturity class: very early (<105 d), early (105 to 115 d), medium (115 to 130 d), and late (<130 d). The average water table depths were summed over the period 30 cm before flowering to 20 cm after flowering based on mean flowering date of each maturity group. IRRI, 1982.

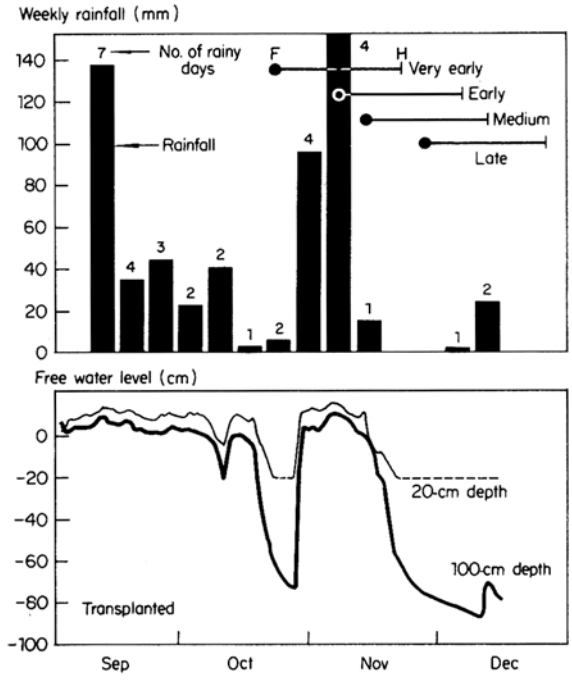
moisture stress.

Figure 16 shows the relationship of average water table depth and grain yield for each maturity group (each point is an average of the two highest yielding varieties or lines for each location). By using the highest yielding entries, the effects of other biological and physical-chemical factors determining growth and yield should be negated. This allows the focus to be placed on the role of subsurface water in determining crop yield response to rainfall in rainfed wetland culture. Significant correlations of 0.67* in the very early, 0.69* in the early, and 0.92** in the late-maturing entries were observed. However, in the medium-maturity groups, the correlation coefficient of 0.28 was not significant for the shallow water table. For the deeper water table, the early-maturity group had a low correlation coefficient of 0.57, but significant correlations of 0.76** in the early, 0.70* in the medium, and 0.82* in the late-maturing entries were observed, although grain yield generally decreased with decreasing water table depth. Although water table depth during the crop season was very low in some localities, grain yields were high possibly because of adequate amount and distribution of rainfall and not because of the total rainfall per se. For example, at Iloilo during the 1981 WS (Fig. 17), rainfall was well distributed 10 d before flowering to 20 d after flowering, with 154 mm rainfall for the early-maturing group and a mean grain yield of 3.9 t/ha. However at Guimba, during the 1980 WS, although rainfall was high (347 mm) for the same growth stages, mean grain yield was rather low (2.1 t/ha) because a short-term water deficit followed flowering in mid-October (Fig. 18).

The results suggest that records of water table depths within and below the rice field can be a useful indicator of field-level hydrology. Using these easily measured parameters in tandem with meteorological data, particularly rainfall, allows interpretation of crop moisture stress at remote sites. It is the only practical method currently used in large variety trials. The daily nature of these hydrological values allows interpretation of yield response to moisture stress for the varying sensi-



17. Water level in the field (piezometer at 20 cm) and below the field (piezometer at 60 cm), and rainfall, Oton, Iloilo, Philippines, 1981 WS.



18. Water level in the field (piezometer at 20 cm) and below the field (piezometer at 100 cm), and rainfall, Guimba, Nueva Ecija, Philippines, 1980 WS.

tivities of each of the rice crop growth stages.

Although numerous other biological, physical, and chemical factors contribute to the site-specific stresses that affect yield, the rice field hydrological records aid significantly in the interpretation of differences in nursery performance over time and locations.

ROOT STUDIES

Plant Breeding and Agronomy Departments

Aeroponic culture technique (*Plant Breeding*). The reliability of the aeroponic culture in root studies was investigated in efforts to perfect a systematic, efficient, and rapid method of screening for root characteristics. Twenty-seven varieties with various reactions to drought in intensive field and greenhouse studies were tested (Table 10).

The experiment was carried out in the Phytotron glasshouse with a randomized complete block design, with three replications. It was repeated three times on different dates to assess its reproducibility.

The growth trends of root characters obtained in the aeroponic culture were similar to those obtained from the field, root boxes, mylar tubes, and greenhouse studies.

In all three plantings, IR20 had the shortest roots and IAC 25, Kalakari, and Black Gora consistently the longest. Likewise, IR20 had the thinnest roots ($\bar{x} = 0.51$ mm) and Moroberekan ($\bar{x} = 1.26$ mm) the thickest. Moroberekan (0.95) and Padi Tatakin (0.70) had the highest root-shoot weight ratios, IR20 (0.35) and Tupa 944 (0.27) the lowest ratios.

However, the improved semidwarfs and traditional wetland varieties had higher root numbers (67-116) than the dryland varieties such as OS4, Moroberekan, and Kinandang Patong (38-59).

Among the five root characters, root diameter appeared to be the least affected by environment (Table 11). A high coefficient of variation (CV) was observed in root number, root-shoot ratio, and dry weight. Such variations in root characters from one planting date to another were also observed earlier in roots of 35 varieties grown in mylar cylinders of light-textured soil (Annual report for 1974).

Variety ranking with respect to different root characters, however, were consistent from one planting to another. For more meaningful data,

Table 10. Root characteristics and drought reactions of 27 rice varieties from the germplasm bank, IRRI, 1982.

Variety	Type of culture[a]	Root[b] length (cm)	Root[b] diameter (mm)	Field reaction score[c]	
				Vegetative	Reproductive
IR20	W	66.9	0.51	7	9
IRAT 9	ID	82.9	0.76	3	8
ARC 15107	W	97.3	0.71	7	–
Lalsaita	W	107.8	0.88	7	7
Sintianne Diofor	(?)	104.8	0.83	3	8
Taichung (N) 1	W	89.1	0.71	6	9
Aus 83	W	101.8	0.93	6	7
Digha	W	94.8	0.84	7	–
Tupa 944	W	96.1	0.66	7	9
IR22	W	81.8	0.72	6	9
IR8	W	82.8	0.76	4	9
IR43	ID	75.8	0.72	5	9
IR36	W	84.1	0.68	6	7
IR442-2-58	W	76.9	0.79	5	9
C22	ID	93.3	0.99	2	9
Salumpikit	D	105.1	0.99	4	6
Khao Lo	D	90.1	0.99	5	5
Moroberekan	D	100.9	1.26	5	2
Kinandang Patong	D	97.0	1.04	3	3
IAC 25	ID	108.9	0.94	4	6
Dular	DP	102.0	0.96	5	3
OS4	D	98.3	0.96	4	3
MI-48	D	91.4	0.99	5	4
Padi Tatakin	D	90.0	0.93	4	4
63-83	D	104.8	1.02	4	2
Black Gora	*	108.1	0.89	6	5
Kalakeri	*	113.3	0.83	4	–

[a]W = wetland, D = dryland, ID = improved dryland, DP = dual purpose, * = grown in drought-prone areas in India. [b]Av of nine observations. [c]Score taken from the data bank as evaluated by the Plant Breeding Department: 1 = resistant, 9 = susceptible.

Table 11. Coefficient of variation (CV) of eight root and shoot characters among 27 rice cultivars at three planting dates. IRRI, 1982.

Character	CV (%)		
	Dec-Feb	Feb-Mar	Apr-May
Root length	4.67	3.09	9.04
Root diameter	8.68	7.54	7.90
Root number	17.34	13.51	18.71
Root-shoot ratio	18.53	37.32	17.17
Root dry weight	21.06	14.69	25.95
Shoot dry weight	21.50	25.02	23.69
Plant height	8.62	14.11	9.14
Tiller number	17.12	19.88	21.19

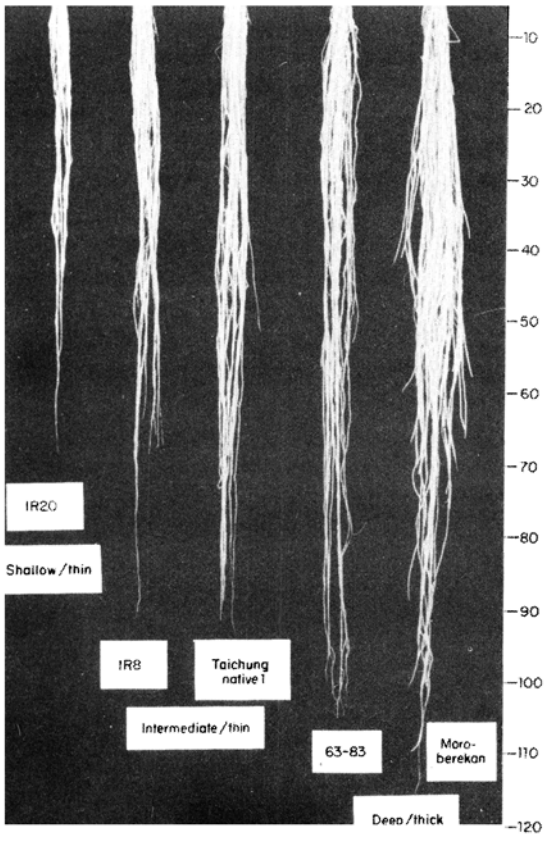
check varieties with both shallow and thin roots (IR20) and deep and thick roots (Moroberekan) should be planted in each drum (Fig. 19). A ratio between the test variety and the check variety could then be extrapolated and used as an index in scoring the different root characteristics.

Correlation analysis showed that root diameter was highly and positively correlated with the root-shoot ratio ($r = 0.83^{**}$), but negatively correlated with root number ($r = 0.61^{**}$). Root length and root-shoot ratio were not significantly related.

Root length was highly and positively correlated with root diameter ($r = 0.57^{**}$). Most of the test varieties with deeper root systems generally have thick roots. Lalsaita, Tupa 944, and ARC 15107 were exceptions; they have a combination of deep and thin roots.

Among the four root characters studied, a combination of deep and thick roots appeared stable and could be a useful criterion in selecting for drought resistance in a program emphasizing the drought-avoidance mechanism.

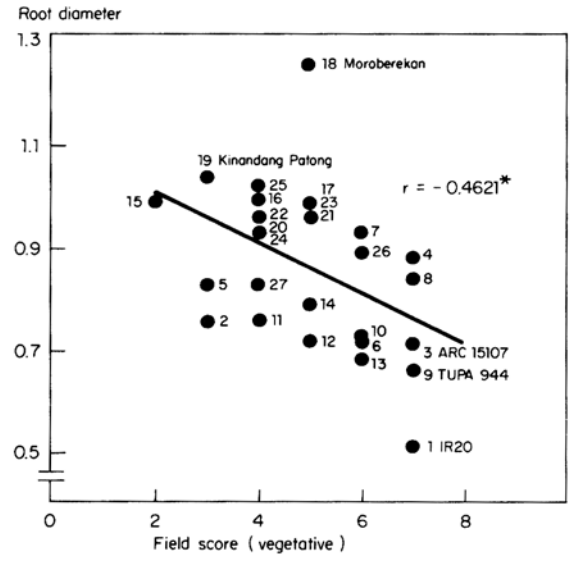
The results show that data on root characters obtained from aeroponic culture are reproducible, indicating an advantage of this technique over the root boxes or field sampling — especially in screening large numbers of rice cultivars and



19. Comparison of root systems of five rices grown in aeroponic culture. IR20 has extremely shallow and thin roots, while Moroberekan has extremely deep and thin roots. IRRI, 1982.

breeding lines. One cycle of testing requires only 45 d.

Relationship between root characteristics and field resistance to drought (*Plant Breeding*). Root length, root number, and root-shoot ratio were not significantly correlated with field reaction to drought during the vegetative growth stage (Table 12). Data on field reaction to drought were based on visual scorings in the field during the DS. Test varieties susceptible to drought at the vegetative stage, such as Lalsaita, Sintianne Diofor, Tupa 944, Digha, and ARC 15107, have deep roots (94.8-107.8 cm), most of them thin. Although deep roots enable the rice plant to reach deeper for water, it is possible that the thin root does not extract or store enough water to meet the atmospheric demand of the varieties. Thus, the shoots readily suffer from a water deficit during prolonged drought periods.



20. Relationship between root diameter and field drought reaction score at vegetative growth stage. IRRI, 1982. Reaction score from Loresto and Chang 1981, IRRN 6(2):9-10.

Table 12. Correlation coefficients between root characters and field resistance to drought at vegetative and reproductive stages of growth.

	Correlation coefficient			
	Root length	Root diameter	Root number	Root-shoot ratio
Vegetative field reaction score[a]	-0.16^{ns}	-0.46*	0.27^{ns}	-0.36^{ns}
Reproductive field reaction score[a]	0.54**	-0.78**	0.53**	-0.77**

[a] 1 = resistant, 9 = susceptible.

On the other hand, root diameter was negatively and significantly correlated with drought reaction scores at the vegetative stage ($r = -0.46$**). Thick-rooted varieties, such as Moroberekan and Kinandang Patong, have a higher drought resistance than the thin-rooted varieties such as IR20, Tupa 944, and ARC 15107 (Fig. 20). Earlier studies on 35 rice selections also indicated that the mean diameter of thick roots is highly correlated with higher levels of drought resistance (Annual report for 1974). Moreover, field resistance for drought at the reproductive growth stage is highly correlated with deep and thick roots, low root number, and high root-shoot ratio (Table 12).

These findings confirmed results of earlier field studies, which indicated that drought-resistant varieties, such as Palawan, M1-48, and OS4 have deep and thick roots in contrast to the thin and shallow roots of IR20 and TN1.

Varietal comparison of the main xylem vessels in rice roots (*Agronomy*). One way of enhancing the ability of rice to extract water from deep soil layers during drought is by decreasing root axial resistance.

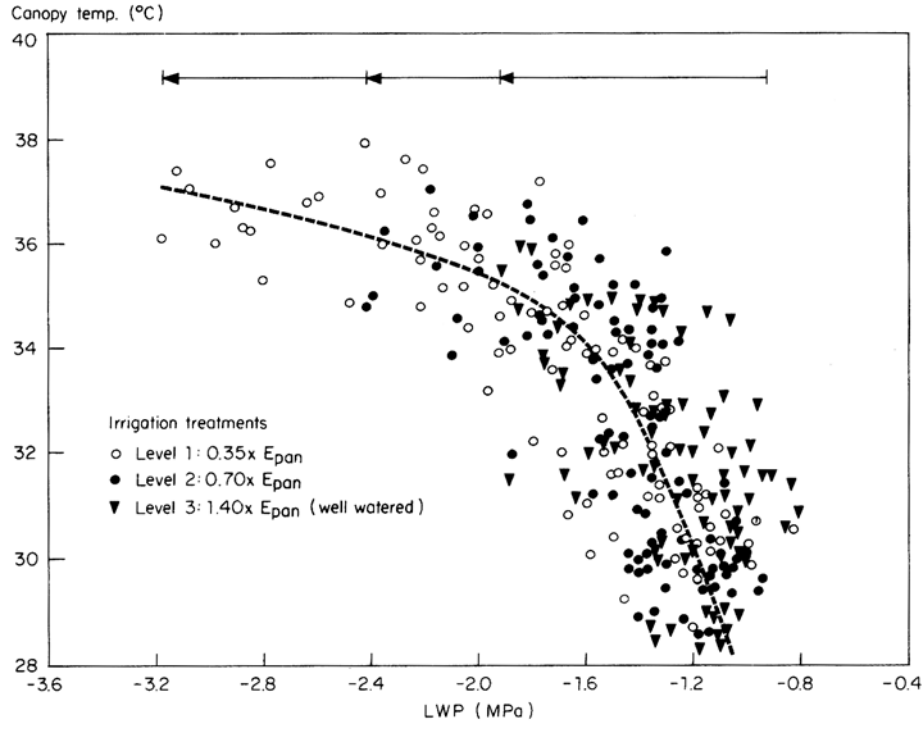
A study was conducted to determine the diameter of the main xylem vessels of seminal and nodal roots of 28 rice varieties. Pregerminated seeds were sown in 3.8-liter pots in a phytotron growth cabinet (29°/21°C, 70°/70% RH, 30 Klux). Four to 5 DAS, the seminal roots were about 10 cm long. Nodal roots of about the same length were collected from 14- to 15-d-old seedlings.

Free-hand, cross-sections of 1-cm roots cut 3.5 cm from the seed were made and stained briefly with 1% toluidine blue. The sections were washed thoroughly with distilled water and examined under a compound microscope. The diameter of main xylem vessels of seminal roots ranged from 29 to 57 μ. Dryland varieties from West Africa (63-83, Moroberekan, IRAT 13) and Brazil (IAC 1246, IAC 25) possess seminal roots with the largest vessels. Most of the small vessels were found in deepwater and wetland varieties. Results obtained from adventitious or nodal roots of six selected varieties illustrate the same trend, although the magnitude was slightly less than that of seminal roots. IR20 had the smallest vessel diameter (27 $\pm$ 6.8 μ) and 63-83 the largest (52$\pm$ 3.5 μ).

SOIL-PLANT-WATER RELATIONSHIPS

Agronomy and Soil Chemistry Departments

Crop canopy temperature in relation to drought resistance mechanism (*Agronomy*). In previous research, visual scoring and the plant-based leaf water potential measurement were used to assess the genotypic response to moisture stress in the field. In 1981, the infrared thermometer was used



21. Relationship between canopy temperature and midday LWP of 11 rice cultivars during the treatment period (6 Apr-4 May) at reproductive stage. Irrigation level refers to a factor multiplied by the amount of water evaporated from a standard class A pan. Arrows indicate progression of plant moisture stress. IRRI, 1982.

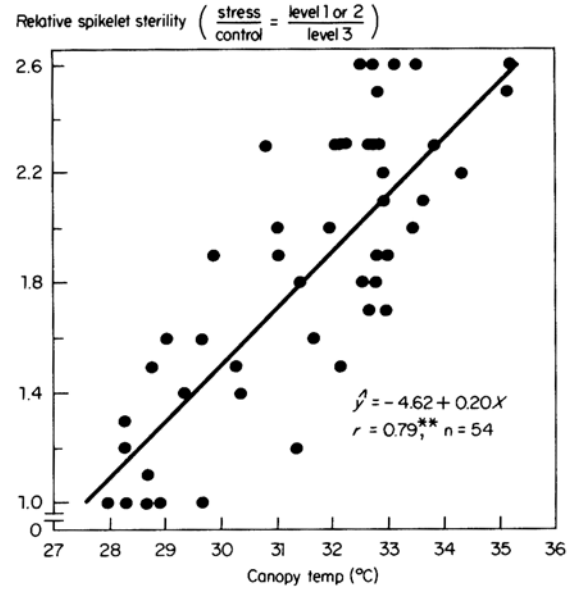
to evaluate genotypes for the ability to maintain low canopy temperatures under various drought conditions. Again in 1982, canopy temperatures of several genotypes at the reproductive stage were measured in the field and related to some drought resistance mechanisms such as maintenance of high leaf water pontential (LWP) and root system development.

Figure 21 shows an inverse curvilinear relationship between canopy temperature and midday LWP of 11 rice cultivars as soil moisture progressively declined from sprinkler irrigation level 3 to level 1. As LWP values ranged from -0.8 to -1.9 MPa, canopy temperatures ranged from 28.5° to 35° C in level 3; and decreased further to -3.1 MPa as canopy temperature increased to 37.5° C in level 1. The scattering of the data could be due to differences in varietal response, and presence of clouds which could vary the amount of radiation received by the rice leaf.

To determine the moisture stress effect on the yield of the same 11 cultivars, the canopy temperature at 50% flowering was related to relative spikelet sterility (Fig. 22). Relative spikelet sterility partially eliminated the high-temperature effects on sterility observed even in the high-irrigation treatment at level 3. Canopy temperature was linearly related to relative spikelet sterility ($r = 0.79^{**}$). There was a 0.20 increase in relative sterility for every degree increase in canopy temperature.

The ability of a cultivar to satisfy evapotranspiration demand and maintain low canopy temperature and high plant water status could be attributed to its rooting behavior. When the irrigation level was 40% greater than the pan evaporation (E_{pan}), the canopy temperatures and LWP values of IR52 and IR36 were similar at about 30° C and -1.1 MPa. However, when irrigation level was 35% of E_{pan}, canopy temperature of IR52 was cooler by 2° C and LWP higher at -1.3 MPa.

IR52 had a root length density of 33.2 cm/cm^3 and a water extraction of 40 mm by partial water balance compared with 27.4 cm/cm^3 and 29 mm for IR36 (Fig. 23). However, roots of both cultivars extended to a soil depth of 60 cm. This indicates that the capability of IR52 to extract more water and satisfy the evapotranspiration demand could be attributed to variation in root length density.



22. Relative spikelet sterility of 11 rice cultivars at harvest and their canopy temperatures at 50% flowering. IRRI, 1982.

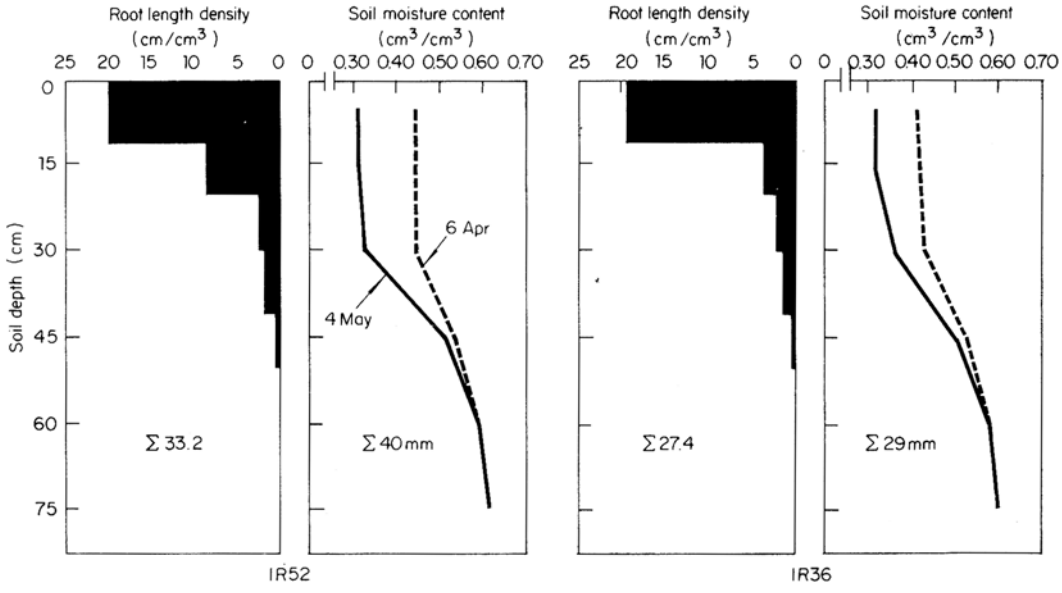
The root length density of IR52 was 24% greater than that of IR36 in the upper 30 cm of soil, where about 93% of the total water extraction occurred.

Results indicate that canopy temperature determined by the infrared thermometer can be used as a reliable, rapid, and noncontact indicator of crop moisture stress. This observation is supported by plant water potential and soil moisture depletion data.

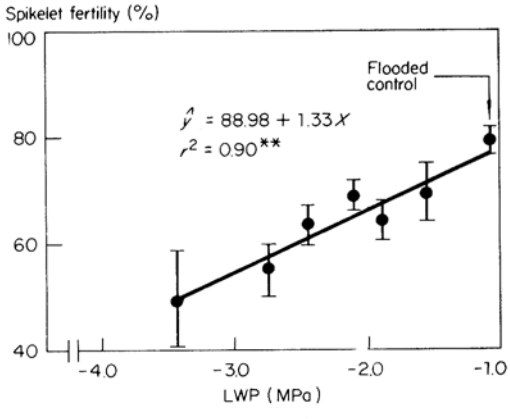
Response of rice to moisture stress: sensitivity of meiosis during pollen development (*Agronomy*). A glasshouse experiment was conducted to determine the effect of moisture stress during pollen development on spikelet fertility. More specifically, the study attempted to investigate some irregularities at the meiotic stage of pollen development that may be associated with moisture stress-induced spikelet sterility in rice.

IR36 was stressed during meiosis when the collar of the flagleaf was 3-6 cm below the collar of the penultimate leaf. The plants were stressed for 4 d with treatments of -1.6, -1.9, -2.2, -2.5, -2.8, and -3.5 MPa LWP. The pots were then irrigated and kept unstressed until maturity. Unstressed (control) plants were flooded continuously.

Leaf and panicle samplings were done between 1030 and 1200 h on the fourth day — the time of maximum stress. Water potential of the flagleaves



23. Root length density (mean of three replications) and volumetric change in soil moisture content (mean of two replications) in the lowest irrigation treatment at level 1. IRRI, 1982.



24. Average percentage of spikelet fertility (± S. E.) of IR36 stressed during pollen development. IRRI, 1982.

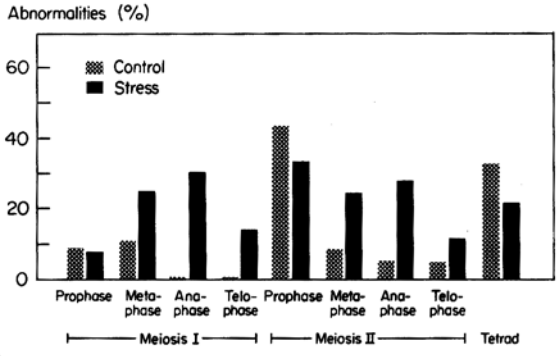
of two to five plants was estimated by a portable pressure chamber. Pollen mother cell (PMC) meiosis was examined on the unexserted panicles of the sampled tillers. The sporocytes of the panicles were fixed in fresh Farmer's solution (3 parts 95% ethanol, 1 part 45% acetic acid, traces of ferric chloride). After storage in the cold room, the panicles were washed in 70% ethanol. About 300-800 cells for each stress level were examined for PMC meiosis using acetocarmine smears. The percentage and types of meiotic irregularities, if any, were determined.

Figure 24 shows the percentage of spikelet fertility of IR36 plants after being stressed at the meiotic stage of pollen development. A linear regression illustrates the steady reduction of fertility as the LWP dropped.

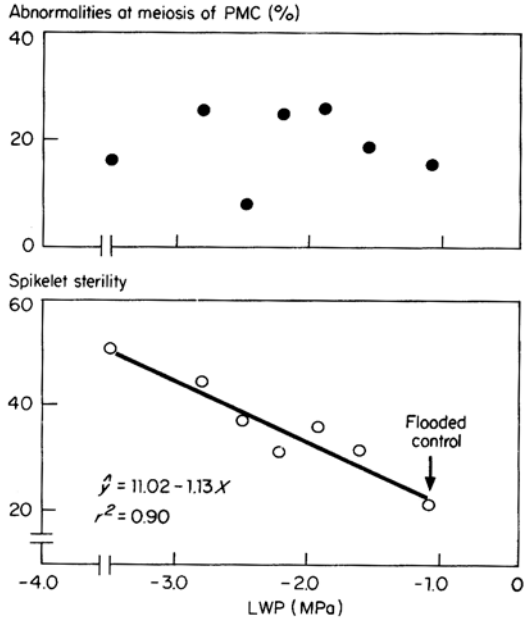
Abnormal chromosome behavior was observed in both stressed and unstressed plants, although moisture stress appeared to accentuate the presence of meiotic abnormalities (Fig. 25). One or two particular irregularities appeared to characterize each meiotic stage. The chromosome abnormalities observed were:

- presence of univalents in diakinesis (prophase 1);
- noncongression of chromosomes on metaphases 1 and 2;
- micronuclei formation in telophase 1, prophase 2, telophase 2, and resultant tetrads; and
- laggards in metaphases 1 and 2, anaphases 1 and 2, and telophases 1 and 2.

Although the meiotic abnormalities were associated with moisture stress during pollen development, they were not directly associated with spikelet sterility (Fig. 26). The mean percentage of abnormalities across all meiotic stages at a particular stress level does not show a distinct trend that could be correlated with increased sterility. It was postulated that the association of moisture stress, at the



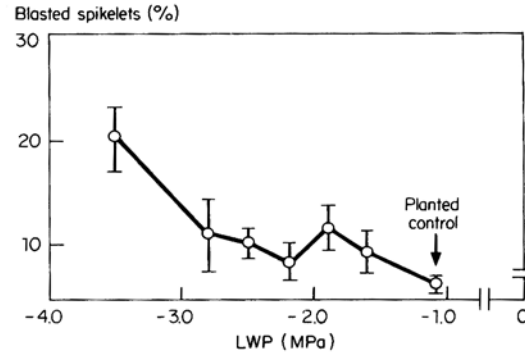
25. Moisture stress often intensified during pollen development of IR36. IRRI, 1982.



26. Relationship between meiotic abnormalities of the PMC and spikelet sterility in IR36 as affected by moisture stress. Percent abnormalities were summed across meiotic stages for each moisture stress level. IRRI, 1982.

time in panicle development when the meiotic stages were present, with decreased fertility is linked to some latent effects such as lack of anther dehiscence.

A corollary observation of the spikelets at maturity revealed a significant, although unexpected, percentage of the total sterility to be associated with blasted or poorly developed spikelets (Fig. 27). The actual cause of this type of spikelet degeneration or partial development is not known.

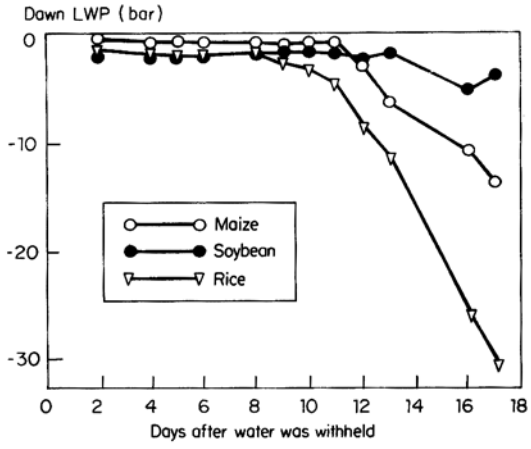


27. Average percentage of blasted spikelets (± S. E.) in IR36 stressed during pollen development. IRRI, 1982.

Comparative response of rice, maize, and soybean to moisture stress (*Agronomy*). Rice (IR36), maize (DMR-2), and soybean (Clark 63) were grown in trays (32 × 24 × 10 cm) containing 6.5 kg of sieved soil in a greenhouse experiment conducted to compare their nutrient uptake rates under moisture stress. N [$(NH_4)_2(SO_4)$], P (solophos), and K (muriate of potash) were applied at 90-30-30 kg/ha furrow slice on rice and soybean 12 DAS and on maize 5 DAS. In the stress treatment, water was withheld from rice, maize, and soybean starting 19, 12, and 15 DAS, respectively. Control plants continued to receive water daily. Stress was imposed when the crops, which have different growth rates, had a uniform leaf area of approximately 2 dm^2. Before the stress treatment, the trays were covered with polyethylene sheets to minimize soil evaporation.

The dawn LWP values were similar during the first 10 d of stress, after which dawn LWP of rice sharply decreased (Fig. 28). Dawn LWP of soybean remained above -6 bar. The transpiration rate of maize was lower than that of either soybean or rice in both the stress and control treatments and moisture stress reduced transpiration rates of all three (Fig. 29). However, transpiration was reduced to the lowest rate in maize. At the end of the stress period, transpiration rates of the stressed rice, maize, and soybean were 38, 22, and 28%, respectively, of the control plants.

Figure 30 illustrates the nutrient uptake trends during the 17-d stress period. The well-watered crops continuously accumulated N, P, and K with time (Fig. 30 A, C, E). Nutrient uptake response to moisture stress was markedly different among the



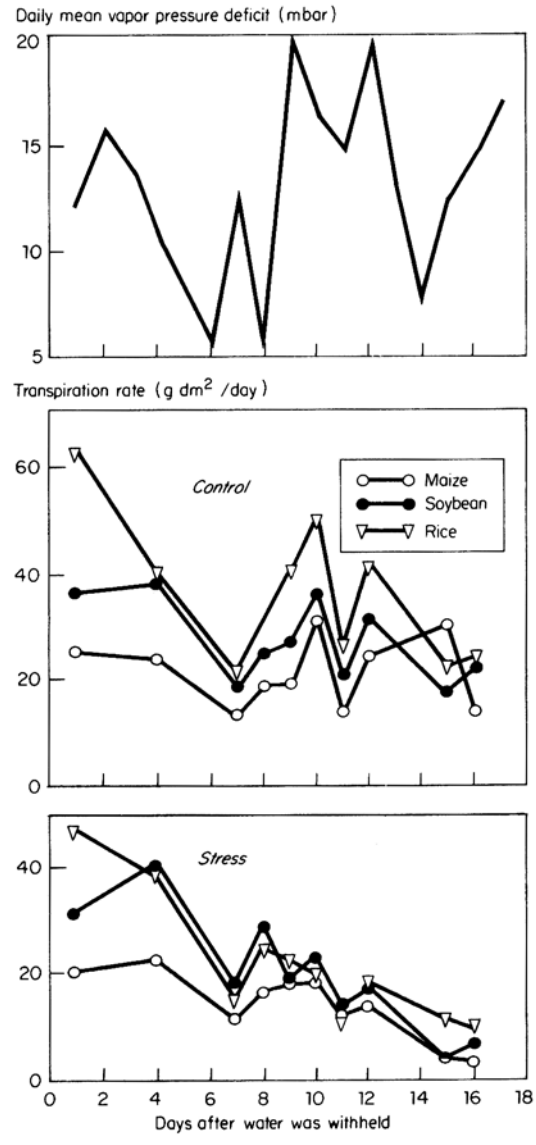
28. Dawn LWP of rice, maize, and soybean during the 17-d stress period. IRRI greenhouse, 1981 DS.

crops. Total N content in the three crops differed significantly from that of control plants on days 9 (rice), 11 (soybean), and 12 (maize). N accumulated slowly in stressed maize and soybean until days 13 and 16, whereas it leveled off in rice after 8 d of withholding water (Fig. 30B). N uptake was reduced by as much as 61% in rice, 48% in soybean, and 41% in maize. Trends were similar in P uptake (Fig. 30D). The final P content was 70% of the control plants for maize, 42% for rice, and 32% for soybean. Moisture stress did not alter the K uptake pattern in maize (Fig. 30F). K uptake decreased 59% in rice and 38% in soybean.

Moisture stress affected rice most and maize least.

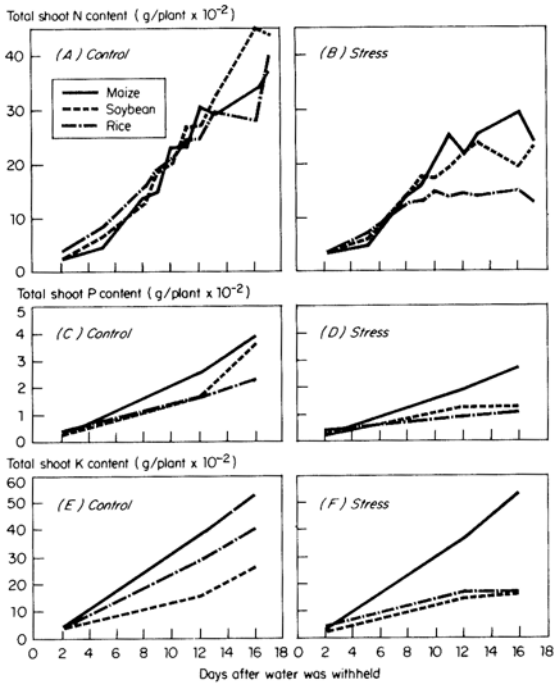
Drought tolerance at shallow rooting depth (*Agronomy*). Greenhouse screening for drought tolerance at shallow rooting depth (about 45 cm) and for the ability to recover from moisture stress was continued.

One hundred and five GEU elite lines, including a few selected varieties and lines, were evaluated at the vegetative stage during the DS and WS. Three entries, including the indicator plant Leb Mue Nahng, were seeded into dry soil in steel drums and watered regularly until 30 DAS. The soil was then allowed to dry naturally by evapotranspiration. As soon as Leb Mue Nahng was apparently dead from moisture stress, the entries were scored for drought tolerance, the soil was sampled for moisture content, and the plants were rewatered. Recovery ability was scored at desired growth stages.



29. Transpiration rates of control and stressed rice, maize, and soybean plants during the 17-d stress period. IRRI greenhouse, 1981 DS.

Tables 13 and 14 list the entries that consistently recovered in both replications during the DS and WS. The drought tolerance and recovery of IR9752-1-2-1 were outstanding (Table 13). However, 1 and 3 wk after relief from stress recovery was slow in the listed entries. During the WS, several of the promising entries, such as IR10068-18-2 and IR13146-41-3, had better recovery after 4 wk after rewatering.



30. Total shoot N, P, and K contents of control (A, C, and E) and stressed (B, D, and F) rice, maize, and soybean plants during the 17-d stress period. IRRI greenhouse, 1981 DS.

Use of a line source sprinkler system to evaluate sources and methods of nitrogen application (*Agronomy*). The yield response of rice to various N sources and application techniques was assessed with a LSS system. Treatments consisted of six irrigation levels, two cultivars, and six N treatments replicated four times.

IR52 and Kinandang Patong were hand-drilled in 30-cm rows at 100 kg/ha. Basal application of 13.2 kg P/ha and 24.4 kg K/ha was made at seeding. The seedlings were established by uniform irrigation with four lines of sprinklers from seeding (day 0) to day 39. On day 43, the LSS (initiated at IRRI in 1979) was used to create a gradient of six irrigation levels (IL) ranging from well watered (IL 1) to droughty (IL 6). On day 108, uniform irrigation was resumed over the entire area.

Water applied. Figure 31 shows the total water applied for seedling establishment and the amount from the LSS. The amount of water used (including rainfall) in establishing the seedlings was more or less uniform among the six plots. Water application by the LSS decreased linearly with distance from the sprinkler line (Fig. 31). IL 1 had a water application rate of about 390 mm from the LSS. This value decreased progressively to about 36 mm at IL 5.

Visual drought score. Table 15 shows the drought tolerance scores of IR52 and Kinandang Patong at the different irrigation levels and N treatments. Moisture stress was more apparent at IL 6, 5, and 4, which received 0, 36, and 137 mm of LSS water, respectively. With these levels, N-fertilized plots had generally higher drought tolerance scores than

Table 13. Drought tolerance ratings at vegetative stage of promising entries and their drought recovery scores 1 and 3 wk after relief from stress. IRRI greenhouse, 1982 DS.

Variety or line	Drought tolerance score[a]	Recovery from drought[b]	
		1 wk	3 wk
IR9752-1-2-1	6	6	6
IR13365-253-3-2	7	8	8
IR13240-82-2-3-2-3-1	6	8	8
IR43	7	8	8
IR15496-219-2-3-2	6	8	8
IR9209-181-3-5	6	9	9
IR10710-23-1	7	9	9
IR9764-45-2-2	7	9	9
BPI Ri 6	7	9	9
IR10011-16-3	7	9	9
IR2649-83-3	8	9	9
Leb Mue Nahng (tolerant check)	9	9	9

[a]Based on the 1980 SES 0-9 scale. [b]Based on 1980 SES 1-9 scale.

Table 14. Drought tolerance ratings at vegetative stage of promising entries and their drought recovery scores 2 and 4 wk after relief from stress. IRRI greenhouse, 1982 WS.

Variety or line	Drought tolerance score[a]	Recovery from drought[b]	
		2 wk	4 wk
IR10068-18-2	7	6	4
IR13146-41-3	7	7	6
Kulawalai	6	7	7
IR14632-22-3	7	8	7
IR8073-65-6-1	7	8	8
IR25621-94-3-2	8	8	8
Khao Dawk Mali	8	9	8
IR5440-1-1-3	7	9	9
Leb Mue Nahng (tolerant check)	9	9	9

[a]Based on the 1980 SES 0-9 scale. [b]Based on 1980 SES 1-9 scale.

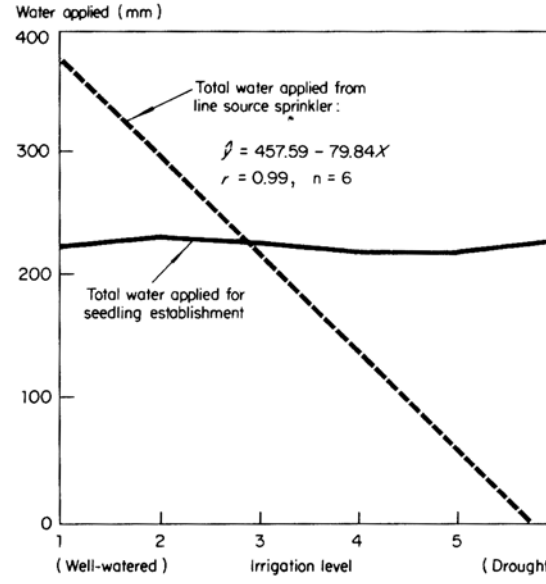
Table 15. Drought tolerance of IR52 and Kinandang Patong as affected by irrigation level (IL) and N treatment. IRRI, 1982 DS.

N treatment	Drought tolerance score at IL[a]					
	6	5	4	3	2	1
			IR52			
Control	2.8	2.5	1.3	0.0	0.0	0.0
Urea, 90 kg N/ha, 3 split[b]	3.8	3.8	2.5	1.0	0.0	0.0
Urea, 90 kg N/ha, band placed at planting	4.3	3.5	2.8	2.5	0.0	0.0
Urea + dicyandiamide, 90 kg N/ha B&I[c] at planting	4.3	3.8	2.5	1.0	0.0	0.0
Sulfur coated urea, 90 kg N/ha B&I[c] at planting	3.5	3.0	1.8	0.5	0.0	0.0
Ammonium sulfate, 90 kg N/ha, 3 split	4.0	3.5	2.0	0.8	0.0	0.0
Mean	3.8	3.4	2.2	1.0	0.0	0.0
			Kinandang Patong			
Control	1.5	1.5	0.8	0.0	0.0	0.0
Urea, 90 kg N/ha, 3 split[b]	3.0	2.8	1.5	0.3	0.0	0.0
Urea, 90 kg N/ha, band placed at planting	3.0	3.0	2.3	0.8	0.0	0.0
Urea + dycyandiamide, 90 kg N/ha B&I[c] at planting	3.3	3.0	2.3	0.8	0.0	0.0
Sulfur coated urea, 90 kg N/ha B&I[c] at planting	2.8	2.5	1.0	0.3	0.0	0.0
Ammonium sulfate, 90 kg N/ha, 3 split	3.3	2.8	1.0	0.5	0.0	0.0
Mean	2.8	2.6	1.4	0.5	0.0	0.0

[a]Based on the 1980 SES 0-9 scale. Irrigation levels range from well watered (1) to droughty (6). [b]Three equal split doses: broadcast and incorporated at planting topdressed 25 DE and at PI. [c]Broadcast and incorporated.

the control plots. The effect of moisture stress was smaller on Kinandang Patong than on IR52 with a limited water supply.

Grain yield. There was a significant interaction between variety, irrigation level, and N treatment (Table 16). The two varieties reacted differently to the various combinations of water and N application. In both varieties, no significant yield difference was observed among the six N treatments at IL 6 or 5. With an adequate water supply (IL 1), IR52, which was fertilized with urea + dicyandiamide at 90 kg N/ha (a nitrification inhibitor), yielded similarly to plots with three split applications of urea or ammonium sulfate, or those with basally incorporated sulfur-coated urea. At the same irrigation level, all IR52 N-fertilized plots had significantly higher yields than the control plots. On the other hand, Kinandang Patong obtained its highest yield of 305 g/m^2 with an adequate water supply and no N application. Its lower yield when fertilized with 90 kg N/ha, regardless of the N



31. Total water applied (including rainfall) for seedling establishment and amount applied from the LSS system. IRRI, 1982 DS.

Table 16. Grain yield of IR52 and Kinandang Patong as affected by irrigation level (IL) and nitrogen treatment. IRRI, 1982 DS.

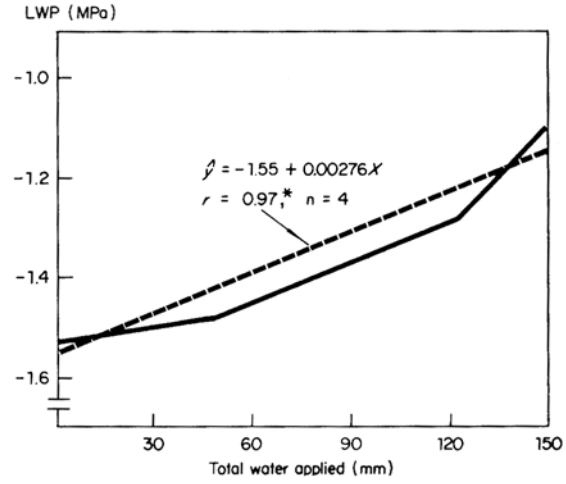
N treatment	Grain yield (g/m^2) at IL[a]					
	6	5	4	3	2	1
			IR52			
Control	30 a	57 a	199 a	468 a	493 c	502 c
Urea, 90 kg N/ha, 3 split[b]	24 a	32 a	104 b	417 a	728 ab	897 a
Urea, 90 kg N/ha, band placed at planting	7 a	9 a	39 b	314 a	714 b	780 b
Urea + dicyandiamide, 90 kg N/ha B&I[c] at planting	6 a	27 a	68 b	398 a	799 ab	946 a
Sulfur-coated urea, 90 kg N/ha B and I[d] at planting	19 a	56 a	79 b	443 a	802 a	893 a
Ammonium sulfate, 90 kg N/ha, 3 split	32 a	24 a	93 b	404 a	726 ab	880 a
			Kinandang Patong			
Control	27 a	35 a	103 a	297 a	282 a	305 a
Urea, 90 kg N/ha, 3 split	25 a	26 a	62 a	211 abc	234 ab	205 bc
Urea, 90 kg N/ha, band placed at planting	5 a	25 a	22 a	103 d	185 b	135 c
Urea + dicyandiamide, 90 kg N/ha B&I at planting	13 a	21 a	78 a	139 cd	210 ab	186 bc
Sulfur-coated urea, 90 kg N/ha B&I at planting	20 a	22 a	79 a	254 ab	226 ab	258 ab
Ammonium sulfate, 90 kg N/ha, split[b]	19 a	23 a	54 a	190 bc	288 a	250 ab

[a]Irrigation levels range from well watered (1) to droughty (6). [b]Three equal split doses: broadcast and incorporated at planting, topdressed 25 DE and at PI. [c]Broadcast and incorporated.

source and application method, was partly due to lodging.

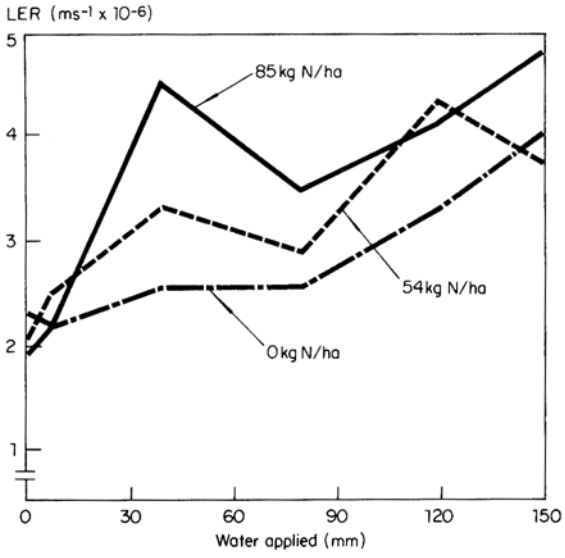
The LSS system proved useful in assessing the effects of different N sources and application methods at varying moisture levels. The use of urea + dicyandiamide was comparable with properly timed application of other N sources.

Evaluation of nitrogen management for rice in rainfed environment using line source sprinkler system (*Agronomy and Soil Chemistry*). In the 1982 trial, a LSS system was used to evaluate different N management practices in a puddled condition. A split plot design was used with the water management regime as main plot and three N rates as subplots using prilled urea (PU) and urea supergranule (USG) as N sources. Six water management regimes were oriented perpendicular to the sprinkler line with the farthest water regime receiving the least water. Plots closest to the line were continuously flooded until maturity. Two weeks after seedling establishment, flood irrigation was switched to the sprinkler system and continued for 23 d with a 4-d irrigation interval. After the sprinkler irrigation period, the whole field was reflooded and maintained until harvest.

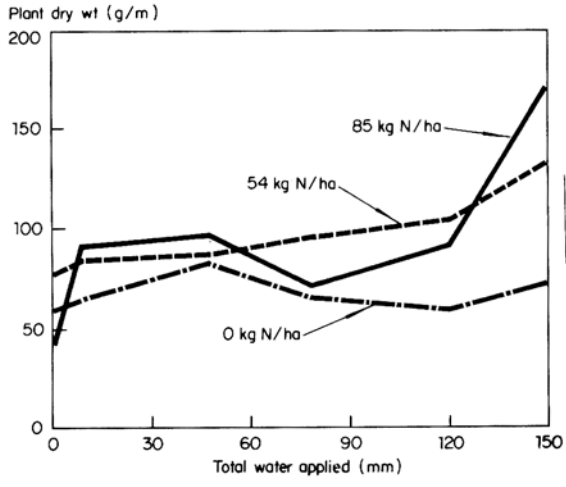


32. Effect of the amount of water applied on LWP of IR52. Average of three replications, two N rates, and eight diurnal measurements. IRRI, 1982.

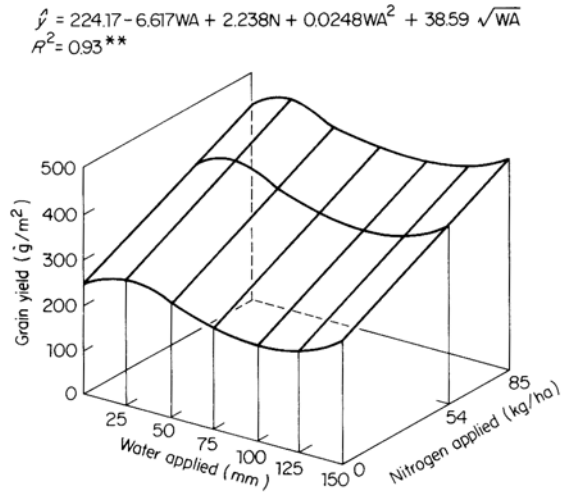
Figure 32 shows the effect of decreasing water supply on the plant water status during stress. On the last day of stress (day 23 of line source), the LWP, average of two N rates and eight diurnal measurements, showed a direct relationship with



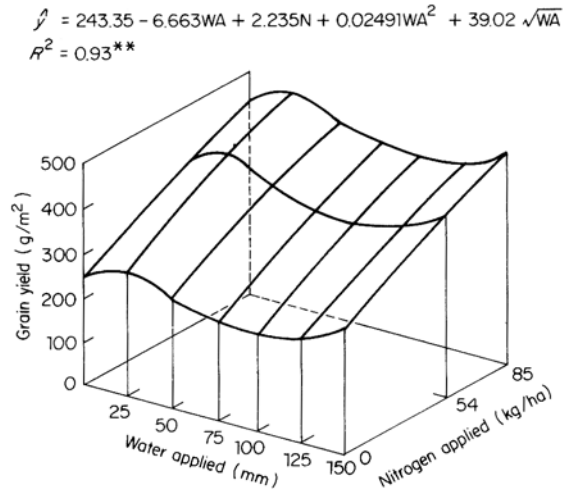
33. Effect of the amount of water applied on LER of IR52 fertilized with PU. Average of five replications. IRRI, 1982.



34. Effect of the amount of water applied on IR52 dry weight when fertilized with PU. Average of five replications. IRRI, 1982.



35. Response surface showing the combined effects of water applied and N rates on yield of IR52 fertilized with PU. IRRI, 1982.



36. Response surface showing the combined effects of water applied and N rates on yield of IR52 fertilized with USG. IRRI, 1982.

the amount of water applied by LSS. The LWP values were 0.42 MPa higher in the continuously flooded plants than in those with the driest water regime. This indicated that stressed plants were suffering from internal moisture stress, although no symptoms were visible. This difference in plant water status was reflected in the leaf elongation rate (LER) (Fig. 33). The LER at all the N rates used showed an increasing trend with water management regime. However, responses to N rates were similar at the drier water regimes. Plant dry weight accumulation showed the same trend (Fig. 34). These results might be due to the restricted movement of N in the root zone where water availability was low. They agree with other findings that N addition does not alleviate the effects of moisture stress on plant growth.

The effects on grain yield after reflooding in both PU- and USG-fertilized plots are in Figures 35 and

36. Logarithmic responses of grain yield to water was noted for both forms of urea. N addition contributed significantly to the yield increase. The lowest predicted yield at all N rates occurred in plots that had undergone wetting and drying during the vegetative period. No significant difference in effect was detected between PU and USG. The similarity in yield response of rice to the two forms of urea was attributed to the deep PU incorporation.

Genetic evaluation and utilization (GEU) program

Adverse soils tolerance

Soil Chemistry and Plant Physiology Departments

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SCREENING

Soil Chemistry Department

In 1982, more than 15,000 (about 2,000 from international nurseries) rices were screened. More than 2,800 rices were found to be tolerant of one or more of nine adverse soil conditions (Table 1).

Salinity. *Mass screening.* Of the 11,912 entries screened at the greenhouse, 2,445 showed tolerance. Outstanding entries included IR44, IR46, 10 IR lines that had been consistently rated tolerant; 22 from the world collection; and five hybrids from the salt tolerance breeding program.

In a field, with an electrical conductivity of the saturation extract (EC_e) of 8 dS/m, the outstanding entries included IR50, IR52, IR54, IR56, IR19670-263-3, IR19735-5-2, IR18348-51-2, and IR19670-203-2. Forty percent of the entries tested were rated tolerant.

IRSATON. IR36, IR2307-247-2, IR2863-35-3, IR4422-6-2, IR4432-28-5, IR9217-58-2, IR9732-119-3, IR9975-5-1, IR10206-29-2, IR13426-19-2, IR14632-23-3, and Nona Sail were as tolerant as the resistant check IR9884-54-3.

Yield trials at IRRI. Of 24 rices found tolerant in the greenhouse, 12 yielded 2.2-3.1 t/ha in the field. IR8073-65-6 yielded highest.

Tests in farmers' fields. Fourteen rices were tested in nine experiments at six locations in three Luzon provinces during the 1982 DS and WS. The salt source came from brackish rivers or sea inundation. The EC_e trend was 1 to 12 dS/m in the DS and 16 to 3 dS/m in the WS. Two rices bred for salt tolerance (IR9884-54-3 and IR10198-66-2) and IR42, IR44, and IR54 had mean yields of 3-3.5 t/ha. IR5657-33-2 although not specifically bred for salt tolerance gave the same mean yield.

Twelve rices were tested in a farmer's field in Bohol (EC_e 11 to 2 dS/m). IR9884-54-3, IR54, IR9846-215-3, and IR52 yielded 3.3-3.7 t/ha.

Alkalinity. *Mass screening.* Thirty-eight of 1,009 rices screened in the greenhouse showed tolerance. IR36, IR8192-200-3, IR9129-209-2, and IR9752-71-3 were outstanding.

In the field, 180 entries were tested in a soil made alkaline by the addition of sodium carbonate. IR9217-58-2, IR13423-10-2, IR13525-43-2, IR13540-56-3, and IR17494-32-1 were the best lines.

Concrete-bed tests. On an artificial sodic soil (pH 8.6), IR36, IR46, IR2307-247-2, IR8192-31-2, and IR9764-45-2 did well. In a saline sodic soil, IR9764-45-2 was best.

IRSATON. The rices found tolerant previously and again in 1982 at IRRI were: IR36, IR4432-38-6, IR2307-247-2, IR10781-143-2, and IR14632-22-3.

Yield trial at IRRI. On an artificial sodic soil (pH 8.5) in the WS, 7 of 22 rices rated tolerant in mass screening tests yielded 1.5 to 1.9 t/ha. These were IR38, IR46, IR52, IR4227-28-3, IR9224-22-2, IR9736-16-1, and IR9884-54-3.

Yield trial in a farmer's field. Of 10 rices tested in an unamended alkali soil, IR46, IR4432-38-6, IR5657-33-2, IR9764-45-2, and IR9884-54-3 yielded from 2.2 to 2.8 t/ha compared with 1.0 t/ha for IR2307-247-2.

Acid sulfate soils. *Mass screening.* One hundred of 188 rices screened in the field at Burabod (pH 3.8, exchangeable sulfate 0.13%) and Balza (pH 3.6, exchangeable sulfate 0.20%), were tolerant; they included IR36, IR52, IR56, IR9828-41-2, IR13525-43-2, and IR19672-155-2.

Yield trials in farmers' fields. Rices previously found tolerant in mass screening tests were evaluated at two locations in Albay. In the DS, mean yields ranged from 4.3 to 4.8 t/ha. The top yielders were IR13423-10-2 (5.8 t/ha) and IR19431-72-2 (5.4 t/ha).

In the WS, acid symptoms were so severe that yields only ranged from 0.71 to 2.7 t/ha. Only IR9752-71-3, IR13149-43-2, IR13423-17-1, and

Table 1. Summary of screening tests for adverse soils tolerance. IRRI, 1982.

Soil condition	Rices (no.)	
	Screened	Tolerant
Salinity	11 912	2 445
Alkalinity	1 009	38
Acid sulfate soil condition	188	100
Fe toxicity	340	14
Peat soil	155	98
Zn deficiency	656	47
P deficiency	616	31
B toxicity	94	22
Aerobic soil		
Al or Mn toxicity	63	13
Fe deficiency	16	3
Total	15 049	2 811

IR56 yielded more than 2.0 t/ha.

Iron toxicity. Fourteen of 340 entries tested on an Fe-toxic soil from Malinao (pH 3.5, active Fe 2.5%) in the greenhouse were rated tolerant. IR36 and IR1974340-3 were outstanding entries during both the DS and WS. IR9729-67-3, IR19743-3-2, IR25924-57-2, IR13149-19-1, B2149B-PN-26-1-1, IR4683-54-2, and IR42 were also tolerant.

Peat soil. *Mass screening.* One hundred and fifty-five rices were screened on a peat soil (pH 5.4, organic carbon 16.4%, available Zn 0.1 mg/kg) where Zn stress was eliminated by ZnO root dip. IR3880-29, IR19058-107-1, and IR21015-80-3 were tolerant.

Concrete-bed tests. IR34 and IR8192-31-2 performed best in the DS. In the WS, IR9764-45-2 did as well.

Yield trials in farmers' fields. Fifteen cultivars were evaluated in two peat soils in Laguna with a basal application of 50-25-50 kg (N,P,K)/ha and with ZnO root dip treatment. At both locations, IR19743-40-3 was the consistent low yielder (1.9 t/ha); IR42 and IR8192-31-2 were the consistent high yielders (3.7 and 3.1 t/ha, respectively).

Zinc deficiency. *Mass screening.* The Zn deficiency tolerance of 656 rices was tested on a farmer's field (pH 7.0, available Zn 0.05 mg/kg) in Laguna Province. IR20, IR22, IR50, IR9752-71-3, and IR13419-113-1 were among the 47 tolerant rices.

Concrete-bed tests. IR34, IR46, IR9754-45-2, and IR8192-31-2 were the best of eight selected rices on a Zn-deficient soil (pH 8.1, available Zn 0.1 mg/kg) in concrete beds.

Yield trials at farmers' fields. Thirty rices were tested on three sites in the 1982 DS. Without Zn amendment, IR34, IR42, IR52, and IR9764-45-2 consistently yielded 2.8-3.8 t/ha at Laguna and Quezon. At South Cotabato, only 13 of 28 rices survived; they included IR34, IR52, and IR15813-504-2 with yields of 1-1.2 t/ha. Yield response among varieties to a 4% ZnO dip at the three sites ranged from 0 to 4.0 t/ha.

In the WS, 17 rices were tested in four Zn-deficient farmers' fields. IR34 and IR9764-45-2 had the highest mean yields (2.5 and 2.8 t/ha, respectively). Of 15 rices tested at two sites in Gen. Santos City, IR13149-19-1 had the highest mean yield (1.7 t/ha). At all sites, response to Zn application ranged from slightly negative for the tolerant rices to 2.6 t/ha for the susceptible ones.

Phosphorus deficiency. *Mass screening.* Thirty-one of 616 rices screened in the greenhouse in culture solution were rated efficient P users. They included IR5, IR32, IR40, IR42, IR56, two IR25588 lines, two PR 174-13 lines, and three 32-Xuan lines.

Yield trials in a farmer's field. During the 1982 DS and WS, 30 IR rices were tested on a P-deficient Ultisol (pH 4.4, Olsen P 1.2 mg/kg). The DS yields confirmed the P utilization efficiency of IR26, IR34, IR40, IR42, IR44, IR46, IR48, IR50, IR52, and IR54 and identified 12 IR lines and B3895-C-11 as promising with yields ranging from 4.3 to 6.6 t/ha.

In the WS, the 10 IR cultivars and the promising lines had mean yields of 3.5 t/ha.

Crop maturity. Absence of P fertilization delayed maturity by as many as 16 d (Table 2). All the susceptible varieties, except one, had short duration (118 d) and the efficient P users had medium duration (130 d).

Boron toxicity. *Mass screening.* Ninety-four rices were tested in the greenhouse on a soil treated with 10 mg B/kg as boric acid. IR8192-200-3 and IR13423-17-1 led the 22 most tolerant lines.

Table 2. Growth duration of some IR varieties or lines on a P-deficient soil. 1982 DS.

Variety	Growth duration (d)	
	25 kg P/ha	No P
Resistant		
IR26	142	147
IR34	131	147
IR46	120	140
IR48	131	135
IR54	128	140
IR9129-209-2	131	146
IR9763-11-2	128	147
IR9764-45-2	138	147
IR21526-37-2	138	147
IR21734-16-3	124	140
Susceptible		
IR36	118	133
IR5982-7-6	118	128
IR6115-1-1	138	145
IR7790-18-12	118	130
IR8608-189-22	118	133
IR13427-40-2	118	124
IR19139-8-2	118	128
IR20985-35-2	118	124

IR13427-40-2 and IR17488-2-3 were the most susceptible.

In the field, the best entries were IR3839-1, IR9729-67-3, IR13423-17-1, IR13429-107-2, IR19660-131-3, and IR21912-131-3.

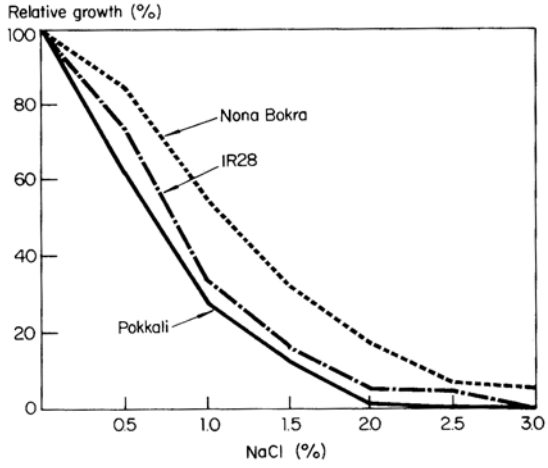
Yield trials at IRRI. During 1982 DS and WS, 50 rices were evaluated on a soil treated with 10 mg B/kg as borax. IR9129-209-2, IR9217-58-2, IR9764-45-2, IR9884-54-3, IR13423-10-2, and IR13426-19-2 had no foliar symptoms and yielded more than 3.5 t/ha in both seasons. IR42, IR46, IR48, IR50, and IR54 consistently displayed greater tolerance than the IR varieties named before 1976.

Aerobic soils. The main growth-limiting factors are Al and Mn toxicities in acid soils and Fe deficiency in both acid and neutral soils.

Mass screening. Thirteen of 63 rices tested in an Ultisol (pH 3.8) in Albay were tolerant. They included IR56, IR1561-228-3, IR5931-110-1, Azucena, and five dryland varieties from Nigeria.

Concrete-bed tests. IR43, IR3839-1, and IR1754-F5B-22 performed well on aerobic soils that ranged from strongly acid (pH 3.8) to alkaline (pH 7.9).

Yield trial in a farmer's field. Twelve dryland varieties earlier found tolerant of Al and Mn toxicities were yield tested in farmers' fields (pH 3.9 and 4.8) in Laguna. In the DS, IR9995-76-2, IR8608-3-2, IR10206-29-2, IR9101-37-1, and IR6115-1-1 yielded best (4.5 to 5.1 t/ha) in the pH 3.9 soil; IR6115-1-1, IR9101-37-1, IR9560-6-3, and IR11297-170-3 performed best in the pH 4.8 soil. In the WS, IR6115-1-1 and IR9995-76-2 did best at both pH levels.



1. Effect of NaCl on growth of callus cultures derived from three rices. IRRI, 1982.

MULTIPLE-STRESS TOLERANCE

Soil Chemistry Department

In 1982, the following varieties or lines with multiple stress tolerance in greenhouse and field tests were outstanding:

- IR36, for its tolerance for salinity, alkalinity, acid sulfate soils, and dryland soils. Except for P deficiency, IR36 has repeatedly shown its wide range of tolerance.
- IR46, for its tolerance for salinity, alkalinity, and acid sulfate soils.
- IR9764-45-2-2, for tolerance for salinity, alkalinity, peat soils, P deficiency, Zn deficiency, and B toxicity.

PHYSIOLOGICAL STUDIES OF SALT TOLERANCE

Plant Physiology Department

Varietal difference in salt tolerance at the cellular level. A rational approach to breeding salt-tolerant rice varieties requires an understanding of the physiological mechanisms that allow rice to tolerate salinity. At present, two mechanisms appear to exist for salt tolerance of nonhalophytes: tissue tolerance and low accumulation.

To determine if these mechanisms operate in rice, the salt tolerances of calluses derived from Pokkali and Nona Bokra, salt-tolerant varieties, and IR28, a susceptible variety, were compared. At the callus level, the salt tolerance of Nona Bokra is much greater than that of Pokkali and IR28 (Fig. 1). Surprisingly, the salt tolerance of Pokkali was found to be as low as that of IR28 at the cellular level. In a separate experiment with the same varieties, Pokkali was found to be a slow Na accumulator. Nona Bokra appeared to tolerate high salinity by regulating the rate of salt uptake and by high tissue tolerance. It is evident that both tolerance mechanisms operate in rice.

Varietal difference in rate of absorption of sodium and chloride. *Short-term experiment.* To determine if rice's tolerance for salinity relates to low accumulation of salts in the shoot, Pokkali, Nona Bokra, and IR28 were compared for their Na

Table 3. Na and Cl contents in Pokkali, Nona Bokra, and IR28 seedlings grown in culture solution with NaCl. IRRI, 1982.

Variety	Hours after salinization	50 mM NaCl				125 mM NaCl			
		Na content (μmol/g)		Cl content (μmol/g)		Na content (μmol/g)		Cl content (μmol/g)	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Pokkali	0	16	70	296	144	14	61	285	152
	6	27	152	273	130	39	287	330	239
	72	113	283	465	296	161	448	490	301
Nona Bokra	0	16	57	268	127	13	61	259	130
	6	27	204	276	141	39	270	315	220
	72	113	352	432	290	222	509	515	338
IR28	0	13	65	172	115	11	65	144	118
	6	33	230	186	169	67	335	254	321
	72	183	357	490	363	396	643	670	431

and Cl absorption. Twenty-one-day-old seedlings were salinized in culture solution with 50 mM and 125 mM NaCl, and sampled 0, 6, 9, and 72 h after salinization. The short periods were chosen to study ion absorption by the plants before the excess salt caused any visible damage. Na and Cl in plant tissue were extracted into water and analyzed with the ion electrode. Na content was much higher in the roots than in the shoots. However, varietal differences in Na content were more pronounced in shoots than in roots (Table 3). Salt-susceptible IR28 accumulated more Na in shoots than tolerant varieties. The Cl content, different from Na content, was higher in shoots than in roots. Varietal difference in the Cl content of shoots and roots was clear only at 125 mM NaCl.

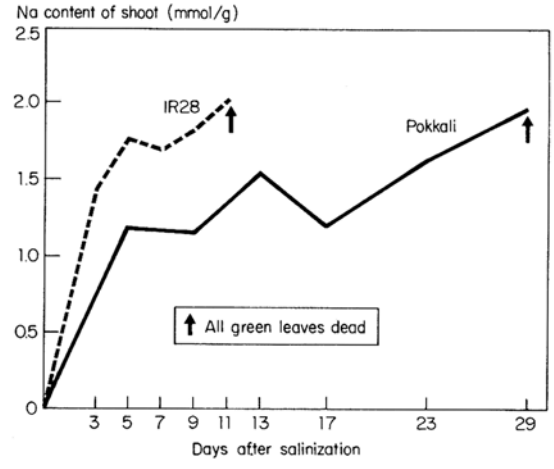
This experiment indicates that salt tolerance of the two tolerant varieties is associated with the ability to prevent Na and Cl accumulation in the shoots.

Long-term experiment. In a study, for a much longer period, of varietal difference in the rate of Na and Cl absorption, 8-d-old seedlings of Pokkali and IR28 were grown in culture solution salinized with 125 mM NaCl until all the leaves were almost dead. As shown in Figure 2, IR28 accumulated Na much faster than Pokkali. Consequently, IR28 seedlings died 11 d after salinization and Pokkali survived for 29 d. Na accumulation was accompanied by Cl accumulation (Fig. 3). Na and Cl absorption was not chemically paired when concentrations of these ions were low (short-term experiment), but it held an equimolar relationship when the concentrations were high (long-term experiment). Thus, both Na and Cl are accumulated in shoots when salt injury becomes apparent. Both the short-term and long-term experiments indicate that Pokkali is a slow accumulator and IR28 is a fast accumulator.

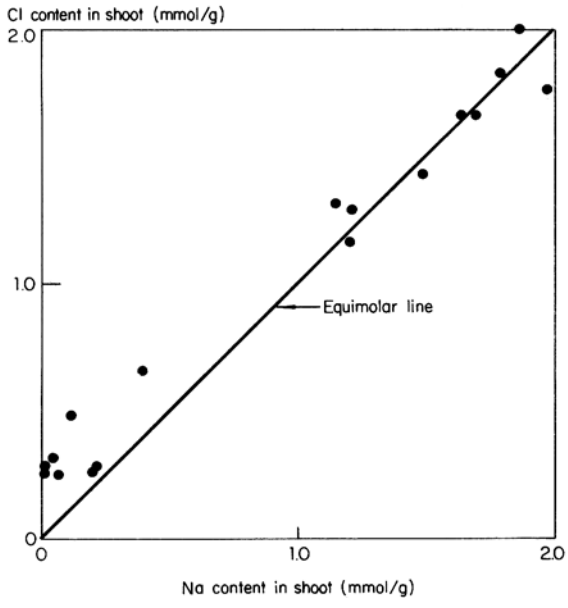
ALUMINUM TOXICITY TOLERANCE AT LOW ALUMINUM CONCENTRATIONS

Plant Physiology Department

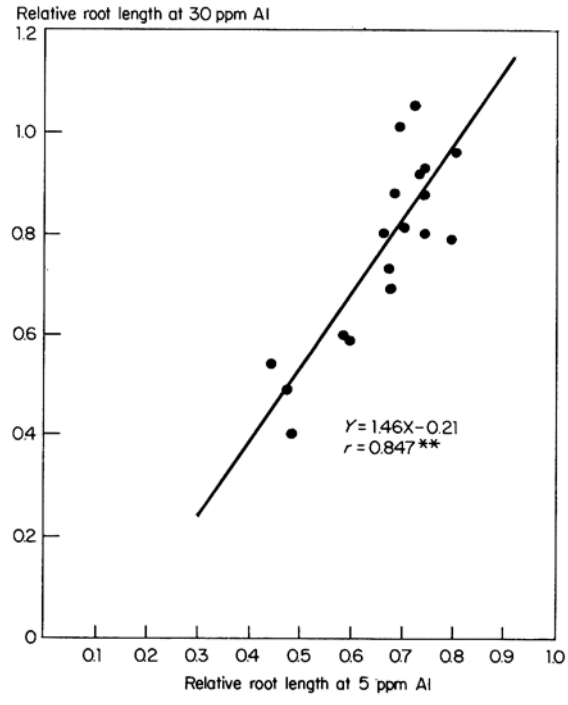
Screening rice cultivars for Al toxicity tolerance is usually done by solution culture using 30 ppm Al.



2. Na uptake by IR28 and Pokkali from culture solution salinized at 125 mM NaCl. IRRI, 1982.



3. Relationship between Na and Cl contents in rice shoots. IRRI, 1982.



4. Relationship between Al toxicity tolerance values screened at low and high Al in culture solution. IRRI, 1982.

In soil solution, 5 ppm Al or even lower concentrations can be toxic to rice. Thus, it is important to know if differences in aluminum toxicity tolerance among varieties screened at 30 ppm Al remain the same at lower Al concentrations.

Nineteen varieties were examined for Al toxicity tolerance at 5, 10, and 30 ppm Al. At 5 and 10 ppm Al, concentrations of Ca, Mg, and P were maintained at one-tenth the standard solution to simulate the soil solution of acid dryland soils. Al toxicity tolerance at 5 ppm Al was closely correlated with that at 30 ppm (Fig. 4). A similar relationship was also obtained for 10 ppm Al. Either 5 or 10 ppm Al combined with a low salt concentration or 30 ppm Al in the standard culture solution can be used to screen rice cultivars for Al toxicity tolerance. Tolerant varieties screened at 5 ppm Al were M1-48, OS4, Monolaya, IAC 3, E425, Moroberekan, Palawan, Khao Lo, Amarelao, and 20 A; the susceptible varieties were IR8, IR45, IR20, and Cica 4.

Genetic evaluation and utilization (GEU) program

Deepwater and flood tolerance

Plant Breeding; Plant Physiology; Multiple Cropping; and Rice Production, Training and Research Departments and Thailand-IRRI Cooperative Deepwater Rice Project

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SCREENING FOR SUBMERGENCE TOLERANCE

Plant Physiology Department

A total of 2,855 entries were screened for submergence tolerance. Of 850 test entries from the germplasm collection, 18 were comparable to the resistant checks FR13A and Nam Sagui 19 (Table 1). Urarkaruppan, an entry from India, showed good submergence tolerance in tests done in artificial facilities. In continuous darkness for 7 d, Urarkaruppan showed better performance than the other entries.

In Thailand, after continuous exposure to darkness for 10 d, 40-d-old seedlings of the submergence-tolerant FR13A survived while submergence-susceptible Khao Dawk Mali 105 died. The findings may have implications for future screening for submergence tolerance.

DIAGNOSING FARMERS' DEEPWATER PROBLEMS

Plant Breeding, Multiple Cropping, and Rice Production Training and Research Departments

In the Philippines, many areas are flooded during the WS.

Farmers were provided with rice samples representing different strategies for deepwater survival to:

- diagnose the type of flooding from the variety reaction, and
- show farmers that varieties may exist to cope with their particular problems.

The 'diagnostic sets' contained 8-10 varieties representing the following key types of deepwater tolerance:

- No tolerance: modern variety (RD9).
- Slight tolerance: tall traditional Khao Dawk Mali 105 (KDML).
- Elongation ability up to 100 cm: modern deepwater variety (RD19).
- Slight submergence tolerance: modern variety with some submergence tolerance (IR8234-OT-9-2).
- Strong submergence tolerance: tall submergence-tolerant traditional variety (FR13A).
- Elongation ability up to 300 cm: Thai floating rice (Pin Gaew 56).
- Fast emergence from flood: Bangladesh floating rice (Baisbish).

Sets were planted at five sites. Table 2 indicates the best surviving varieties in relation to survival strategy and flood characteristics.

Table 1. Outstanding submergence-tolerant varieties screened from 850 germplasm bank entries. IRRI 1982.

Acc. no.	Variety	Origin	Survival (%)		
			Greenhouse (10 d)	Dark (7 d)	Greenhouse or darkroom (8 d)
28045	Munji Sufaid 78	Pakistan	56	85	0
28058	Mushkan Chahi 87	Pakistan	41	80	0
28060	Mushkan 4	Pakistan	55	85	0
28074	Mushkan 312-2	Pakistan	42	75	0
28098	P 580	Pakistan	42	85	0
28151	P 697	Pakistan	51	80	0
28250	Sathra 348	Pakistan	44	70	0
28307	TALK	Pakistan	41	75	0
28311	TIRI 219	Pakistan	60	55	0
28347	17	Pakistan	50	15	0
28375	40	Pakistan	49	30	0
28616	Urarkaruppan	India	56	70	10
28753	Padi Dari	Malaysia	73	55	0
28879	Aus 16	Bangladesh	50	75	0
28167	P 731	Pakistan	38	50	0
28249	Sathra 343	Pakistan	33	70	0
	FR13A (check)		63	85	
	NS 19 (check)		40	100	
	IR42 (check)		11	0	

Table 2. Best surviving varieties at various sites, in relation to survival strategy and flood characteristics, Philippines, 1982.

Site	Type of tolerance[a]							Flood duration(d)	Max depth (cm)
	MV	Tall	MV+Long	MV+Sub	Tall+Sub	Floating	Floating+ fast emerg		
Solana	*	*	*	*	FR13A	*	*	± 7	150
San Clemente	†	KDML	*	IR8234	FR13A	*	Baisbish	3	135
Victoria	*	*	*	*	FR13A	*	Baisbish	5	150
Sibuguey I	*	KDML	*	IR8234	FR13A	*	Baisbish	5	138
Sibuguey II	†	†	†	†	FR13A	†	†.	9	188

[a]MV = modern variety — tolerance; Tall = tall traditional variety — slight tolerance; MV+Long = modern variety with some submergence tolerance; MV+Sub = tall submergence-tolerant traditional variety; Floating = elongation ability up to 300 cm; Floating+fast emerg = fast emergence from flood. † = Completely destroyed; * = Some survival, but very inferior to varieties named.

All flooding types in this sample can be characterized as flash flooding given the good performance of FR13A and the poor showing of the floating rices and the elongating dwarfs. All types clearly did not favor the use of MVs without submergence tolerance.

In the milder floods, the floating rice Baisbish performed well even though it is not known for flash-flood tolerance. Where FR13A survived under water, Baisbish tended to maintain its canopy above the water at all times.

These experiments have helped focus future trials mainly on submergence-tolerant entries and Baisbish derivatives. Also, a good deal of interest in deepwater rice has been aroused among farmers and local officials.

DEEPWATER RICE IN THAILAND

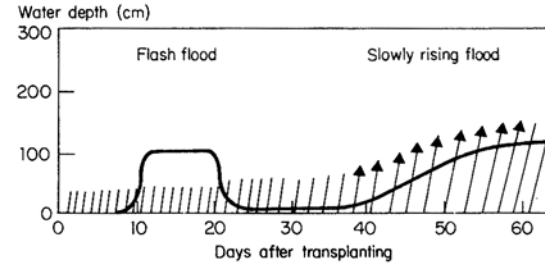
Thailand-IRRI Cooperative Deepwater Rice Project

Breeding work. In Thailand, SPR7270-18 and SPR7233-32-1-6-1, crosses of C4-63, a high quality rice, with the floating rice varieties Khao Nahng Nuey and Leb Mue Nahng 111, respectively, are being evaluated as possible alternatives to RD19.

Production from early lines harvested before flooding. On the Central Plain of Thailand, rain usually starts in April, but in some parts floodwater does not begin to rise until mid-August. In areas without irrigation water, it may be possible to produce a crop from very early rice varieties and still establish the deepwater rice crop. Twelve promising materials were dry-seeded on 26 Apr. Rainfall was well distributed. The field was flat and bunded so there was no surface runoff. Several lines matured within 97 DE, and yields were as high at 3 t/ha for IR15429-268-1-2-1; four other IRRI lines yielded from 2.5 to 2.9 t/ha. RD25 gave 2.4 t/ha. IR36 and IR52, with 110- and 118-d maturity, were too late, but yielded 1.99 and 1.45 t/ha.

Crop cuts in deepwater rice. Average yields of deepwater rice are low. Potential production and the yield variation between locations are being studied. Thirty farmers' fields were sampled in a transect across the southern Central Plain of Thailand. Soil type greatly influenced production: yields were as high as 3.6 t/ha in the west, but down to an average of 1.0 t/ha on acid soils of the Eastern Plain where RRSV was severe. There were marked varietal differences, and several farmers' varieties were collected for testing.

Prototype development combining elongation ability with flash-flood tolerance. In general, submergence-tolerant rice varieties are either tolerant of flash floods for a short duration or can elongate



1. Two flood types are simulated in succession to screen lines adapted to both. IRRI, 1982.

Table 3. Results of selection to combine submergence tolerance with elongation ability. IRRI, 1982.

Cross	Lines (no.)	
	Tested	Both elongation and submergence tolerant
BKNFR78019 BKN6988-52-1/FR13A	15	6
BKNFR780212 DWCT134/FR13A	8	1
BKNFR78023 DWCT156/FR13A	9	9
BKNFR78025[a] SPR7297-405/FR13A	27	17
BKNFR78026 HTAFR77022/FR13A	15	0
BKNFR78057 B922C-MR-91-4/FR13A	7	3
HTAFR78010 BKN6986-108-3/FR13A	9	4
HTAFR79060 KLG6986-161/FR13A	1	1

[a]Including its reciprocal, BKNFR78049.

their stems in slowly rising water. However, in many areas, elongation ability is needed at one growth stage and flash flood tolerance at another.

Starting in 1980, F_2 hybrid populations of crosses between FR13A, a source of outstanding submergence tolerance, and several breeding lines with elongation ability were tested.

In 1982, 91 F_4 lines of eight crosses that had passed two generations of testing for both elongation ability and submergence tolerance were placed in a deepwater tank. They were subjected to a standard submergence test at 45 DAS (10 DT). The 110-cm flood was kept for 10 d then drained.

After 10 d recovery, surviving plants were treated with 5-cm daily increments of rising water until the level reached 110 cm. The hydrograph is in Figure 1.

Surviving lines (Table 3) were harvested and will be further selected for good plant type.

Genetic evaluation and utilization (GEU) program

Low temperature tolerance

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

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NEW VARIETIES

Several entries from the International Rice Cold Tolerance Nursery (IRCTN) have been released as new varieties or are being tested in farmers' fields in countries participating in the IRTP.

Nepal. Two varieties selected from the 1977 IRCTN — Kanchan from IR3941-4-PLPB and Himali from IR2298-PLPB-3-2-1-1B — have been released. Another IRCTN entry, K39-96-1-1-1-2, is being tried in farmers' fields.

Cameroon. Seeds of IR1846-296-3, HPU741, and Kulu have been distributed to farmers for trial.

Upper Volta. Calrose 76 and Fujisaka 5, selected from IRCTN lines, are now recommended.

Larnoo, India. Several lines from the cross K312 (Kuch/IR1846-308-1) were outstanding. IR1846-308-1 was an IRCTN entry from 1975 to 1979. Several crosses with the native varieties were made using this IR1846 line as one of the parents. An outstanding selection from K312 will most likely be named a variety.

Himachal Pradesh, India. Two IRCTN entries, HPU734 and HPU71, were named Himalaya 1 and Himalaya 2.

Kashmir, India. K39-96, a cross of China 1039 with IR580, will be released as a variety.

KOREA-IRRI COLLABORATIVE PROJECT

Rapid generation advance for cold tolerance. In Chuncheon, 57 RGA bulk populations were planted in 1982, compared with 19 in 1981 and 23 in 1980. The same populations were also planted at Jinbu, Unbong, and Yungduk, Korea, for evaluation. Jinbu and Unbong are both high-elevation stations; Yungduk is near the east coast of Korea and is affected by cold and wet sea winds during the early growth stages and dry winds from the west during flowering.

A large number of plants were selected from the RGA bulk materials planted at Chuncheon, Unbong, Jinbu, and Yungduk. The selected plants will be tested in the IRCTN.

Screening for tolerance for low air temperature during the reproductive stage. The outstanding IRCTN entries that flowered between 17 and 23 Aug, when the average temperature was 18.6°C, are listed in Table 1. In spite of the low air temperature, several entries had high spikelet fertility.

Table 1. Best entries from plants that flowered between 17 and 23 Aug (average minimum temperature 18.6°C). Chuncheon, Korea, 1982.

Designation	Heading date (Aug)	Fertility (%)
Ching-Hsi 15	17	95
IR19746-28-2-2-3	21	95
K434	21	94
Shoa-Nan-Tsan	21	93
YR1641-GH59-1	21	91
IR18476-55-2	22	93
IR20910-B-67	23	96

IR18476-55-2 had high fertility even at late planting. It had high fertility in the cold-water screening nursery and tolerance for both low air and low water temperatures. There is no correlation between spikelet fertility in plants grown in low water temperatures and plants grown in low air temperatures.

Rice cold tolerance screening nursery. The most serious problem resulting from low temperatures at meiosis and heading is high sterility.

Several IR lines had high spikelet fertility even at 17° C water temperature. In 1982 there were many good lines coming from RGA. IR20656-R-R-R-1-3 (97% fertility) and SR4095-14-3-1-4 (98% fertility) were especially outstanding.

Leaf yellowing, one of the earliest symptoms of cold-temperature damage in rice during the vegetative stage, can occur at any growth stage. Thirty percent of the 1,103 plants screened had a discoloration score of 3 (on a scale of 1-9), similar to that of the resistant check. One entry, Wasetoramochi, had a score of 1. Entries selected in Banaue had very poor discoloration scores. Most of the entries selected in the experiment stations in Korea, except those from Honam, had relatively good tolerance for leaf discoloration. Entries from the IRCTN generally had good discoloration scores.

Several entries in the IRCTN had a high number of spikelets per panicle (Table 2). Most of the entries came from Himachal Pradesh (HPU), Kashmir (K), and Bulgaria (B) where there seems to be a preference for large panicles.

Observational yield trial. The OYT has shown the advances made in crosses at IRRI and selected

Table 2. Entries with large panicles in the late IRCTN planting. Chuncheon, Korea, 1982.

Designation	Spikelets (no./panicle)
B298B-SR-85-3-2-4	162
H115-20-1-1	173
HPU5039-PLP13-6-6	187
HPU5070-NAG-3-5-3	174
HPU5101-NAG-1-2	187
IR13155-4-1	176
IR15889-113-3	190
IR22623-R-R-4-3	176
Jubilieni	160
K39-96-3-1-1-1-2	173
K315	161
K436	156
Komsomolski	195
Lieto	183
PVT-32/E	165
Salvra	163

Table 3. High-yielding entries in the OYT. Chuncheon, Korea, 1982.

Designation	Grain yield (t/ha)
IR8455-K2	8.4
Suweon 287	7.8
IR5716-18-1	7.4
IR9129-136-2-2-1-2	7.1
IR8608-298-3-1-1-2	7.1
IR9758-K2	7.1
IR9224-K1	6.9
IR9202-6-1-1	6.9
IR7167-33-2-3-3-1	6.7
SR5204-39-2-1	6.7
IR13155-60-3-1-2-1	6.6
SR4131-19-3-1	6.6
Hokuriku 109	6.5
IR7167-33	6.5
SR5204-39-5-3	6.5

in cooperation with other countries. The number of IRRI entries (22 of 80) greatly increased in the 1982 OYT. Ten of these were included in the best 15 entries (yields higher than 6.5 t/ha) (Table 3).

The highest yielder, IR8455-K2, was selected in Kashmir, India. Similarly, IR9758-K2 and IR9224-K1 were also Kashmir selections. The other IRRI lines came from selections in the IRCTN in Korea. IR9202-6-1-1, IR7167-33-2-3-3-1, and IR7167-33 were also high yielders in the previous OYT.

The poor yields of some of the entries were mainly due to low spikelet fertility caused by neck blast infection. Lodging occurred in 16% of the entries.

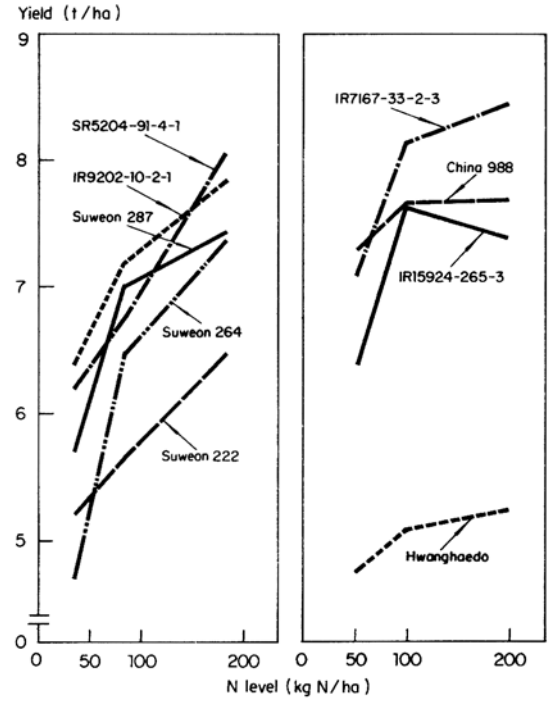
In general, the entries had good seedling vigor, well-exserted panicles, and high fertility.

Nitrogen response of elite varieties and lines under low water temperature at vegetative stage. Rice varieties respond differently to N fertilizer. The optimum N level for maximum grain yields has been shown to differ among varieties.

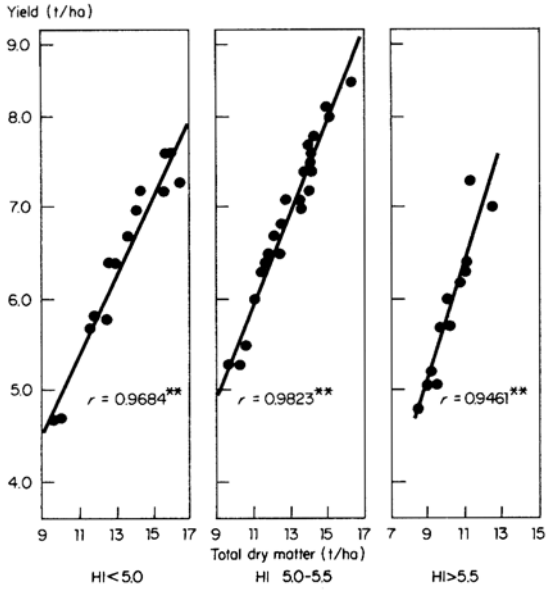
In selecting lines to be tested at different low-temperature rice-growing areas, two N levels may be necessary. High N levels (>150 kg/ha) are used in areas like Korea, Japan, and China. However, low N levels (<100 kg/ha) are generally used in the hill areas of India, Nepal, Indonesia, and Philippines.

The grain yield response to different N levels showed two types, one in which the maximum N level is probably beyond 200 kg N/ha and the other in which the optimum N level is about 100 kg N/ha (Fig. 1).

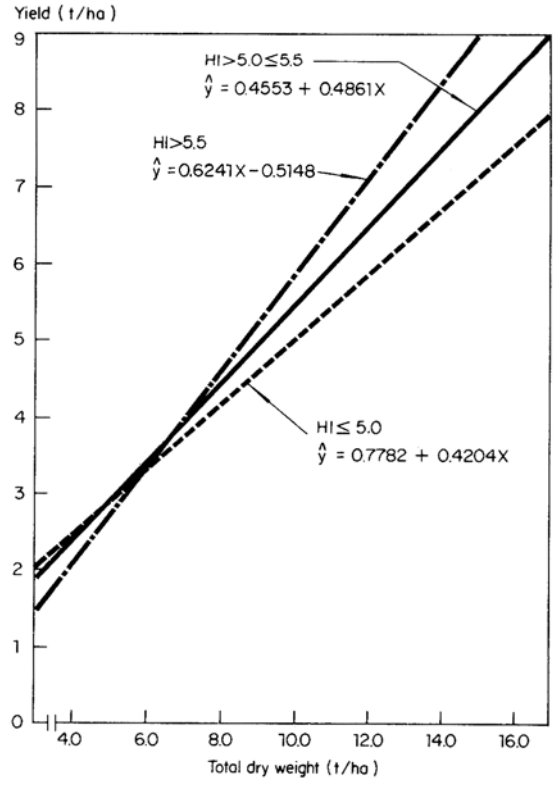
IR7167-33-2-3, IR9202-10-2, and China 988 showed consistently high yields regardless of N level. IR7167-33-2-3 had the highest yield (8.4 t/ha)



1. Grain yield response to different N levels. Chuncheon, Korea, 1982.



2. Relationship between total dry matter and grain yield at different harvest indices (HI). Chuncheon, Korea, 1982.



3. Regression lines for grain yield and total dry matter at different harvest indices. Chuncheon, Korea, 1982.

although several lines had yields only slightly lower.

Generally, the entries with high yields at low N levels also yielded high at high N levels. It is possible, however, that at higher N levels (>200 kg N/ha), the present high yielders (IR7167-33-2-3 and IR9202-10-2-1) will not yield any higher because of sterility and lodging and the shorter statured varieties (SR5204-91-4-1 and Suweon 287) would produce yields higher than 8 t/ha.

It is possible that the shorter statured rices can stand higher N levels and yield higher although they give comparatively lower yields at low N levels. This would indicate a different selection criteria for areas using high vs low N levels.

Farmers from many hill rice areas of India and Nepal apply relatively low levels of N fertilizer. In such areas, varieties such as China 988 that have relatively high yields at low N levels should be used.

There is an optimum N level for different varieties and it should be determined to make the use of N fertilizer profitable.

With the entries grouped into three on the basis of harvest index (HI), the highest grain yields were obtained at HIs of 5.0 to 5.5 and not at >5.5 (Fig. 2). Yields were also relatively high at <5.0. Although the higher HIs should increase yield potential more efficiently, results of tests using available varieties and N levels showed that high yields came from plants with HIs less than 5.5.

At lower yields (3.5-4.0 t/ha), differences in HIs between 4.5 and 5.5 do not seem important (Fig. 3). The regression line even suggests that lower or nonsignificant yield differences will be obtained at low total dry matter weight at harvest (2-4 t/ha). At poor management levels or poor soil fertility, HI differences may not be important.

An HI >5.5 will give higher yields at a given total dry matter above 8 t/ha than a lower HI. However, higher yields at HI >5.5 may be more difficult to obtain in present varieties.

A high and low N level should be used in screening N-response varieties for temperate areas such as Korea, where farmers use high N levels, and for high-altitude areas such as Kashmir, India, where low N levels are used.

Genetic evaluation and utilization (GEU) program

Innovative breeding methods

Plant Breeding, Plant Pathology, and Plant Physiology Departments; Collaborators in Philippines, India, and Korea

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TISSUE CULTURE

Plant Physiology Department

Somaclonal variation in visible traits. The tissue culture cycle itself generates a wide range of variability in various traits of rice. To study the frequencies of varieties in visible traits, plants were regenerated from calluses of Taichung 65 that had been grown up to the third passage.

Unusual traits in R1 plants (first generation of the regenerate) included abnormal glumes (open spikelets, long glumes, and small and round glumes), awns, dwarfs, sterility, stripes, and tetraploids. Tetraploids, high sterility, and other traits were recorded (Table 1). Tetraploids in rice are characterized by somewhat stunted growth, fewer panicles, thicker and coarser leaves, thicker culms, poor panicle exsertion, larger grain size and awns, and high sterility (less than 50% fertility).

About 15% of the R1 plants had high sterility, caused partly by environmental factors. Tetraploid frequency was 3.4%, and obvious variations, such as stripes and abnormal glumes, were 0.9%. Some of the abnormal characters observed in R1 plants, such as high sterility and dwarfness, might be due to chromosomal aberration. Occurrence of tetraploid plants is another indication of that type of variation.

Table 1. Observed variants of Taichung 65 in R1 plants. IRRI, 1982.

	Total	<50% fertility		Tetraploid		Others	
1.5% NaCl							
Callus lines (no.)	16	9		3		3	
R1 plants (no.)	165	22		5		4	
1.0% NaCl							
Callus lines (no.)	35	10		5		1	
R1 plants (no.)	201	18		19		1	
0% NaCl							
Callus lines (no.)	58	20		1		2	
R1 plants	201	18		19		1	
Total[a]							
Callus lines (no.)	109	39	(35.8)	9	(8.3)	6	(5.5)
R1 plants (no.)	742	108	(14.6)	25	(3.4)	7	(0.9)

[a]Numbers in parentheses are percentages of variants of the total callus lines or plants.

Plants originating from the same callus line varied in the expression of these characters (genotype). In R2 plants, several kinds of chlorophyll mutants were observed at the seedling stage: 1) albino, 2) lethal yellow, 3) pale green, and 4) stripes. The pooled frequency of chlorophyll mutants measured for 1,259 lines was 8.8/100 R2 lines. This was as high as that obtained by irradiation, but lower than that induced by chemical mutagens. Table 2 summarizes frequencies of some visible traits, singly or in combination, in R2 lines of Taichung 65. Morphological variations include the appearance of unusual glumes or grains, panicles, leaves, and tiller arrangement. Forty-six percent of the regenerates were considered normal and 54% were variants. Spikelet fertility of R2 plants ranged from 0 to almost 100%; the parent plants showed stable and high fertility (>90%). Among the six traits examined, sterility was most pronounced; it alone accounted for 18% of the total R2 lines and

Table 2. Frequencies of variation in visible traits in R2 plants of Taichung 65. IRRI, 1982.

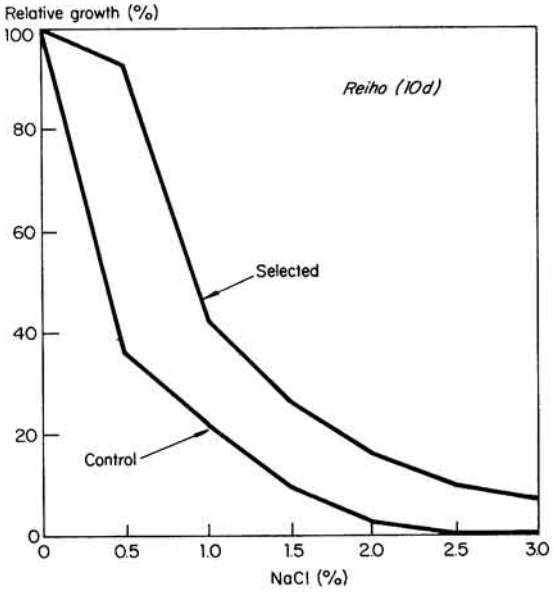
Variant traits[a]	R2 lines (no.)	Frequency[b]
Normal	238	45.6
bl	16	3.1
ch	26	5.0
d	36	6.9
m	19	3.6
s	96	18.3
bl, d	3	0.8
bl, m	5	1.0
ch, d	16	3.1
ch, l	1	0.2
ch, m	1	0.2
ch, s	7	1.3
d, m	4	0.8
d, s	24	4.6
m, s	12	2.3
bl, ch, m	1	0.2
ch, d, m	1	0.2
ch, d, s	3	0.6
ch, m, s	3	0.6
d, m, s	5	1.0
ch, d, m, s	4	0.8
Total of variant traits	283	54.4

[a]bl = brown leaf spot, ch = chlorophyll mutation, d = dwarf, l = late heading, m = morphological variation, s = sterility. [b]No. of lines that segregated variants ÷ no. of lines observed X 100.

was about 30% when combined with other traits. Thus frequency of variants without high sterility was about 25%. The proportion of variants will increase if more traits are examined. Somaclonal variation observed in visible traits suggests that similar variation occurs in physiological and biochemical traits.

Salt-tolerant calluses. When callus is cultured on a salt-enriched medium, some of its cells may gain salt tolerance and proliferate faster than the others. Two callus lines of Reiho and Norin 20 derived from immature grains were continuously cultured on the modified Murashige and Skoog medium containing 8 g/liter of both casein hydrolysate and yeast extract with 1.5% NaCl for 24 and 52 wk. After 24 wk, there was only a slight indication that the callus had gained some degree of salt tolerance. After 52 wk of such culture, however, the callus had gained a substantial degree of salt tolerance (Fig. 1). Plant regeneration from the salt-tolerant calluses is now underway.

Salt-tolerant variant plants. Salt-tolerant variant plants can be obtained from the cultures never exposed to high salinity because tissue culture itself generates a wide range of variability in many plant traits. As shown in Table 3, the frequency of salt-tolerant variant plants produced from the cultures grown in the absence of salinity increases with an increase in length of callus culture. Indeed, a selected variant from this group showed a very high survival rate compared with the parent in a salinized culture solution (Table 4). However, salt tolerance of the variant is still lower than that of the salt-tolerant variety Nona Bokra. Another way of using tissue culture is to modify morphological traits of salt-tolerant varieties. Nona Bokra is salt-tolerant but it has open tillers, which is a drawback to yield. Of 426 plant lines that contained 7,191 plants, one variant was found to have a compact tiller arrangement, slightly shorter plants, earlier maturity, and 20% higher yielding potential than the parent.



1. Growth curve of calluses cultured for 52 wk on the media with or without 1.5% NaCl in response to a gradient of NaCl concentration in the medium. Callus was induced from 10-d-old seed of Reiho. IRRI, 1982.

Table 3. Frequency of salt-tolerant variants in R2 plants regenerated from Taichung 65 calluses.[a] IRRI, 1982.

Passages (no.)	Lines tested (no.)	Variant lines[b] (no.)	Frequency[c] (%)
1	23	0	0.0
2	30	5	16.7
3	29	6	20.7
5	15	5	33.3

[a]About 30 seedlings of each line were salinized for 15 d and seedlings that survived were counted. Parent showed 8% of survival. [b]Lines that showed more than 40% of survival. [c]No. of variant lines ÷ no. of lines tested × 100.

Table 4. Survival rate under high salt stress (0.75% NaCl) of parent variety and a selected salt-tolerant variant derived from tissue cultures. IRRI, 1982.

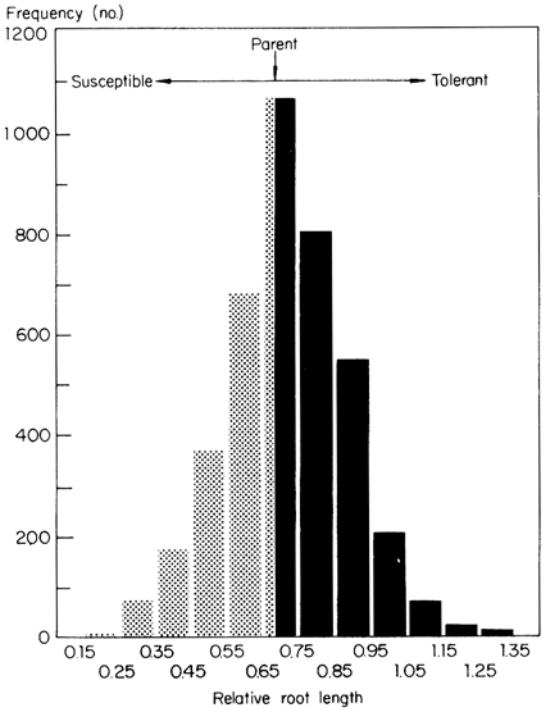
	Live plants (%) on 15th day after salinization[a]
Taichung 65 (parent)	9
A selected variant	60
Nona Bokra (salt-tolerant)	97

[a]Salinization was started at leaf age of 3.0 d.

Aluminum toxicity-tolerant variants. A total of 3,991 R2 plants from 472 lines were regenerated from calluses of Taichung 65 grown in the absence of Al in a culture medium. Al toxicity tolerance was examined by measuring the root growth of young seedlings in the presence of 30 ppm Al in

culture solution. Variation was found in increasing and decreasing tolerance for Al (Fig. 2). Some R2 plants were highly tolerant of Al; their roots at 30 ppm Al were even longer than those of the parent at 0 ppm Al. This suggests that roots of these variants are longer than those of the parent in the absence of Al in culture solution. Occurrence of Al-tolerant variants appears to increase with the increase in length of callus culture; the frequency increased from 18/100 plants for 4 wk (passage 1) to 46 plants/100 plants for 20 wk (passage 5), giving an overall average of 34/100 plants (Table 5). The tissue culture cycle itself appears to generate a wide range of variability in Al toxicity tolerance.

Increasing plant regeneration efficiency. Efficiency of plant regeneration declined with increasing callus age (Table 6). The regenerative capacity of calluses obtained from immature seeds was maintained higher than that of calluses from mature seeds in all the varieties except Nona Bokra. However, even calluses derived from immature seeds lost their regenerative capacity after 48 wk of subculture. In addition, use of immature seeds does not increase plant regeneration in most indicas, particularly IR lines. At present, low efficiency in plant regeneration from long-term cultured callus and from IR lines and other indicas seriously hampers the application of tissue culture to rice improvement. For a given variety, choice of explant and composition of culture medium greatly affect the regeneration efficiency. An intensive study is now under way to increase plant regeneration efficiency of IR lines and long-term cultured callus by choosing young inflorescence as an explant and using the two-step method with abscisic acid.



2. Frequency distribution of the relative root length of 3,991 plants from 472 variant lines from Taichung 65 grown in culture solution with 30 ppm Al. Relative root length of the parent, 0.68. IRRI, 1982.

Table 5. Frequency of aluminum-tolerant variants in R2 plants regenerated from Taichung 65 calluses[a]. IRRI, 1982.

Passage (no.)	R2 lines tested (no.)	R2 plants tested (no.)	Frequency of variant production[b] (%)	
			Lines	Plants
1	69	624	36	18
2	76	674	50	17
3	23	84	70	46
4	118	1093	87	43
5	60	506	87	46
Overall	346	2081	66	34

[a]Subjected to repeated cycles of subculture without selection pressure. [b]Variants have roots longer than average plus 3 X standard deviation of the parent in the presence of 30 ppm Al in culture solution.

Anther culture. In 1982, anthers of 18 F_1 reciprocal crosses of indica/indica, indica/japonica, japonica/japonica, and japonica/indica rice varieties were cultured (Table 7). A simple linear correlation between the number of calluses plated and the number of green plants regenerated among the 18 crosses was studied. The results showed that the computed r values of 0.514 is significant at the 5% level of significance. Seeds from the regenerated homozygous diploid plants were grown in the field during the 1982 WS and plants coming from an individual anther culture-derived plant did not exhibit phenotypic variations, suggesting their homozygous nature.

The incorporation of cold tolerance in rice at the seedling stage is different and the progenies of crosses involving cold-tolerant varieties usually

Table 6. Efficiencies of plant regeneration from calluses that originated from seeds at different developmental stages, cultured 12 to 48 wk. IRRI, 1982.

Variety	Developmental stage of seeds (d)	Efficiency (%) when calluses were cultured for					
		12 wk	16 wk	20 wk	24 wk	28 wk	48 wk
Fujisaka 5	10	61.5	34.3	20.0	13.0	23.0	0.0
	20	27.3	44.4	26.7	40.0	18.2	0.0
	30,	59.1	48.5	28.2	17.6	11.1	2.5
	mature[a]	17.0	12.9	11.4	7.8	12.9	–
Norin 20	10	37.5	43.0	14.8	22.6	20.7	7.5
	20	29.2	25.0	25.0	17.4	45.5	12.5
	30,	70.6	48.9	51.1	30.0	47.2	6.2
	mature[a]	12.5	6.0	17.5	7.5	6.0	–
Reiho	10	56.4	50.0	20.7	20.7	20.0	11.1
	20	39.6	42.5	24.3	26.7	17.0	7.5
	30,	80.0	33.3	27.2	21.8	8.3	3.3
	mature[a]	31.3	21.7	25.4	14.2	14.6	–
Taichung 65	10	52.9	51.5	31.4	28.1	30.0	2.5
	20	48.6	56.7	27.9	47.2	60.5	4.0
	30,	61.8	61.5	35.3	81.1	–	0.0
	mature[a]	61.8	50.8	38.8	25.5	32.9	–
ADT 28	10	47.7	21.1	18.8	15.4	0.0	0.0
	20	38.2	0.0	20.0	4.5	15.4	0.0
	30,	31.0	30.0	25.0	0.0	22.2	0.0
	mature[a]	15.8	48.6	15.0	40.0	2.2	–
Nona Bokra	10	8.6	35.7	37.5	14.2	0.0	0.0
	20	8.8	51.5	42.8	16.1	9.5	0.0
	30,	35.7	32.1	21.2	23.0	10.5	0.0
	mature[a]	53.5	58.8	64.7	40.0	39.7	–

[a]11-, 15-, 19-, 23-, and 27-wk-old calluses were used. Calluses were cultured on medium I without yeast extract and casein hydrolysate.

show very little or no tolerance. Anther culture-derived plants of F_1 sexual crosses whose parents differ in cold tolerance were tested for cold tolerance at the seedling stage (Table 8). Some plants showing tolerance scores of 1 or 3 have been selected and will be used for further evaluation.

Rice varieties, identified as responding well to anther culture, could be used in basic studies and as parents for transferring the capacity of callus production and green plant regeneration to varieties that respond poorly, but have other desirable characteristics. Likewise, by just culturing the anthers, it is possible to identify among the regenerated plants some variants that behave differently from the parents. Table 9 shows a comparison of agronomic characteristics of 14 Taipei 309 anther culture-derived plants and their parents using the least significant difference (LSD) test. Each anther culture-derived plant represents an average of 24 replicates. The LSD analysis showed that the anther culture-derived plants had longer culms, shorter panicles, and taller plants than the parents. However, there was no significant increase in panicle number.

The meiotic behavior of pollen mother cells of 41 random plants regenerated from anther culture of varieties and F_1 hybrids was studied. Chromosome counts of at least 50 dividing cells of each plant showed that 34% of the plants were haploids and 66% diploids (Table 10). No other ploidy level was observed. Among the diploid plants, four showed meiotic aberrations such as late congression, separations, bridges, laggards, and micronuclei.

HYBRID RICE

Plant Breeding and Plant Pathology Departments; Collaborators in the Philippines, India, and Korea

Heterosis studies (*Plant Breeding and collaborators*). *Yield advantage of F_1 rice hybrids under*

Table 7. Green plant regeneration from pollen culture of 18 F_1 reciprocal crosses. IRRI, 1982.

Parents[a]	Anthers plated (no.)	Calli plated for green plant regeneration[b] (no.)	Green plants regenerated (no.)
BG90-2/Tatsumi mochi (I/J)	274	64	132
Tatsumi mochi/BG90-2 (J/I)	238	23	29
BG90-2/IR48 (I/I)	180	8	3
IR48/BG90-2 (I/I)	192	20	40
BG90-2/Suweon 290 (I/I)	82	6	6
Suweon 290/BG90-2 (I/I)	383	48	35
BG90-2/Taipei 309 (I/J)	1085	445	80
Taipei 309/BG90-2 (J/I)	193	15	10
Tatsumi mochi/Suweon 290 (J/I)	341	79	58
Suweon 290/Tatsumi mochi (I/J)	68	0	0
IR48/Suweon 290 (I/I)	609	171	43
Suweon 290/IR48 (I/I)	100	12	13
IR48/Taipei 309 (I/J)	214	16	1
Taipei 309/IR48 (J/I)	240	111	21
Suweon 290/Taipei 309 (I/J)	484	19	0
Taipei 309/Suweon 290 (I/J)	106	0	0
Taipei 309/Tatsumi mochi (J/J)	171	103	30
Tatsumi mochi/Taipei 309 (J/J)	58	48	1
Total	5018	1188	502
Av		66	27.89

[a] J = japonica, I = indica. [b] The number of calluses plated for plant regeneration is only a part of the total number of pieces of calluses actually obtained from pollen grains.

Table 8. Cold tolerance response of anther culture-derived plants. IRRI, 1982.

Cross	Lines (no.)	Seedling cold tolerance score[a]				
		1	3	5	7	9
With a cold-tolerant parent						
Tatsumi mochi/Suweon 290 (J/I)	17	–	1	8	7	1
Tatsumi mochi/BG90-2 (J/I)	7	–	1	4	2	–
Taipei 309/Tatsumi mochi (J/J)	14	–	–	10	4	–
BG90-2/Taipei 309 (I/J)	13	3	10	–	–	–
Silewah/Taichung 65 (I/J)	1	–	1	–	–	–
Parents						
Tatsumi mochi (J)		–	x	–	–	–
Suweon 290 (I)		–	–	–	x	–
BG90-2 (I)		–	–	–	–	x
Taipei 309 (J)		–	x	–	–	–
Silewah (I)		–	x	–	–	–
Taichung 65 (J)		–	x	–	–	–

[a] Scale of tolerance: 1 = seedlings dark green, 3 = seedlings light green, 5 = seedlings yellow, 7 = seedlings brown, 9 = seedlings dead.

Table 9. LSD test of some agronomic characteristics of 14 anther culture-derived plants from Taipei 309. IRRI, 1982.

Anther culture plant no.	Plant height	Culm length	Panicle length	Panicle number
96	111.89^{ns}	87.39^{ns}	24.17^{ns}	14.88^{ns}
133	116.56*	93.52**	23.02**	12.79^{ns}
152	117.67**	93.81**	23.85^{ns}	11.58^{ns}
157	115.52*	92.79**	22.73**	11.46^{ns}
171	114.25^{ns}	91.41**	22.83**	10.04^{ns}
182	111.56^{ns}	88.56*	22.95**	9.62^{ns}
184	116.29*	93.56**	22.73**	10.33^{ns}
196	111.44^{ns}	87.31^{ns}	23.92^{ns}	9.83^{ns}
204	107.87^{ns}	89.60**	23.10**	11.21^{ns}
185	116.17*	92.95**	23.21**	10.62^{ns}
331	108.69^{ns}	84.54^{ns}	22.98**	12.54^{ns}
318	109.79^{ns}	87.37^{ns}	22.42**	9.62^{ns}
386	108.98^{ns}	89.66*	20.79**	10.21^{ns}
356	107.14^{ns}	84.31^{ns}	22.96**	12.29^{ns}
Taipei 309 (from seed)	109.12	84.72	24.39	10.08

irrigated conditions. Some experimental F_1 hybrids continued to show positive standard heterosis (advantage of F_1 over the best check variety) for yield or productivity per day, or both, at the IRRI farm; Maligaya Rice Research and Training Center (MRRTC), Muñoz, Philippines; Kapurthala, Punjab, India; and Suweon, Korea (Table 11). Two combinations, IET 3257/IR2797-105-2-2-3 and IET 3257/IR54, found superior in 1981 trials at the IRRI farm (Annual report for

Table 10. Ploidy level of anther culture plants derived from F_1s of sexual crosses and varieties, as determined by chromosome study of pollen mother cells. IRRI, 1982.

F_1 hybrid or variety	Different anther culture-derived plants studied from each cross or variety (no.)	Level of ploidy	
		Diploids (no.)	Haploids (no.)
BG90-2 X Tatsumi mochi	4	1	3
IR48 X Suweon 290	1	1	–
Suweon 290 X BG90-2	7	2	5
Taipei 309 X Tatsumi mochi	1	1	–
Tatsumi mochi X BG90-2	1	1	–
Tatsumi mochi X Suweon 290	6	6	–
Baekgogna	1	1	–
Giza 170	4	2	2
IR30	1	1	–
IR40	1	1	–
Minehikari	1	1	–
Moosa tarum	1	1	–
Nong Baek	1	1	–
Pai-Kan-Tao	1	1	–
Suweon 290	1	1	–
Taichung Sen Yu 195	1	1	–
Tainan 5	1	1	–
Taipei 177	4	–	4
Taipei 309	3	3	–
Total	41	27	14

1981), were also superior during 1982, indicating that their heterosis effects were consistent.

Yield advantage of F_1 rice hybrids under rainfed, shallow, favorable wetland conditions. During 1981, some experimental F_1 rice hybrids showed yield superiority over check varieties in rainfed wetland conditions in Pangasinan, Philippines (Annual report for 1981). To confirm these observations, 14 experimental hybrids were tested in a trial under rainfed wetland conditions at Nansangaan, Pangasinan Province, Philippines. V20A/IR54 and 97A/IR54 combinations, derived from cytosterile lines from China and restorer lines from IRRI, were significantly superior in yield or productivity per day to check varieties IR36, IR42, and IR52 (Table 12). Their superiority in the 1981 trials indicates that F_1 rice hybrids may also be adapted to favorable rainfed shallow wetland conditions.

The hybrids derived from Chinese male steriles and IRRI restorer lines did not perform as well under irrigated conditions at the IRRI farm and at MRRTC during the WS possibly because of the greater pressure of diseases and insects in the experimental farms than in the farmers' fields. Despite their yield superiority under irrigated and rainfed wetland conditions in Pangasinan, they probably will not be successful. It would be difficult to produce their seed in bulk quantities because the male-sterile parents are susceptible to tropical diseases and insects.

Analysis of yield-heterosis in rice. In the 1981-82 trials, the yield increase in the heterotic combinations resulted from their increased dry matter production or higher HI. The higher HI was attributable to an increase in number of filled spikelets per square meter or increase in 1,000-grain weight. The hybrids tended to have reduced tillering, but the increase in spikelets per panicle overcompensated for the loss.

Heterosis for root characteristics. Two F_1 hybrids, Zhen Shan 97A/IR13420-6-3-3-1 and IET 3257/IR54, were aeroponically grown in the IRRI phytotron along with their parents. Their root characteristics were observed 45 DAS. The results indicated the presence of significant positive heterobeltiosis for root number and root diameter in one of the hybrids (Table 13). There was positive heterobeltiosis for root dry weight and root length in the same F_1 combinations, but the difference was not statistically significant. Difference for root-shoot ratio was minor and nonsignificant. More comprehensive and critical studies on root characteristics of F_1 hybrids showing heterosis for yield will be useful.

F_1 rice hybrids to pyramid blast resistance genes (*Plant Breeding and Plant Pathology*). Most of the blast resistance genes have been found to be dominant. Therefore, the resistance genes in cytoplasmic male-sterile (cms) lines and different resistance genes in restorer lines can be combined easily in the F_1 hybrid providing it with more resistance genes than those of the two parents. Table 14 shows the blast reactions of the parents Seokwang, HR 1619-6-2-1-2-2, and Milyang 54 and the F_1 hybrids Seokwang/Milyang 54 and HR 1619-6-2-1-2-2/Milyang 54. The blast fungus isolate 750778 (IC-13) could attack Milyang 54, but not Seokwang

Table 11. Performance of elite F_1 hybrids in yield trials conducted during 1982.

Hybrid	Yield (t/ha)	Standard heterosis[a] (%)	Growth duration (d)	Productivity (kg/day per ha)	Standard heterosis[a] (%)
IRRI Farm, DS					
IET 3257/IR2797-105-2-2-3	8.9	34.3	129	82	32.2
IET 3257/IR54	8.2	24.2	128	77	24.2
V20A/IR54	6.4	- 3.0	110	72	16.1
IRRI Farm, WS					
IR10154A/IR2307-247-2-2-3	5.4[b]	25.6	115	57	54.0
V20A/IR13420-6-3-3-1	4.2	- 2.3	109	48	29.7
97A/IR54	4.5	4.6	121	45	21.6
MRRTC, Muñoz, WS					
IET 3257/IR42	5.3	6.0	127	50	25.0
V20A/IR54	4.4	-12.0	109	50	25.0
Kapurthala, Punjab, India					
97A/IR2307-247-2-2-3	9.5	33.8	117	99	41.4
V20A/IR2307-247-2-2-3	8.9	25.4	117	93	32.8
COA Farm, Suweon, Korea					
V20A/Suweon 294	8.9	48.3	–	–	–
97A/Suweon 294	7.2	20.0	–	–	–
ORD, Suweon, Korea					
V20A/Suweon 294	9.1	7.1	–	–	–
97A/Suweon 294	8.4	- 1.2	–	–	–

[a]Standard heterosis was estimated in relation to the best check variety in each trial: IR54 (IRRI farm, DS), IR42 (IRRI farm, WS, MRRTC, Muñoz), PR 103 (Kapurthala, Punjab, India), and Suweon 287 (Korea). [b]Mean of two replications only, other means are based on three or four replications.

Table 12. Performance of heterotic F_1 rice hybrids in rainfed wetland conditions. Nansangaan, Pangasinan, Philippines, 1982 WS.

Hybrid or variety	Yield (t/ha)	Growth duration (d)	Productivity (kg/ha per day)
V20A/IR54	7.5 a	121	75
97A/IR54	7.0 ab	124	68
IR36	6.4 bc	112	70
IR42	6.2 bc	132	56
IR52	5.7 c	116	60

Table 13. Heterobeltiosis for root characteristics in two experimental rice hybrids[a] grown aeroponically. IRRI, 1982.

Characteristic	H_1	Heterobeltiosis (%)	H_2	Heterobeltiosis (%)
Root number	55	37.5*	43	-14.0
Root dry weight (g)	0.631	45.7	0.383	-23.8
Root-shoot ratio	0.296	- 2.0	0.255	2.8
Root length (cm)	86.1	6.4	73.2	4.6
Root diameter (mm)	0.61	29.8*	0.49	-19.7*

[a]H_1 = 97A/IR13420-6-3-3-1 (F_1), H_2 = IET3257/IR54 (F_1).

and HR 1619-6-2-1-2-2; the isolate 43 (IH-1) could attack Seokwang and HR 1619-6-2-1-2-2, but not Milyang 54. The parents were susceptible to the mixture of isolates 750778 (IC-13) and 43 (IH-1) but the F_1 hybrids were resistant. The F_1 hybrid HR 1619-6-2-1-2-2/Milyang 54 was resistant to the mixture of isolates 750778 (IC-13) and IK 81-3 (IA-61), and the two parents were susceptible. Thus, the F_1 hybrid breeding approach can help in pyramiding different resistance genes from different parents.

Cytoplasmic genetic male sterility and fertility restoration (*Plant Breeding*). The cytoplasmic-genetic male sterility and fertility restoration system has been found to be a most effective genetic tool for developing F_1 hybrid rices in China. IRRI continued to maintain a collection of cms lines. The cytosterile Zhen Shan 97A, V20A, Er-Jiu-Nan 1A, V41A (all derived from wild rice, *Oryza sativa* f. *spontanea* or *O. perennis*? or WA cytoplasm), Yar Ai Zhao A (Gambiaca cytoplasm), Pankhari 203A (TN1 cytoplasm), Wu 10A (Chinsurah Boro II or BT cytoplasm), and MS 577A (*O. sativa* f. *spontanea* cytoplasm) have been found stable for

Table 14. Leaf blast reactions of two F_1 hybrids and their parents to some isolates and mixtures of isolates. IRRI, 1982.

Parent or F_1 hybrid	Reaction to isolate or mixture of isolates inoculated						
	750778 (A)	43 (B)	IK 81-3 (C)	P 06-6 (D)	A + B	A + C	A + D
Seokwang	R	S	–	S	S	–	S
HR 1619-6-2-1-2-2	R	S	S	–	S	S	–
Milyang 54	S	R	R	S	S	S	S
Hybrid 1[a]					R	–	S
Hybrid 2[b]					R	R	–

[a]Hybrid 1: Seokwang/Milyang 54. [b]Hybrid 2: HR 1619-6-2-1-2-2/Milyang 54.

pollen or spikelet sterility. These lines, however, cannot be used as such to develop F_1 hybrids for the tropics because of their poor adaptability to tropical rice-growing conditions or their unimproved plant type.

Pollen stainability or fertility and spikelet fertility of male-sterile lines. The frequency of different categories of pollen grains in some stable cms (A) and maintainer (B) lines indicated that a majority of the pollen grains of Zhen Shan 97A, V20A, Yar Ai Zhao A, and Pankhari 203A were unstained and withered, and a majority of the pollen grains of Wu 10A and MS 577A were partially stained to completely stained and round (Table 15). Almost all the pollen grains of the B lines were completely stained and round. The spikelet fertility of all A lines with unstained pollen grains was zero when their panicles were bagged, suggesting that unstained pollen grains were unviable. Wu 10A and MS 577A with stained and round pollen grains, did not show any seed set on bagged panicles, indicating that the pollen grains were also unviable and did not affect fertilization. The B lines of all A lines with completely stained and round pollen grains showed 85-94% spikelet fertility. The pollen grains of Wu 10A, derived from Chinsurah Boro II (BT) cytosterility system identified in Japan, are known to abort at the binucleate stage. It appears that stainability reaction and shape of pollen grains in lines is determined by the stage at which the pollen grains abort. The pollen grains aborting at the uninucleate development stage would be unstained, withered, and spherical but those aborting at the binucleate or later stages would be partially to completely stained and round. It is possible that pollen grains of MS 577A, which are stained normally but unviable, may also abort at or after the binucleate stage of pollen development.

Table 15. Frequency of different categories of pollen grains in six A lines and their corresponding B lines. IRRI, 1982.

Line	Frequency (%) of pollen grain in category[a]				Spikelet fertility (%)
	UW	US	PSR	CSR	
Wu 10A	22.8	7.1	25.1	45.0	0
Wu 10B	1.9	2.1	0.1	95.9	87
P 203A	86.5	1.8	4.6	7.1	0
P 203B	0.6	2.0		97.4	94
97A	97.2	2.8			0
97B	0.6	0.5		98.9	92
V20A	97.6	2.4			0
V20B	0.8	0.8		98.4	92
V20A	97.6	2.4			0
V20B	0.8	0.8		98.4	92
YAZ A	90.4	8.4	0.8	0.8	0
YAZ B	1.3	0.8		97.9	85
577A	1.6	5.0	23.4	70.0	0
577B	0.5	1.5		98.0	91

[a]UW = unstained withered, US = unstained spherical, PSR = partially stained round, CSR = completely stained round.

Transfer of the WA cytosterility system into elite lines adapted to tropical conditions. Since 1979 when hybrid rice research at IRRI was revived, it was recognized that the WA cytosterile lines introduced from China were not adaptable to the tropics because of their disease and insect susceptibility. Since then, a number of improved rice varieties and elite breeding lines developed at IRRI and other national rice improvement programs have been identified as effective maintainers. Back-

crossing is in progress to transfer the WA cytosterility system into the genetic background of these elite lines. The stable A lines have been developed after four to six backcrosses in the genetic background of elite lines IR10154-23-3-3, IR10176-24-6-3, IR10179-2-3-1, IR19792-15-2-3-3, IR19807-21-2-2, and Jikkoku Seranai 52-37 (from India). These lines are better adapted to tropical rice-growing conditions.

Cytogenic relationship among male-sterile and maintainer lines. Six of the A lines found stable for pollen sterility — Zhen Shan 97A, V20A, Yar Ai Zhao A, Pankhari 203A, Wu 10A, and MS 577A — were crossed with their corresponding B lines in all possible A/B crosses. The six B lines were also crossed in all possible B/B crosses. The same six A lines and their corresponding B lines were also crossed with a set of elite lines (used as male parent). The F_1 of these crosses were analyzed for their pollen and spikelet fertility.

The pollen and spikelet fertility of all possible crosses involving the six A and their B lines (Table 16) indicated that:

- The male sterility of Wu 10A was maintained by Wu 10B and P 203B; the other maintainers acted as partial restorers.
- The male sterility of 97A and V20A was maintained by all the B lines except YAZ B, which behaved as partial restorer.
- The male sterility of YAZ A was maintained by YAZ B, P 203B, and Wu 10B; the other three B lines behaved as partial restorers.
- The male sterility of MS 577A was maintained only by MS 577B; the crosses with other B lines showed a high frequency of completely stained, round pollens (such as MS 577A) but low spikelet fertility.

These results imply that:

- the cytoplasmic male sterility systems in Wu 10A and P 203A are identical;
- the cytoplasmic male sterility systems in 97A and V20A are identical;
- the cytoplasmic male sterility system in YAZ A is different from those of Wu 10A/P 203A, 97A/V20A, and MS 577A; and
- the cytosterility system of MS 577A is different from those of Wu 10A/P 203A, 97A/V20A, and YAZ A.

Pollen and spikelet fertility of all possible B/B crosses (Table 17) indicated that:

- crosses involving 97B, V20B, YAZ B, and 577B were normally fertile, without showing reciprocal differences;
- crosses involving Wu 10B and P 203B used

Table 16. Frequency of completely stained round (CSR) pollen and spikelet fertility, of F_1s derived from the six A lines with their corresponding B lines in all possible crosses. IRRI, 1982.

A line	CSR pollen and spikelet fertility[a] (%) of F_1s involving						Mean
	Wu 10B	P 203B	97B	V20B	YAZ B	577B	
Wu 10A	45 (0)	33 (1)	49 (21)	56 (12)	84 (27)	53 (11)	53 (12.1)
P 203A	56 (2)	7.1 (0)	59 (21)	56 (22)	55 (29)	54 (20)	47.6 (15.6)
97A	0 (0)	0 (0)	0 (0)	0 (0)	33 (13)	0 (0)	5.5 (2.2)
V20A	0 (0)	0 (0)	0 (0)	0 (0)	11 (10)	0 (0)	1.9 (1.7)
YAZ A	0 (0)	2.3 (1)	50 (25)	43 (26)	1 (0)	27 (16)	28.7 (11.2)
577A	50 (6)	74 (5)	76 (6)	70 (4)	82 (7)	70 (0)	70 (4.8)
Mean	25.2 (1.3)	19.4 (1.2)	38.8 (12.4)	37.5 (10.7)	44.3 (14.2)	42.2 (7.8)	

[a]Spikelet fertility values in parentheses.

either as the maternal or paternal parent among themselves and with the other B lines showed partial fertility, without showing large and consistent differences among the reciprocal crosses.

Partial fertility of crosses involving P 203B and Wu 10B with the other four B lines may be due to gametic development genes known in rice. Therefore, cytoplasms of the six B lines do not possess factors inducing male sterility.

The values of correlation coefficients for spikelet fertility of A/B crosses involving the six A lines and all the B lines are in Table 18. These values indicated that behavior of Wu 10A and P 203A in crosses with the B lines was highly correlated (r = 0.92); 97A and V20A also showed similar behavior (r = 1). These results further confirmed that cytosterility systems in cytosterile Wu 10A and P 203A, and 97A and V20A, were the same. All other possible comparisons among A lines showed nonsignificant correlations; therefore, the cytosterility systems possessed by the lines should be different.

The values of correlation coefficients on spikelet fertility of crosses involving the A lines with elite lines are in Table 19. The results confirmed the high correlation (r = 0.99) between the behavior of 97A and that of V20A in crosses with elite lines. Behavior of crosses involving Wu 10A and P 203A showed no significant correlation (r = 0.29). Wu 10A is a japonica line and P 203A is derived from Pankhari 203. P 203A gives less fertile hybrids regardless of other parents involved. Therefore, the confounding effect of intervarietal hybrid sterility due to nuclear genes cannot be ruled out. The relationship between Wu 10A and P 203A may be studied further by following up the crosses showing differential behavior in backcross generations where the effects of intervarietal hybrid sterility are reduced.

Correlated behavior of YAZ A and 97A (r = 0.55) and V20A (r = 0.41) may be due to the ability of some elite lines to restore fertility in the two A lines.

Based on these results, the six A lines can be classified into four groups of cytosteriles. These groups and their tentative cytoplasmic constitution are:

- Wu 10A/P 203A — S_1 (designated as BT by Shinjyo, 1969)
- 97A/V20A — S_2 (designated as WA by Yuan, 1977; Lin and Yuan, 1980)
- Yar Ai Zhao A — S_3 (designated as Gam by Lin and Yuan, 1980)
- MS 577A — S_4 (not designated earlier)

Table 17. Frequency of CSR pollen and spikelet fertility in F_1s involving six B lines in all possible combinations. IRRI, 1982.

B line	CSR pollen and spikelet fertility[a] (%) of F_1s involving					
	Wu 10B	P 203B	97B	V20B	YAZ B	577B
Wu 10B	96 (87)	57 (27)	48 (47)	19 (18)	92 (25)	60 (38)
P 203B	49 (28)	97 (94)	45 (46)	31 (25)	37 (26)	44 (20)
97B	76 (41)	47 (49)	99 (92)	99 (89)	99 (84)	97 (70)
V20B	20 (16)	47 (25)	99 (94)	98 (92)	99 (84)	99 (86)
YAZ B	99 (26)	40 (24)	99 (72)	99 (65)	98 (85)	94 (91)
577B	50 (29)	36 (23)	95 (94)	96 (90)	98 (91)	98 (91)

[a] Spikelet fertility values in parentheses.

Table 18. Linear correlation coefficients for spikelet fertility of sets of A/B crosses involving different A lines. IRRI, 1982.

A line	P 203A	97A	V20A	YAZ A	577A
Wu 10A	0.92*	0.69	0.69	0.41	0.24
P 203A		0.55	0.55	0.47	–0.07
97A			1.00**	–0.44	0.46
V20A				–0.44	0.46
YAZ A					0.24

Table 19. Linear correlation coefficients for spikelet fertility of sets of A/elite line crosses involving different A lines. IRRI, 1982.

A line	P 203A	97A	V20A	YAZ A	577A
Wu 10A	0.29	0.06	0.10	0.26	–0.12
P 203A		0.06	0.04	0.33	0.19
97A			0.99**	0.55**	0.16
V20A				0.48*	0.01
YAZ A					0.03

The corresponding nuclear genes interacting with a specific cytoplasmic factor inducing male sterility in these lines may be designated as S_1-rf (for S_1), S_2-rf (for S_2). S_3-rf (for S_3), and S_4-rf (for S_4). Based on these assumptions and the results presented in Table 16, the cytoplasmic and genotypic constitution of the six A and B lines are proposed in Table 20. Studies conducted in China have also shown that the WA cytosterility system is different from the BT system.

Identification of additional sources of cytoplasmic male sterility. Among a set of crosses made in 1980 with *Oryza glaberrima* and some elite lines, the cross *Oryza glaberrima* (Acc. 102726)/IR2797-105-2-2-3^2//IR36 gave increased pollen sterility in successive backcross F_1 generations. It appears distinctly possible to develop an A line from *Oryza glaberrima* cytoplasm. Because IR36 is a restorer of WA cytosterility system, the A line developed in *Oryza glaberrima* cytoplasm should possess a different cytosterility system. If found stable, the cytosterile IR36 would make a very good female parent to develop F_1 rice hybrids for the tropics because it is the most widely adapted rice variety.

Identification of maintainer and restorer lines for various male-sterile lines. On the basis of fertility behavior of test cross F_1s from crosses of the six A lines with elite lines and of B lines with elite lines, several effective B lines were identified (Table 21) for cytosteriles: Zhen Shan 97A, V20A, Yar Ai Zhao A, Wu 10A, P 203A, and MS 577A.

No effective restorer (R) line was identified for Wu 10A, and the restoration ability of line IET 5103 for cytosterile MS 577A needed confirmation.

Large-scale screening of elitė lines for maintenance-restoration ability of WA cytosterility system was continued. A total of 400 additional lines were test-crossed during the year and 25 were found effective maintainers and 102 effective restorers; the remaining lines were partial restorers.

Use of restorer lines identified at IRRI in hybrid breeding program in China. Most of the commercial indica rice F_1 hybrids in China involve R parents from IRRI (IR24, IR26, IR30, IR661, and IR665). IRRI and Chinese scientists have been working collaboratively for the past 3 yr to identify additional R lines among IRRI's elite breeding lines, which possess multiple disease and insect resistance. Through the collaborative research, elite R lines IR9761-19-1, IR10167-129-3-4, IR15847-135-1-1, IR19746-28-2-2-3, and IR21177-22-3-1-2, have been identified at Hunan Academy of Agricultural Sciences. These lines have multiple disease and insect resistance and give F_1 hybrids that are 10-15 d earlier in maturity than the currently grown commercial F_1 hybrid Wei U 6 (±135 d). These early-duration hybrids are in various stages of testing and when released may be grown in the first crop season (March-April to June-July) and late in the second crop season. This would help expand the area planted to hybrid rice in China.

A joint study between IRRI and China was conducted to identify effective R lines among elite breeding lines developed at IRRI and other na-

Table 20. Proposed cytoplasmic and genotypic constitution of the six A and their B lines. IRRI, 1982.

A/B line	Cytoplasmic constitution				Genotype							
Wu 10A	S_1				S_1-rf	S_1-rf	S_2-rf	S_2-rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
Wu 10B	N_1				S_1-rf	S_1-rf	S_2-rf	S_2-rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
P 203A	S_1				S_1-rf	S_1-rf	S_2-rf	S_2-rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
P 203B	N_1				S_1-rf	S_1-rf	S_2-rf	S_2-rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
97A		S_2			S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-Rf	S_4-Rf
97B		N_2			S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-Rf	S_4-Rf
V20A		S_2			S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-Rf	S_4-Rf
V20B		N_2			S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-Rf	S_4-Rf
YAZ A			S_3		S_1-Rf	S_1-Rf	S_2-Rf	S_2-Rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
YAZ B			N_3		S_1-Rf	S_1-Rf	S_2-Rf	S_2-Rf	S_3-rf	S_3-rf	S_4-Rf	S_4-Rf
577A				S_4	S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-rf	S_4-rf
577B				N_4	S_1-Rf	S_1-Rf	S_2-rf	S_2-rf	S_3-Rf	S_3-Rf	S_4-rf	S_4-rf

tional programs. The results indicated that about 15% of the lines tested in China and 24% of the lines tested at IRRI were effective restorers (Table 22). The restoration ability of the remaining R lines was site specific. Frequency of R genotypes was higher in a tropical environment than in a subtropical environment.

Inheritance of fertility restoration. The inheritance of fertility restoration was studied in a cross involving A line Zhen Shan 97A and R line IR54.

Table 21. Effective maintainers and restorers of six A lines. IRRI, 1982.

	97A	V20A	YAZ A	Wu 10A	P 203A	577A
		Whecheon Yukdo Jikkoku Seranai 52-32				IR19795-17-3-2 IET 3257
Maintainer	IR747B2-6-3 IR10154-23-3-3 IR10176-24-6-2 IR19657-87-3-3 IR19795-17-3-2 C 652159/Milyang F_5 1295 IR9859-45-2-3 IET 5324			IR10179-2-3-1 IR9859-45-2-3 (?) C 652159/Milyang F_5 1259 (?) IR11248-242-3-2		IR747B2-6-3 IR10154-23-3-3 Suweon 105 IR26 IR2797-105-2-2-3 IR9703-41-3-3-1 IR13525-118-32-2-2-2 IR17494-32-2 IR11248-242-3-2
Total (%)	10 (32%)	8 (26%)	2 (7%)	6 (19%)	4 (13%)	11 (36%)
Restorer		IR26 IR36 IR50			IR13525-118-32-2-2-2	IET 5103 (?)
	IR54		IR10154-23-3-3			
	IR9703-41-3-3-1	IR9715-74-3	IR9703-44-3-3-1			
	IR9752-39-2	IET 5103	IR2797-105-2-2-3 IR9093-211-6 IR9852-39-2 IR13420-6-3-3-1 IR13525-118-32-2-2-2 IR17494-32-2 IET 5103 IET 3257			
Total (%)	6 (19%)	6 (19%)	13 (42%)	0	1 (3%)	1 (3%)

Table 22. Restoration ability of 218 elite breeding lines tested in China and IRRI, 1981.[a]

Test in IRRI	Test in China				Total
	Restorer	Partial restorer	Partial maintainer	Maintainer	
Restorer	13	37	3	–	53
Partial restorer	17	66	25	3	111
Partial restorer:maintainer	–	–	7	–	7
Partial maintainer	–	2	8	–	10
Maintainer	–	4	15	4	23
No data	3	4	5	2	14
Total	33	113	63	9	218

[a]Figures given are number of lines. About 90% of the breeding lines were developed at IRRI, the rest in other national programs.

Progenies of Zhen Shan 97A (P_1), IR54 (P_2), Zhen Shan 97A/IR54 (F_1, F_2), and Zhen Shan 97A//Zhen Shan 97A/IR54 (BC_1 F_1) were analyzed for pollen and spikelet fertility. The results (Table 23, 24) showed that restoration ability was dominant and the cytosterility system of Zhen Shan 97A was sporophytic in nature. The F_2 population segregated into 273 fully fertile (such as IR54), 84 fertile (70-95% pollen fertility), 72 partially fertile (1-70% pollen fertility), and 30 completely sterile (such as Zhen Shan 97A). The segregation gave a good fit to digenic ratio 9:3:3:1. These results were confirmed by the backcross segregation ratio, which conformed to the 1:1:1:1 segregation ratio. The data on segregation for spikelet fertility (Table 24) also showed behavior similar to that of pollen fertility. It appears that restoration ability of IR54 is governed by two independent major genes, one with a stronger fertility restoration ability. If both genes are present, fertility is like the R line, IR54. If the gene with stronger fertility restoration ability is present alone, fertility is somewhat reduced. However, if the gene with weaker restoration ability is present, the plants show partial fertility ranging from 1 to 70%. The plants possessing the double recessive genotypes are completely sterile.

Effect of sterility-inducing cytoplasm on agronomic characters. Comparative evaluation of the six A and the corresponding B lines for some agronomic characters showed that:

- Plant height was significantly lower in Zhen Shan 97A, V20A, Yar Ai Zhao A, and Wu 10A than in the respective B lines.
- Tillering was significantly higher in all the A lines than in the corresponding B lines except Wu 10A and MS 577A.
- Panicle exsertion was significantly poorer in Zhen Shan 97A, V20A, and Yar Ai Zhao A than in the respective B lines.
- There was no significant difference among A and B lines in panicle length, number of spikelets per panicle, and flag leaf length and width.

Obviously, the cytoplasmic factors inducing

Table 23. Frequency distribution for pollen fertility in parental F_1, F_2, and BC_1 F_1 populations of the cross Zhen Shan 97A/IR54. IRRI, 1982.

Population	Pollen fertility (%) class						Total	X^2	*P* value
	0	0.1-10	10-30	30-70	70-95	95-100			
Zhen Shan 97 A (P_1)	10						10		
IR54 R (P_2)						10			
F_1 (P_1/P_2)						10	10		
F_2 (P_1/P_2)	30	4	9	59	84	273	459	3.23[a]	0.38
			72						
BC_1 F_1 ($P_1//P_1/P_2$)	24	2	15	21	6	24	92	2.34[b]	0.50
			17		27				

[a]Segregation ratio 9:3:3:1. [b]Segregation ratio 1:1:1:1.

Table 24. Frequency distribution for spikelet fertility in parental F_1, F_2, and BC_1 F_1 populations of the cross Zhen Shan 97A/IR54. IRRI, 1982.

Line	Spikelet fertility (%) class							Total	X^2	*P* value
	0-1	1-10	10-30	30-50	50-70	70-80	80-100			
Zhen Shan 97A (P_1)	10							10		
IR54 (P_2)					4	2	4	10		
F_1 (P_1/P_2)				2	3	2	3	10		
F_2	27	22	69	107	159	52	23	459	7.78[a]	0.06
			91		234					
BC_1 F_1 ($P_1//P_1/P_2$)	30	17	8	13	17	3	4	92	6.70[b]	0.09
			25		24					

[a]Segregation ratio 9:3:3:1. [b]Segregation ratio 1:1:1:1.

male sterility affect some agronomic characteristics negatively, but their effects are cytoplasm specific.

The effects of cytoplasmic factors inducing male sterility on agronomic characteristics (days to flower, plant height, tillers per hill, panicle length, and grain number) were also studied by comparing characteristics of test cross F_1 progenies of crosses involving the six A and B lines with elite lines. The results showed that effects of cytoplasmic factors inducing male sterility in Zhen Shan 97A and V20A were more pronounced than the others. However, the effects were positive, negative, or neutral depending on the cross. These observations further confirm the significance of developing a number of A lines with diverse cytoplasmic factors inducing male sterility in rice, so that the positive effects of cytoplasm on agronomic characters can be selected for and the negative effects selected against in the hybrid breeding program.

Seed production (*Plant Breeding*). *Outcrossing on male-sterile lines during dry and wet seasons.* The techniques of hybrid seed production developed in China (Annual report for 1981) continued to be used to multiply seeds of selected A lines and produce hybrid seeds of selected F_1 combinations. The observations made during the year on a number of A line multiplication and hybrid seed production plots (10-40 m^2) during the DS and WS indicate that:

- Up to 35% outcrossing on A lines is possible during DS and WS.
- Outcrossing on A lines is generally lower during the WS than during the DS because of heavy rains, typhoons, and a higher incidence of diseases and insects during the WS.
- The most important factor determining the outcrossing rate on A lines is their synchronization for flowering with the pollen parent.
- Because the available A lines introduced from China and elsewhere do not grow well in the tropics, a bulk quantity of hybrid seed cannot be produced unless the A lines are adapted to tropical conditions.

Floral characteristics of male-sterile and maintainer lines. Influencing floral characteristics on A lines in rice include: duration of flowering, of anthesis, and floret opening and stigma size, exsertion, and receptivity.

Duration of flowering of the six A lines and corresponding B lines ranged from 13 to 19 d, although in most cases it occurred between 6 and 9 d. This duration allowed sufficient natural outcrossing in the seed production plot. But the flowering peak of A lines was 2 to 3 d later than that of the corresponding B lines, which would hinder the natural outcrossing A lines in the seed multiplication plot. It is therefore essential to have staggered plantings of B lines to attain synchronization in flowering.

Duration of anthesis among the six A and B lines ranged from 1 to 14 h; the longest anthesis periods were in Zhen Shan 97A and V20A. Peak anthesis, however, occurred between 0900 and 1100 h, but it did not synchronize with the peak anthesis in the corresponding B lines of Zhen Shan 97A, V20A, YAZ A, and MS 577A. This may cause reduced cross pollination. The peak anthesis of the A lines Wu 10A and P 203A synchronized with that of their B lines, indicating that selection for synchronized anthesis among the A lines is possible.

The duration of floret opening in A lines varied from 37 to 141 min (Table 25). Florets of A lines remained open longer than those of the corresponding B lines, which provided opportunity for A lines to become cross-pollinated.

The A lines showed variability for stigma length, breadth, and exsertion. Attempts to transfer the large stigma trait from a genetic stock 6209-3 (Annual report for 1981) into B lines have not been successful. This trait appears to be recessive and linked with poor plant characteristics of wild rices so that in segregating generations, plants possessing improved plant type and large stigma are very infrequent. Biparental mating in the F_2 of the crosses with 6209-3 may help to break this undesir-

Table 25. The duration of opening of florets of six A lines and their corresponding B lines. IRRI, 1982.

Line	Duration of opening of florets (min)	
	A	B
97	141 ± 36	56 ± 15
V20	141 ± 45	37 ± 4
Yar Ai Zhao	92 ± 15	61 ± 11
P 203	124 ± 30	33 ± 4
Wu 10	37 ± 6	48 ± 2
577	72 ± 16	58 ± 10

Table 26. Stigma exsertion in six A lines and their corresponding B lines. IRRI, 1982.

Line	Stigma exsertion			
	Total no. observed	Two side (%)	One side (%)	Total exserted (%)
Zhen Shan 97A	1335	15	25	40
Zhen Shan 97B	1217	2	17	19
V20A	695	9	22	31
V20B	859	2	19	21
Yar Ai Zhao A	1596	13	36	49
Yar Ai Zhao B	1379	9	33	42
Pankhari 203A	1100	60	19	79
Pankhari 203B	955	49	16	95
MS 577A	1281	10	32	42
MS 577B	468	14	37	51
Wu 10A	1134	0	0	0
Wu 10B	1067	0	0	0

able linkage relationship. Alternatively, growing of large (5,000-10,000) F_2 population may give some desirable recombinants.

Stigma exsertion in the six A lines ranged from 0 to 79% (Table 26). P 203A showed the highest stigma exsertion and Wu 10A showed no stigma exsertion. In general, A lines showed higher stigma exsertion than their corresponding B lines. Besides, one-side stigma exsertion was more frequent in A and B lines than two-side stigma exsertion, except in P 203A and P 203B, in which two-side stigma exsertion was more frequent. Because stigma exsertion is influenced considerably by environmental factors, the observed values of stigma exsertion should be taken on a relative basis and not considered absolute.

Studies in 1981 and 1982 showed that A lines can receive pollen longer than the corresponding B lines can provide them. Therefore, the extent of natural outcrossing on the A lines would be influenced by the receptivity of the exserted stigma. Effective stigma receptivity (not necessarily the exserted stigma) resulted in 40-50% seed set and ranged from 1 to 5 d in different A lines. Critical studies on receptivity of the exserted stigma will be important.

The improved A, B, and R lines adapted to tropical conditions should be available during 1983 so that the development of F_1 hybrids for the tropics can start. A number of crosses involving newly developed A and R lines have been made for the purpose. Hopefully some of these would show significant standard heterosis. Techniques of hybrid seed production have been found adaptable in the tropics. India, Indonesia, Philippines, South Korea, and the USA have initiated hybrid rice research. Progress made during the next 5 yr will determine the success of this technology.

Genetic evaluation and utilization (GEU) program

International Rice Testing Program

International Rice Testing Program

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The IRRI-coordinated International Rice Testing Program (IRTP), which completed its eighth year in 1982, has effectively linked national and regional rice improvement programs with the GEU program. The network's strength comes from rice scientists in various countries who collaborate in the evaluation of elite germplasm, varieties, and advanced breeding lines. In 1982 IRTP continued to strengthen international linkages through its nurseries, monitoring tours, and workshops. During these events, the participating scientists identified problems of mutual interest.

INTERNATIONAL NURSERIES

In 1982, 1,351 nursery sets were assembled and went to 50 network countries. Simultaneously, 1981 trial results from more than 600 tests were

Table 1. More than 150 rices showed good performance at many sites in 1981 IRTP tests. Data from the tests were submitted by scientists at test sites, and analyzed and summarized at the IRTP headquarters at IRRI.

Nursery	Promising entries
Yield-irrigated	
IRYN-VE (very early)	• BG367-4, IR50, IR9729-67-3, BG276-5, BG367-7
IRYN-E (early)	• Taichung sen yu 285, IR9828-91-2-3, IR36, Chianung sen yu 13, IR13429-196-1
IRYN-M (medium)	• IR13540-56-3-2-1, BR51-282-8, IR54, IR13423-17-1-2-1, Taichung sen 10, IR42
Observational-irrigated	
IRON	• *IR13538-48-2-3,* Chianung sen yu 13, 32-Xuan-5-C, IR9698-16-3-3-2, C1321-9, C1322-28, IR9830-26-3-3, IR13240-108-2-2, MRC603-303
IRARON (arid regions)	• Several Giza lines, *IR129-209-2,* IR9129-320-3-3, IR19746-28 2-2, IR8608-298-3, IR19819-31-2-3
Yield-rainfed	
IURYN (dryland)	• IR5931-110-1, IR6115-1-1-1, UPL Ri-5, IR43, IET4094, IR52
IRLRYN (wetland)	• IR14632-2-3, IR14753-49-2, BR4, IR13146-45-2-3, BR51-282-8, IR46, IR4819-77-3-2, IR10781-75-3-2
Observational-rainfed	
IURON (dryland)	• IR9761-19-1, IR19793-25-2-2, IR9256-59, ITA175, ITA235, UPL Ri-3, IR10004-3-1, IR129-79-24-1, IR6023-10-1-1, IR3794-9-2-3, IAC1246, IR10110-23-1, IR5440-1-1-3
IRLRON (wetland-early group)	• IR2987-13-1, IR3179-25-3-4, IR5853-198-1-2, IR13146-13-3-3, IR3880-10, IR8608-82-1-3, IR9698-16-3-3
IRLRON (wetland-medium group)	• IR10781-143-2-3, IR13358-16-3-2, IR13369-86-2-2, IR46, IR14497-15-2, IR14753-86-2, IR4819-77-3-2, IR4829-89-2, IR14875-98-5, IR19083-22-2-2, IR19256-88-1 *BKNFR76001-36-4-2,* GEU77057-1-1, HTA7403-110-1-5, SPR7292-151-2-1
Stress screening	
IRCTN (cold)	• JC99, Shin-ei, Fuzi 102, Jodo, Eiko, China 1039, K39-96-1-1-2, K143-1-2, IR19743-46-2-3, IR19746-26-2-3, IR9224-K1, IR9758-K2, IR9202-5-2-2
Problem soils	
IRSATON (salinity and alkalinity)	• *Salinity* - IR8236-B-B-336 *Alkalinity* - IR4227-28-3-2, IR4432-28-5
Acid sulfate	• IR1632-93-2-2, IR46, IR36
Acid dryland	• *B2433b-Kn-10,* Salumpikit, ITA116, *O. glaberrima* (BG187)
Iron toxicity	• BW100, IR4625-269-4-2, IR4683-54-2-2
Peat soils	• IR34, IR52, IR2071-685-3-5
Diseases	
IRBN (blast)	• Fukunishiki, IR1905-PP11-29-4-61, IRAT104, Tetep, CIAT-ICA5, Camponi SML
IRTN (tungro)	• ARC10342, ARC11353, ARC11554, Utri Merah, Utri Rajapan
IRBBN (bacterial leaf blight)	• RP633-76-1, RP633-519-1, IR4442-46-3-3, IR13423-17-1-2-1, IR9209-48-3-2, IR54, IR20
Brown spot	• *B2360-6-7-1-4,* Cica 8, IR54, IR4227-28-3-2, RP1045-60
Cercospora	• *IR13149-43-2,* IR15318-2-2, IR4568-86-1
Sheath rot	• IR19762-2-3, IR9209-181-3
Leaf scald	• IR8192-200-3, IR5853-18-2
Ragged stunt	• Murungakayan 101
Insects	
IRBPHN (brown planthopper)	• BG367-9, BG379-4, PTB33, Sinna Sivappu, Suduru Samba, IR15324-117-2-2-3, IR17488-2-3-2, IR19660-46-1-3-2, IR19661-150-2-2-2, IR13427-40-2-3-3
Yellow stem borer	• *Vegetative stage* - CO 18, CO 21, MTU15, W1253, W1263 *Flowering stage* - W1263, IR15795-151-2
Leaf folder	• IR13429-170-3, IR9209-26-2-2, TKM6

analyzed and many new promising entries were identified (Table 1). All these superior entries are freely available to national rice improvement programs. Details of entry performance in different nurseries are in individual nursery reports.

Some of the disease and insect nurseries (BPH, gall midge, blast, RTV, bacterial leaf blight) continue to provide significant information on the genetic variation in biotypes and pathotypes.

Fifty-six IRTP entries originating from the breeding programs of seven countries and from IRRI have been released to date to the farmers in 30 countries in Asia, Africa, and Latin America. Recent varieties named are in Table 2.

Several hundred entries were utilized in hybridization programs in different countries and at IRRI to improve specific agronomic traits or to incorporate resistance to specific stresses.

MONITORING TOURS

The 1982 monitoring tours focused on cold tolerance, dryland rice, and rainfed wetland rice.

Cold tolerance breeding materials and international nurseries were reviewed in India (Kashmir and Himachal Pradesh states), Nepal, Korea, and Philippines. Strategies were formulated for international collaboration.

Scientists from Latin America and Asia joined rice researchers in Africa to review dryland rice improvement efforts in Nigeria and Ivory Coast.

Table 2. IRTP entries named as varieties in three countries, 1980-81.

Country where named	Culture type	Varieties
Burma	Dryland	C22 (Yar-1), KN96 (Yar-2), KN117 (Yar-3), IR1529-680-3 (Yar-5)
	Deepwater	BKN6986-108-3 (Yenet-1). BKN6986-167 (Yenet-2)
India (Himachal Pradesh)	High altitude	HPU734 (Himalaya-1), Pusa 33-C-30 (Himalaya-2)
Nepal	Rainfed	IET1444 (Bindeswari)
	Irrigated (early)	Mala/J15 (Mallika)
	High altitude	IR3941-4-PLP-2B (Kanchan), IR2298-PLPB-3-2 (Himali)

This monitoring tour preceded an international workshop on dryland rice held at Bouake, Ivory Coast, in October. The diverse problems in developing better dryland rices on the three continents were compared. Plans were made to give more attention to germplasm adapted to the more difficult dryland rice environments, specifically areas with short growing seasons or poor soil, or both.

The problems of the vast areas of rainfed wetland rice in northeastern Thailand and eastern India were the target of another monitoring tour. The need for improved photoperiod-sensitive varieties was highlighted and greater international efforts were outlined in several group discussions.

RICE-WEATHER RELATIONSHIPS

IRTP irrigated yield trials for rices of early maturity were conducted during 1976-81 in 40 environments. The field data were analyzed to determine the relationship of grain yield to solar radiation and minimum and mean temperature during the 1-mo ripening stage after flowering.

Correlation between radiation and temperature within the same physiological stage was minimal during ripening. A decreasing relationship of yield with temperature at ripening was strongly evident with an additional indication of a curvilinear relationship. Simple and partial correlation analysis, coupled with regression methodology, showed that correlations were higher during the ripening stage when both solar radiation (RAD) and minimum temperature (MINT) were included, and that a quadratic polynomial model best handled the curvilinear relationship between yield and temperature. The relationship is estimated as:

$$\hat{Y} = 36.8 + 0.00462\ \text{RAD} - 2\ .73\ \text{MINT} + 0.0516\ (\text{MINT})^2,$$

where $\hat{Y}$ is predicted yield. Replacement of MINT with mean temperature (MEANT) during ripening resulted in the estimated prediction equation:

$$\hat{Y} = 83.3 + 0.00607\ \text{RAD} - 5.68\ \text{MEANT} + 0.0970\ (\text{MEANT})^2$$

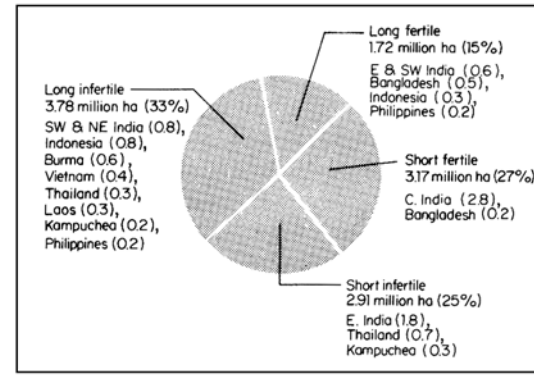
Overall, the residual standard deviation with mean temperature was 0.51 t/ha, whereas it was 0.46 t/ha with minimum temperature.

These studies will continue with more systematic data-gathering from selected sites representing a wide range of combinations of solar radiation and temperature at flowering and ripening stages of the crop.

ASIAN DRYLAND RICE ENVIRONMENTS

Asian farmers grow dryland rice on 11.5 million ha in widely varying environments. Differences in growing season length and soil constraints will require improved dryland rices with a range of characteristics suited to specific locations. To achieve a better understanding of their distribution and importance, dryland rice environments must be differentiated.

The region's dryland rice was divided into four major ecosystems (Fig. 1). The most favorable environments, those with a rainy season of 5 or more months and relatively good-quality soils, account for 15% of the total. The largest ecosystem (33%) includes a long rainy season and relatively poor soils and is most commonly found in Indonesia and southwestern and northeastern India. Environments with a short rainy season and poor soils are also common (25%) and the most difficult areas for dryland rice improvement.



1. Asian dryland rice was classified into four major ecosystems according to the length of the rainy season and soil fertility. IRRI, 1982.

This classification system serves an accelerated dryland rice improvement effort targeted to each of the major ecosystems. The international dryland rice observational and yield nurseries are being further reinforced to meet the requirements of the different ecosystems.

Genetic evaluation and utilization (GEU) program

Integrated GEU Program

Plant Breeding Department

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EXCHANGE OF GERMPLASM

In 1982, 8,124 seed packets of improved breeding lines and varieties were sent abroad in response to 170 seed requests from national program scientists. The International Rice Testing Program (IRTP) provided another 53,315 seed packets of IRRI breeding lines and varieties to national programs in response to 1,334 requests.

The germplasm bank provided 26,403 seed samples of germplasm accessions in response to 445 requests from foreign countries. The germplasm bank also sent 417 seed packets of wild rices to fill 20 requests and 138 seed samples of genetic testers and mutants to fill 18 requests.

IRRI LINES NAMED IN NATIONAL PROGRAMS

IRRI breeding lines were tested worldwide in various growing environments. During 1982, national programs named seven IRRI breeding lines as varieties, bringing the number overall to 117. These varieties are now planted on more than 30 million ha in Asia, Africa, and Latin America. The following were named in 1982.

- IR2061-214-3-8-2, a multiple disease- and insect-resistant and early-maturing selection, was recommended in Cameroons. This is the same line which was earlier released by IRRI as IR28 in 1974. It has also been recommended in the Philippines, Indonesia, Burma, Bangladesh, China, India, and Egypt.
- IR2070-199-3-6-6, a multiple disease- and insect-resistant sister line of IR38, was released in Vietnam as NN8A.
- IR2071-586-5-6-3, released as IR42 in Philippines, Indonesia, Malaysia, Kampuchea, and Nigeria, was recommended as NN4B in Vietnam. In addition to its multiple disease and insect resistance, IR42 has multiple tolerance for several problem soils, especially acid sulfate soils.
- IR4570-83-3-3, earlier released in the Philippines as IR48, was recommended in Vietnam as NN5B. This variety is also suitable for growing on acid sulfate soils.
- IR3941-4-Plp 2B, a cold-tolerant line, was recommended as Kanchen for the hill zone of Nepal.
- IR2298-PIP B3-2, a cold-tolerant line, was recommended for the hill zone of Nepal as Himali.
- IR13429-109-2-2-1 was named IR56 for countrywide planting by the Philippine Seedboard. This variety matures 2-3 d earlier than IR36 (Fig. 1) but has the same yield potential. It has long, slender, and translucent grains with high amylose content, low gelatinization temperature, and high milling recovery.

In the Philippines, IR56 is resistant to all the major diseases and insects such as blast, bacterial blight, RTV, RGSV, GLH, and three BPH biotypes. The main superiority of IR56 over IR36 is its higher level of resistance to RTV and its resistance to three BPH biotypes. It has the *Bph 3* gene for resistance to BPH, whereas IR36 has *bph 2*. IR56 should help diversify the genetic base of improved materials being grown in Asia.

BREEDING OPERATIONS

After a rapid growth in the early 1970s, when new plant breeding positions were added, the volume of the plant breeding programs has stabilized at the level shown in Figure 2. During 1982, 4,188 crosses were made, 1,003 F_2 populations were grown, 102,397 pedigree nursery rows were planted, and 61,439 seed packets of IRRI breeding lines and varieties were sent abroad.

Progress in developing improved germplasm for specific growing conditions. During 1982, the breeding programs were reorganized to develop improved breeding materials for each type of rice culture with specific problems. The breeding programs for irrigated, dryland, and deepwater environments will continue to operate at about the same level. However, rainfed wetland environments are very diverse and have been subdivided into several major categories:

- rainfed, shallow drought-prone,
- rainfed, shallow submergence-prone,
- rainfed, shallow drought- and submergence-prone, and
- rainfed, medium-deep waterlogged.

Varietal requirements for each of these situations are quite different. Because these growing conditions do not occur in the Philippines, segregating early-generation materials, if grown here,



1. IR56, the newest variety released by the Philippine Seedboard, is the first MV with resistance to all known biotypes of BPH.

cannot be exposed to appropriate stresses. Therefore, a series of collaborative projects are being developed with the countries where large areas of different rainfed wetland types occur. The objective is to develop the materials suitable for these areas collaboratively with the national program scientists. The deepwater breeding program formerly located in Thailand has been moved to IRRI. However, close collaboration with the Thai deepwater program will continue and collaboration with the deepwater rice breeding programs in Bangladesh and India will be strengthened.

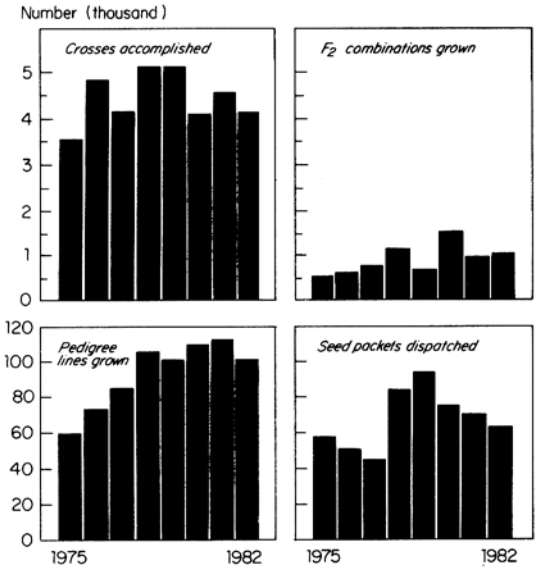
RICE IMPROVEMENT FOR DIFFERENT CONDITIONS — INTEGRATED GEU PROGRAM

Irrigated rice. The breeding program for irrigated conditions continued to emphasize the development of early-maturing rices with multiple disease and insect resistance, high yield potential, and superior grain quality. Of 907 crosses made for irrigated conditions, 457 were single crosses and 450 were topcrosses. F_2 populations from 583 combinations were grown and 65,270 pedigree nursery rows were planted during the year. The pedigree nurseries included F_3 to F_8 breeding lines. As usual, the F_2 populations and pedigree nursery rows were grown without insecticide protection. This allowed the early discarding of many susceptible genotypes.

Eight hundred and five advanced generation breeding lines in replicated yield trials were evaluated. Their growth duration varied from 95 to 145 d. A vast majority of the entries, however, had a short growth duration (100-110 d) and multiple resistance to major diseases and insects. For the first time, there was a large number of entries with intermediate amylose content in the replicated yield trials.

The IRRI Agronomy Department evaluated 22 promising lines in N response trials at four locations in the Philippines. The results of these trials are reported in the agronomic characteristics section of this report.

Thirty-four breeding lines were nominated to the wetland rice performance trials conducted at 12 locations throughout the Philippines by the Rice Varietal Improvement Group of the Philippine



2. Growth of the IRRI breeding program, 1975-82.

Seedboard. The seedboard uses data for two or more seasons to recommend varieties for growing in the country. IR56, as discussed earlier, was approved for general cultivation throughout the country and large amounts of seed are being multiplied. The Rice Varietal Improvement Group also recommended the prerelease seed multiplication of five additional lines.

- IR9752-71-3-2, an early-maturing line with short growth duration and 100-d maturity, has excellent medium, long, and slender grains with excellent milling recovery. It has a very high yield potential — 4-6 t/ha during the WS and 7-8 t/ha during the DS.
- IR9729-67-3, maturing in 100 d, has outyielded all the other early-maturing lines in many trials. It has medium, long, and slender grains.
- IR13429-299-2-1-3, a sister line of IR56 and resistant to three BPH biotypes, matures in 110 d and has excellent long, slender grains with strong grain dormancy.
- IR13525-43-2-3-1-3, maturing in 115-120 d, has excellent long, slender grains and is resistant to three BPH biotypes.
- IR19672-140-2-3-2-2, maturing in 130 d, has long, slender, and translucent grains and is resistant to three BPH biotypes.

Other important characteristics of these five and other new promising lines are in Table 1.

Cold-tolerant rice. Efforts have been made over several years at IRRI and by the national rice improvement programs to incorporate the various cold tolerance characters into the modern varieties. During 1982, emphasis was put on combining low leaf discoloration and high spikelet fertility into high-yielding indica rices. Japonicas were used as donors of low leaf discoloration and indica rices as donors of high spikelet fertility.

A total of 433 crosses for the cold tolerance program were made. Of these, 238 were single crosses and 195 were topcrosses and double crosses. F_2 populations from 151 cross combinations were grown and 7,030 plants were selected based primarily on plant type and maturity. Pedigree nurseries of F_3 and later generation lines were grown at IRRI as well as at Banaue in the Mountain Province of northern Luzon.

F_2 populations from 58 cross combinations were grown at Banaue and 362 plants with less leaf discoloration and high fertility were selected. A total of 2,907 pedigree nursery rows were grown at Banaue and 426 plant selections were made.

Nine hundred and ten advanced breeding lines and introduced varieties were evaluated at Banaue in the observational nurseries including the international rice cold tolerance nursery.

Of 51 improved plant type breeding lines which were evaluated in the OYT, nine with high-yield potential were identified (Table 2). IR8866-30-3-1-42 yielded 8.5 t/ha. It has medium growth duration and semidwarf stature. IR2061-522-6-9, IR15579-135-3, and IR9202-33-4-2-1 yielded more than 6 t/ha. These improved plant type breeding lines yielded 2 to 3 times more than the local check variety (Onoy) and had low spikelet sterility.

Rainfed wetland rice. Several IRRI rainfed breeding lines have performed well at IRRI and in international nurseries (Table 3). They are moderately tolerant of drought and submergence and are highly resistant to insects and diseases. Most have intermediate stature and good lodging resistance.

Drought and submergence tolerance. Further work in the rainfed wetland program will focus on incorporating drought and submergence tolerance into productive plant types with disease and insect resistance. Tall varieties are grown in many rainfed

Table 1. Some promising breeding lines with multiple attributes suitable for irrigated wetland culture. IRRI, 1982.

Designation	Cross	Growth duration (d)	Amylose content (%)	Reaction to[a]					BPH biotype		
				Blast	Bacterial blight	RTV	RGSV	GLH	1	2	3
IR9729-67-3	BG34-8/IR28//IR2071-625-1-252	98	26	6	1	3	1	3	1	1	7
IR9752-71-3-2	IR28/Kwang-chang-Ai//IR36	99	26	2	1	3	1	3	1	1	7
IR13429-299-2-1-3	IR4432-53-33/PTB 33//IR2071-625-1-252	107	26	4	1	3	1	3	1	1	1
IR13525-43-2-3-1-3	PTB 33/IR30//IR36	116	26	4	1	3	1	3	1	1	1
IR19672-140-2-3-2-2	PTB 33/3*IR4432-53-3//IR4432-53-3	135	27	7	1	3	1	3	1	1	1
IR19743-46-2-3-3-2	IR9129-192-2-3//IR10176-79	95	26	3	1	3	1	3	1	1	7
IR21015-80-3-3-1-2	Batatas/IR2071-625-1	115	27	4	1	3	1	3	1	1	7
IR21820-154-3-2-2	IR1529-680-3-2/IR4432-52-6-4//IR7963-30-2	130	24	6	1	3	1	3	1	1	7
IR21848-65-3-2-2	IR4570-124-3/IR4432-52-6-4//IR4570-124-3-2	132	23	6	1	1	1	3	1	1	7
IR22082-41-2	IR5853-162-1-2-3/IR5657-33-2	130	23	7	1	1	1	3	1	1	7
IR25603-20-2-1-3-2	IR19660-73-4/IR4570-124-3-2-2-2	128	25	7	1	3	1	3	1	1	1
IR25861-153-1	BPI121-407/IR7963-30-2//IR9129-209-2-2	110	21	5	1	1	1	3	1	1	7
IR28128-45-2	IR36/IR10154-23-3-3/IR9129-209-2-2-2-1	105	22	5	1	3	1	3	1	1	7
IR28210-96-4-3-3	IR19657-37-3/IR2588-2-3-3//IR9129-209-2-2-2-1	107	23	7	1	3	1	3	1	1	1

[a]Scoring based on 1980 SES for Rice.

Table 2. Cold-tolerant lines from the OYT at Banaue, 1982 DS.

Designation	Yield (t/ha)	Flowering (d)	Height (cm)	Sterility (%)
IR8866-30-3-1-4-2	8.5	124	78	16
IR2061-522-6-9	6.7	125	91	12
IR15579-135-3	6.0	124	112	18
IR9202-33-4-2-1	6.0	126	105	18
IR9202-5-2-2-2	5.8	115	86	15
IR5853-118-5	5.7	124	78	17
IR3880-17	5.4	127	104	10
IR5716-18-1	5.4	127	84	17
B29806-Sr-2-1-1-1	5.0	120	84	6
Onoy (local check)	2.7	117	109	23

areas. They can often escape submergence because of their height and fast seedling growth. In breeding shorter, more productive rices, the ability to tolerate complete submergence for up to 10 d will become an important trait.

Submergence tolerance can be effectively incorporated into semidwarf or intermediate-height plant types. Several tall varieties with strong submergence tolerance such as FR13A, FR43B, and Kurkaruppan have been used in the breeding program at IRRI and in the Thai-IRRI collaborative program as donors of submergence tolerance. As a result improved lines, such as IR6402-OT-7-0-0 (FR43B/IR2035-290-2-3) and IR8234-OT-9-2 (Nam Sagui 19/IR1721-11//IR2061-213), have been developed. These lines are being used as improved donors of submergence tolerance in the breeding program. Screening for submergence tolerance begins in the F_2 with transplanting of surviving plants in the field.

Population improvement. One of the difficulties encountered in breeding for rainfed-wetland conditions is in incorporating the large number of traits required into one genotype. Rainfed cultivars require, in addition to high yield potential and resistance to insects and diseases, resistance to one or more environmental stresses. Progress is hampered by the difficulty of combining all the charac-

Table 3. Some promising breeding lines with multiple attributes suitable for rainfed-wetland culture. IRRI, 1982.

Designation	Cross	Height (cm)	Growth duration (d)	Bacterial blight	Reaction[a] to BPH biotype			GLH
					1	2	3	
IR4819-77-3-2	IR1737-19-7-8-3///IR480-5-9-3/ IR1514A-E588//BRJ1-13-B-10/ IR1487-194-5-1	110	120	R	R	S	R	R
IR10781-143-2	BG90-2/IR44	110	115	R	R	R	R	MR
IR13146-45-2-3	BG90-2/IR34//IR46	115	125	R	R	S	R	R
IR13369-86-2-2	IR36/BG90-2//IR42	120	100	R	R	R	S	MR
IR13564-95-1	Sigadis/IR42[2]	115	120	R	R	R	S	S
IR14632-2-3	IR44/IR46	120	125	R	R	R	R	MR
IR14753-49-2	IR4683-54-2/IR46	110	120	R	R	S	R	R
IR14875-98-5	IR4816-70-1/IR46	120	125	R	R	R	R	S
IR19083-22-2-2	Bhadoia 685/IR4227-24-3-1//IR44	110	130	R	R	R	S	R
IR19431-72-2	IR4704-123-3/IR42//IR46	110	130	R	R	R	R	MR
IR21313-39-3-2	IR1754-F5B-23/IR4219-35-3-3//IR52	120	120	R	R	R	R	R

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

ters in one cross, and adverse genetic linkages may inhibit recovery of desirable recombinants. Male sterile-facilitated composite crossing and recurrent selection are techniques designed to overcome these difficulties.

Crosses for the rainfed wetland population IR38499 were made in 1979 and 1980 (Table 4). Intercrossing was facilitated by harvesting seed of male-sterile plants. The composite has been intermated for three generations and is ready for population improvement. Initial selection will focus on improving plant type and increasing the resistance to common diseases and insects. More elaborate schemes may be needed for increasing the levels of drought and submergence tolerance in the population. The population should serve as a valuable source of germplasm for national programs.

Additional populations are now being developed for specific objectives. The composite cross IR38499 is photoperiod insensitive, and intermating is accomplished in the field. In many rainfed-wetland areas, photoperiod sensitivity will be preferred. The photoperiod-sensitive rainfed-wetland populations will be intermated through the RGA facilities. Efforts are being made to diversify the cytoplasm of the populations by using plants heterozygous for the male-sterile genes as male parents. Backcrosses and topcrosses are used to reduce the percentage of IR36 germplasm in the populations.

Population improvement is generally regarded as a long-term approach to breeding. Many national programs may not have the time and resources to devote to this type of program. Collaboration between IRRI and national programs, however, should assist in developing populations with wide adaptability for rainfed conditions and ensure a continued supply of improved germplasm to these programs. Figure 3 illustrates how data collected by national programs can be used to select parents for succeeding cycles of recurrent selection.

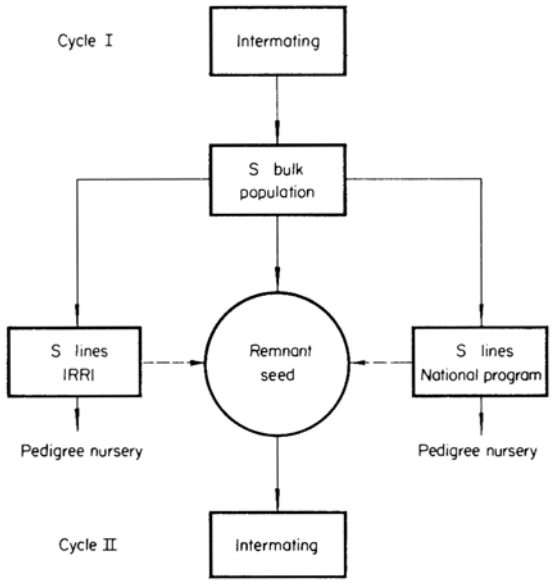
Thai-IRRI collaborative breeding project. More than 3 million ha of rainfed areas of northeastern Thailand are planted to tall, photoperiod-sensitive varieties. Yields average slightly more than 1 t/ha. The government-recommended varieties for these areas generally have low to moderate yields and are susceptible to diseases and insects. Future breeding efforts must focus on breeding varieties that respond to moderate levels of fertilizer and are resistant to the common pests and diseases, particularly gall midge and bacterial blight. It will be important to maintain the photoperiod sensitivity of the local varieties to ensure flowering at the proper time after the rains stop.

The collaborative program between IRRI and Thailand has been expanded. At IRRI, crosses were made between the Thai varieties and breeding lines and donors for submergence tolerance and

Table 4. IR crosses to make the rainfed wetland composite population IR38499. IRRI, 1979-80.

IR no.	Parentage[a]
IR27594	IR36(ms)/IR32
IR27596	IR36(ms)/IR42
IR27601	IR36(ms)/IR4570-74-2-2-3-3
IR27602	IR36(ms)/IR4570-83-3-3-2
IR27603	IR36(ms)/IR4608-6-2
IR27604	IR36(ms)/IR4683-54-2
IR27610	IR36(ms)/Mahsuri
IR27612	IR36(ms)/T442-57
IR27614	IR36(ms)/X69-2-27-2
IR29888	IR36(ms)/RPW 6-17
IR29894	IR36(ms)/IR9782-111-2-1-2
IR29895	IR36(ms)/IR11248-13-2-3
IR29904	IR36(ms)/BR4
IR29905	IR36(ms)/BR5
IR29906	IR36(ms)/BR51-196-2
IR29907	IR36(ms)/BR116-3B-28
IR29909	IR36(ms)/BR161-2B-42
IR29913	IR36(ms)/IR2071-863-1-1-6
IR29914	IR36(ms)/IR13464-75-1-1
IR29915	IR36(ms)/IR9884-3-3
IR31942	IR36(ms)//IR36(ms)/IET 3257
IR31943	IR36(ms)//IR36(ms)/IR32
IR31945	IR36(ms)//IR36(ms)/IR42
IR31949	IR36(ms)//IR36(ms)/IR4219-35-3-3
IR31950	IR36(ms)//IR36(ms)/IR4570-74-2-2-3-3
IR31951	IR36(ms)//IR36(ms)/IR4608-6-2
IR31952	IR36(ms)//IR36(ms)/IR4683-54-2
IR31957	IR36(ms)//IR36(ms)/T442-57
IR31958	IR36(ms)//IR36(ms)/X69-2-27-2
IR32122	IR36(ms)//IR20
IR32124	IR36(ms)/IR1545-339-2-2
IR32131	IR36(ms)/IR4744-295-2-3
IR32138	IR36(ms)/IR9703-41-3-3-1
IR32139	IR36(ms)/IR9761-8-2
IR32140	IR36(ms)/IR9764-45-2-2
IR32146	IR36(ms)/IR13426-19-2
IR32147	IR36(ms)/IR13526-42-2-2
IR32148	IR36(ms)/IR13635-8
IR32149	IR36(ms)/IR13635-38
IR32150	IR36(ms)/IR13639-37
IR32151	IR36(ms)/IR13639-42
IR32152	IR36(ms)/IR13641-3
IR32153	IR36(ms)/IR17491-5-4-3-3-1
IR32154	IR36(ms)/IR17494-32-2-2-1-3
IR32155	IR36(ms)/IR19362-174
IR32156	IR36(ms)/IR19362-183
IR32157	IR36(ms)/IR19657-87-3-3
IR32158	IR36(ms)/IR19660-23-2-1
IR32159	IR36(ms)/IR19661-131-1-2
IR32165	IR36(ms)/BG400-1
IR32172	IR36(ms)/IR5
IR32173	IR36(ms)/IR24
IR32178	IR36(ms)/IR4432-28-5
IR32181	IR36(ms)/IR9764-45-2-2
IR32182	IR36(ms)/IR11248-131-3-2-2
IR32195	IR36(ms)/RP1064-2-2

[a] ms = male sterile.



3. Scheme showing population improvement with testing at the national level.

disease and insect resistance. The Thai parents have excellent grain quality (both glutinous and nonglutinous) and adapt to the conditions of the Northeast including photoperiod sensitivity.

F_2 populations will be grown in Thailand and selected for the proper photoperiod sensitivity. F_3 populations will be grown at IRRI and screened for resistance to diseases and insects and grain quality characteristics. Seed harvested from the F_2 lines will be returned to Thailand for further testing. Selection for gall midge resistance can be conducted at various "hot spots" in northeastern Thailand. Selection for submergence and drought tolerance can be conducted at IRRI and in Thailand. Salinity tolerance will also be important for many areas of northeast Thailand, and suitable sites exist for screening.

Rapid generation advance. Use of the RGA facility for rainfed rice improvement has been expanded. The difficulties with working with photoperiod-sensitive materials have limited the number of improved sensitive breeding lines being developed. More reliance on the RGA facility should increase the efficiency of recovering improved sensitive lines.

In crosses involving a photoperiod-sensitive parent, the sensitive segregants are identified by planting early in the WS (May or June) and

selecting the late-flowering plants, or planting late in the season (September) and selecting the earliest plants. By planting F_2 populations in the field, nonsensitive plants can be removed early and sensitive segregants can be rapidly advanced through the RGA facility.

Deepwater rice. *Hybridization.* Although the purposes of the 686 single crosses and 726 multiple crosses for deepwater rice improvement made in 1982 varied, the ongoing objectives are the following:

- RD19 crosses aim at correcting the Thai deepwater variety's susceptibility to BPH and GLH and its lack of Zn efficiency. Also, earlier maturing lines are sought.
- Chenab 64-117 crosses aim at improving the BLB resistance and grain appearance of this variety from Bihar, while maintaining or even improving its submergence tolerance.
- IR11288-B-B-118-1 has shown good elongation ability, combined with resistance to GLH and RTV in Bangladesh and at IRRI. Crosses with this line show good vegetative cover and healthy plants.
- Bangladesh deepwater varieties and lines are used widely in crosses with other deepwater rices and with MVs available at IRRI.

Several F_1 crosses and bulk F_2 populations were sent to interested scientists in Asia (30 to Thailand, 109 to Bangladesh, and 91 to India).

Early-generation selection. The deepwater rice breeding program exploits the strengths of the IRRI headquarters breeding program in combination with the capacities of deepwater rice programs in Thailand and elsewhere. Strong selection for traits irrelevant elsewhere is avoided, but universally relevant traits are selected.

The various selection schemes (Table 5) used featured one or more of the following:

- The seedbed was planted in a deepwater tank, a standard field test for submergence tolerance (1 m water from 30 to 40 DAS) was administered, and only those found resistant by their survival were transplanted (scheme 2).
- The nursery was started in February-March to allow identification of photoperiod-sensitive segregants around July-August. These plants were each cloned into 10 tillers, to be retransplanted into a WS field (schemes 1, 2, and 3).
- For crosses from which elongating segregants were to be retrieved, clones were transplanted into a deepwater tank during the WS and water was applied at daily increments of 5 cm. Surviving lines were then harvested from the deepwater tank (scheme 3).
- In the field plantings, the absence of BPH and GLH protection resulted in heavy selection pressures of RRSV and RTV (schemes 1, 2, and 3).

Even though only one generation was advanced in 1 yr, surviving plants survived two successive selective environments in schemes 1 and 2, and three strongly selective environments in scheme 2. Outstanding crosses were IR37058 (C168/FR43B) and IR37449 (IR17494-32-3/GEB 24) for the submergence-screened F_2s (scheme 1), and IR37033 (RD19/IR9830-27-2-3), IR37026 (RD19/IR54), and IR37025 (RD19/IR46) for the twice-transplanted crosses, including those tested in deepwater areas (scheme 3). These crosses have been earmarked for RGA, in addition to continued field selection in pedigree.

Table 5. Numbers of plants and hybrids in three selection schemes for F_2 populations of deepwater rice. IRRI, 1982.

Scheme[a]	F_2 individual plants (no.)							Crosses (no.)	
	DS		DS		WS		Harvested	Planted	Harvested
1			*Field*		*Field*				
			8 000	(2)	847	(2)	181	38	27
2	*flash flood*		*Field*		*Field*				
	45 000	(1)	14 000	(2)	249	(2)	56	20	10
3			*Field*		*Deepwater*				
			1 800	(2)	739	(3)	238	7	7

[a]Selection pressures: submergence survival (1); photoperiod sensitivity and disease and insect resistance (2); elongation ability (3).

Pedigree selection. In 1982, 7,737 pedigree lines were grown for deepwater conditions and 6,033 lines for flash flood situations. In Thailand, 1,642 lines were screened for elongation ability and 340 for submergence tolerance.

Parental varieties responsible for good submergence tolerance in 28 pedigree lines were FR13A and Goda Heenati. Good elongation ability was obtained in 194 lines with the following parents: BGD5-6-3PE-1, BKN6986-108-2, BKN6986-167, BKNFR76023, Chakia 59, CN540, CNL J3, CNL 241; IR11288-B-B-294-1, KLG 6986-105, KLG 6986-113-4P; KLG 6986-161-7, KLG6986-165-P, Leb Mue Nahng 111, NPS7, RD19, and T442-57.

Promising deepwater lines. Three lines from IR11288 (IR36/Leb Mue Nahng 111) show promise by their performance at IRRI, in Thailand, and in the IRTP nurseries (Table 6).

SPR7411-7-2-1 and SPR7411-7-2-2 (Leb Mue Nahng 111/PTB18) have shown very good resistance to RTV at IRRI and good elongation ability as well. In addition, they are resistant to BPH biotype 1.

Among many pedigree lines tested in Patna, Bihar (India), by Rajendra Agricultural University breeders, 24 lines performed well in 80-cm deep stagnant water. Two were also outstanding under heavy, enhanced natural RTV pressure at IRRI: IR18342-73-2-3 (IR5657-33-2/IR2863-38-1) and IR22168-49-1 (B2025C-Mr-30-2-1/IR4219-35-3-3-2).

Some MV types with good submergence tolerance from greenhouse testing also survived a flash flood in Solana, northern Luzon, Philippines, in October.

The best combinations of submergence tolerance and modern plant type are shown by IR26702-25-1, IR26702-25-2, and IR26702-25-42 (FR13A/IR48//IR42). Though these lines have grains with red pericarp, they are replacing FR13A as submergence tolerance donors in crosses made at IRRI to enhance recovery of good plant types.

Dryland rice. *Hybridization.* During 1982, 572 single crosses, topcrosses, and double crosses were made. Nine backcrosses using Azucena, Black Gora, IAC47, Khao Lo, and Kinandang Patong as recurrent parents were made in the DS. The backcross populations (BC_1) showed poor phenotypic expressions: highly sterile, spreading culm, and highly shattering. They were also highly susceptible to the virus diseases.

Among the F_1 multiple crosses, the best combinations showing good agronomic traits in the progenies were those obtained from topcrosses and double crosses involving advanced breeding lines from the drought-resistant breeding materials, such as IR41718 (IR8990-3-9-3/IR19743-25-2-2-3//IR6023-10-1-1) and IR41803 (IR10110-23-1/C1064-5//IR10110-23-1/IR9729-67-3). Generally, crosses having IR8990-3-9-3 as the female parent produced progenies with desirable phenotypes.

About 28.4% of the crosses made were designed for use by other institutions abroad. Thirty-five crosses were made for Bangladesh, 35 for Brazil, 6 for the International Institute of Tropical Agriculture (IITA), 42 for India, and 47 for Thailand. Crosses made for Thailand involved specifically Khao Dawk Mali 105, its mutant, and Nam Sagui 19. For India, the parents were Kalakari, Black Gora, and Shankal. The BR lines were used for Bangladesh.

Selection. During the 1982 DS, 61 F_2 bulk populations were grown in a dryland field with supplementary irrigation, and another 30 F_2 bulk populations were grown in a simulated rainfed-wetland culture. About 42 F_3 bulk populations were selected.

Table 6. Three promising deepwater rices bred at IRRI. IRRI, 1982.

Line	Plant height (cm)	Days to flowering	Elongation[a] ability	Resistance to[a]			Grain length	Grain shape	Grain chalkiness
				BLB	BPH-1	GLH			
IR11288-B-B-65-1	130	90	5	2	3	4	Med	Slender	Clear
IR11288-B-B-69-1	130	[b]	6	3	3	3	Med	Slender	Medium
IR11288-B-B-118-1	150	[b]	6	1	3	5	Long	Slender	Medium

[a]Scoring based on the 1980 SES for Rice. [b]Photoperiod sensitive.

During the WS, 210 F_2 bulk populations were grown and 150 F_3 bulk populations selected.

During the seedling pulling in the WS, selection for deep and thick roots among F_3 populations started at 21 DAS and before transplanting. Some of the F_3 bulk populations that showed very deep and thick roots were IR30773 (IR3880-13-7/IR13639-42//IR6016-20-1), IR30834 (IR13639-42/Khao Lo//Khao Lo), and IR34338 (63-83/IR13240-83-1). Crosses that involved either Khao Lo, 63-83, Moroberekan, or the progenies of thick-rooted dryland varieties showed a high frequency of progenies with thick and deep roots. On the other hand, crosses of IR30808, IR34346, and IR34347 produced many plants with deep but thin roots. These crosses did not involve thick-rooted parents.

Selection for desirable agronomic traits were then made at maturity. Of the 150 bulk F_3 populations, 1,183 plants were selected. Visual observation showed that the plants preselected for deep and thick roots were generally taller, and had a thicker and spreading culm and other features closer to those of the traditional parents. Refined studies on the selection method for deep and thick roots will be continued.

Yield trials. The yield trials of dryland breeding lines were divided into three groups to accommodate 160 entries. The most promising lines were in group A of 40 entries, replicated four times in 10-m^2 plots. Groups B and C consisted of 60 entries each, replicated twice in 5-m^2 plots. The trials were conducted in a farmer's field at Santo Tomas, Batangas, and at two sites of the IRRI farm.

The crop grown at Santo Tomas did not encounter prolonged moisture stress. Heavy infestations of armyworms and cutworms at the reproductive stage lowered the yield of most entries. The intermediate-to-tall plants also lodged heavily after the typhoon of 9 Sep. The late-maturing semidwarfs (120-130 d) showed slight leaning and escaped the damaging effects of lodging. However, a heavy sheath blight infestation followed with the occurrence of frequent rainshowers.

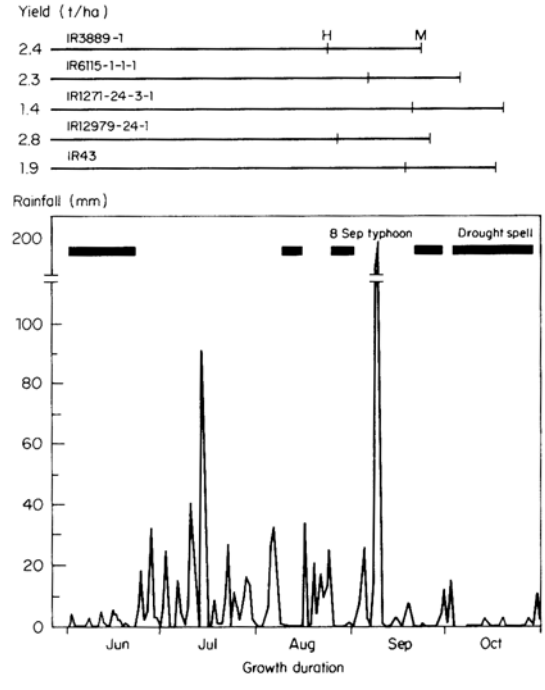
For group A, the yields ranged from 0.4 (IR5440-1-1-3) to 3.9 t/ha (IR43 — a good recoverer). The promising line IR3839-1 yielded 3.3 t/ha and performed well in regional yield trials of the Philippine Seedboard. Another promising line, IR12721-24-3-1 (IR2735-F_3B-6-2/IR9575//B541B-KN-19-3-4), which matures in 130 d, yielded 2.9 t/ha. It has good drought resistance and good recovery ability.

For group B, the yields ranged from 0.3 to 2.7 t/ha. IR3880-10 was the highest yielder, it was followed by an IR9669 selection (2.6 t/ha). The check variety IR45 yielded 2.3 t/ha.

For group C the yields of the test entries ranged from 0.6 to 2.6 t/ha, with the check variety IR43 again yielding the highest (3.0 t/ha). Some promising lines included IR7812-16-1-4 (IR879-314-2/63-83//IR1754-F_5B-14), IR13754-5 (IR3880-10/IR2823-179-5-4), and TOX 515-58-NK5-N1b, a breeding line from IITA (2.3-2.6 t/ha).

At the wet and fertile site on the IRRI dryland farm, moisture stress occurred at frequent intervals throughout the crop season (Fig. 4). Full heading was delayed by 10-20 d. The yields were lower because of the drought during the seedling, vegetative, and reproductive stages (Fig. 4). Grain shattering and lodging due to the typhoon on 9 Sep caused further yield reductions.

For group A, the yields ranged from 0.5 (IR13759-10) to 2.8 t/ha (IR12979-24-1). IR3839-



4. Rainfall distribution, drought spell, growth duration, and yield of five rices at the IRRI dryland farm. 1982 WS.

1, IR6115-1-1-1, and IR12979-24-1 seemed to perform well under intermittent stress periods. Their yields were comparable to that of the early check variety UPL Ri-7 (2.7 t/ha).

In group B, the yields ranged from 0.4 to 2.5 t/ha. The highest yielders were the check variety UPL Ri-7 (2.5 t/ha), followed by an IR9669 selection (1.8 t/ha).

For group C yields of the test entries ranged from 0.1 to 1.4 t/ha. The check varieties IR43 and UPL Ri-7 yielded 0.7 t/ha and 1.8 t/ha, respectively.

The yield differences among the check varieties in the trial groups could be attributed to the variation among blocks within locations. Because of plot size differences, no statistical analysis was made to confirm the variation among groups.

Yield comparisons of promising breeding lines from group A grown in the farmer's field in Santo Tomas and at the IRRI dryland farm are in Table 7. The 27% yield difference of IR3839-1 between locations was due to the 9 Sep typhoon that occurred at the soft-dough stage (Fig. 4).

IR12979-24-1, a selection from IR3179-25/ Kinandang Patong//IR26///IR879-314-2, which has a mean yield of 2.5 t/ha, performed better at the IRRI farm in spite of the short dry spell before heading. The line has good level of resistance to both drought and blast. It has an intermediate-amylose content of 26%. The lower yield at Santo Tomas could be attributed to poor seedling establishment and to waterlogging in some plots shortly after sowing.

Generally, among the test entries, IR12979-24-1 and IR6115-1-1-1 showed the least yield variation. The check variety UPL Ri-7 showed the same yield performance at the two locations while the check variety IR43 yielded 52% less on the IRRI farm. Combined analysis of variance showed significant yield differences among replications within locations (27.79**) and among lines (12.00**). The coefficient of variation was 30.0%.

Only group B was grown at the well-drained and poor site of the IRRI farm. The yields ranged from 0.4 to 2.4 t/ha, with the early-maturing check variety UPL Ri-7 yielding the highest. A promising line, IR12702-10-1-1, yielded 2.1 t/ha, but, it yielded only 1.8 t/ha at the favorable sites of Santo Tomas and 1.0 t/ha at the IRRI dryland farm. A selection from IR1754-F_5B-16/Kwang-lu-ai 4// IR2053-521-3 appears to be adapted to unfavorable conditions.

The traditional dryland variety Kinandang Patong yielded 1.2 t/ha; the improved variety IR45 only 0.5 t/ha. IR3880-10 yielded 1.4 t/ha.

Exchange of materials. During the 1982 drought symposium held at IRRI, rice breeders from Thailand, Indonesia, Liberia, and IITA agreed on a collaborative exchange of materials for drought-prone areas under dryland culture.

Twelve F_2 bulk populations were sent to the Khon Khaen Station of northeastern Thailand. The crosses have either BKN6721-5-7-4 or Niaw San Pahtaung as one of the parents. In addition, 6 F_3 bulk populations and 10 promising dryland lines were provided to the Khon Khaen Station and the Northeast Regional Agricultural Center.

The Indonesian breeders requested 6 F_2 bulk populations and 19 advanced breeding lines.

WARDA in Liberia requested 17 F_2 bulk

Table 7. Yield performance and maturity of promising lines grown in dryland culture at two locations, 1982 WS.

Line	Santo Tomas		IRRI farm		Mean yield (t/ha)
	Yield (t/ha)	Maturity (DAS)	Yield (t/ha)	Maturity (DAS)	
IR3839-1	3.3	112	2.4	121	2.8
IR5931-110-1	2.3	113	1.5	125	1.9
IR6023-10-1-1	2.4	123	1.4	136	1.8
IR6115-1-1-1	2.8	124	2.3	131	2.6
IR10110-24-1	2.7	121	1.2	134	2.0
IR12721-24-3-1	2.9	132	1.4	144	2.1
IR12979-24-1	2.3	110	2.8	120	2.5
IR43 (check)	3.9	124	1.9	142	2.9
UPL Ri-7 (check)	2.7	112	2.7	124	2.7

populations and 30 advanced breeding lines. The F_2 bulk populations had either E425, LAC 23, or Khao Lo in their parentage. IITA in Nigeria requested 16 advanced breeding lines with African parentage.

A report from the CRRI substation at Semiliguda, Orissa (IRRI-India Collaborative Drought Research Program), showed that of the 13 F_2 bulk populations sent in 1981, five populations produced more desirable plants for that area. They are IR36117 (White Gora/IET 3262), IR36119 (White Gora/CR 245-1), IR36130 (N22/Shankal), IR36139 (N22/IET 1444), and IR36186 (Dular/IET 1444).

Control and management of rice pests

Diseases

Plant Pathology Department

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SEED PATHOLOGY **180**

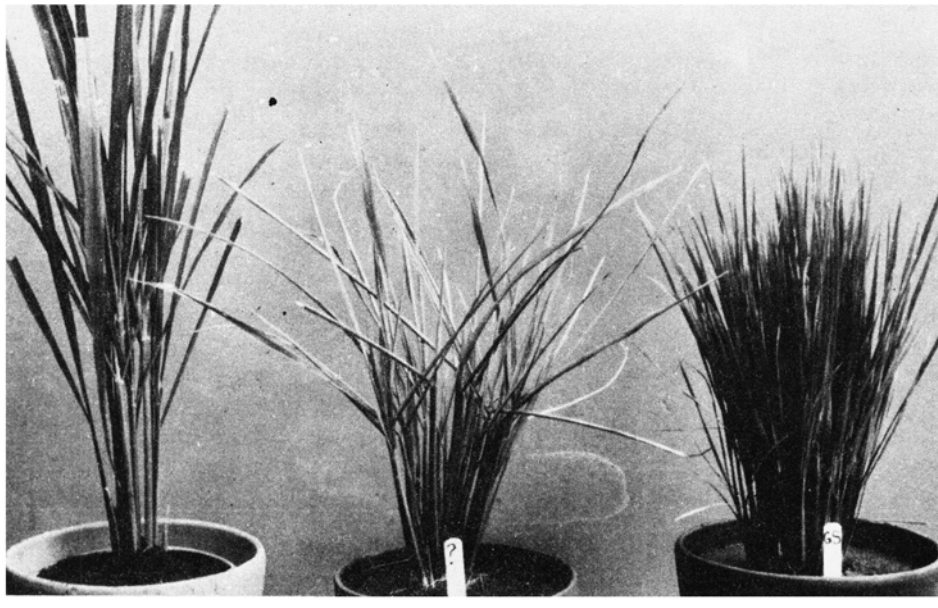
An unknown virus disease characterized by yellowing and stunting symptoms was first observed in IRRI fields in 1979. A survey in October 1980 in IRRI rice fields revealed that 0-7% of the mature plants showed similar symptoms. Similar symptoms were also observed in April 1982 in the demonstration plots, later in the azolla experimental plots and in the IRYN plots, and in September 1982 at Koronadal, South Cotabato, Philippines. The disease was thought to be caused by rice tungro virus (RTV).

Symptomatology. The symptoms of the disease were observed 7-14 DAI of 7-d-old TN1 seedlings. The early symptoms are stunting, yellowing of the lower leaves, and narrowing of the leaf blades. Irregular rusty blotches on the discolored leaves and mottling on the young leaves also occur occasionally. The infected plants showed profuse tillering, very similar to rice grassy stunt symptoms, 4-6 WAI (Fig. 1). However, the symptoms may vary according to the age of the plant when infected and variety. Plants infected at the later growth stage developed symptoms indistinguishable from those of RTV. These symptoms are most prevalent in the field. All plants inoculated at the seedling stage wilted prematurely — similarly to those with wilted stunt in Taiwan, China.

Transmission. Attempts to transmit the virus disease by sap, soil, and seed were unsuccessful. No virus transmission was obtained using insects with sucking mouthparts such as *Sogatella furcifera, Recilia dorsalis,* and *Nephotettix virescens*. However, the disease was transmitted by the brown planthopper (BPH) *Nilaparvata lugens.*

The virus is persistent in BPH. Its incubation period in the BPH ranged from 5 to 21 d (av 8.4 d). The insects remained infective after molting, indicating that virus passage was transstadial. Five to 30% of the insects used in separate tests were active transmitters. The shortest acquisition time was 1 h and the shortest inoculation access time was 15 min.

Serological identification. Because of similarities in virus-vector relations and symptomatology between the unknown rice disease and rice grassy stunt, serological tests were conducted to determine the relationship between the viruses causing the two diseases. The latex agglutination test using an antiserum to rice grassy stunt-associated filamentous particles suspected to be rice grassy stunt virus (RGSV) was applied.

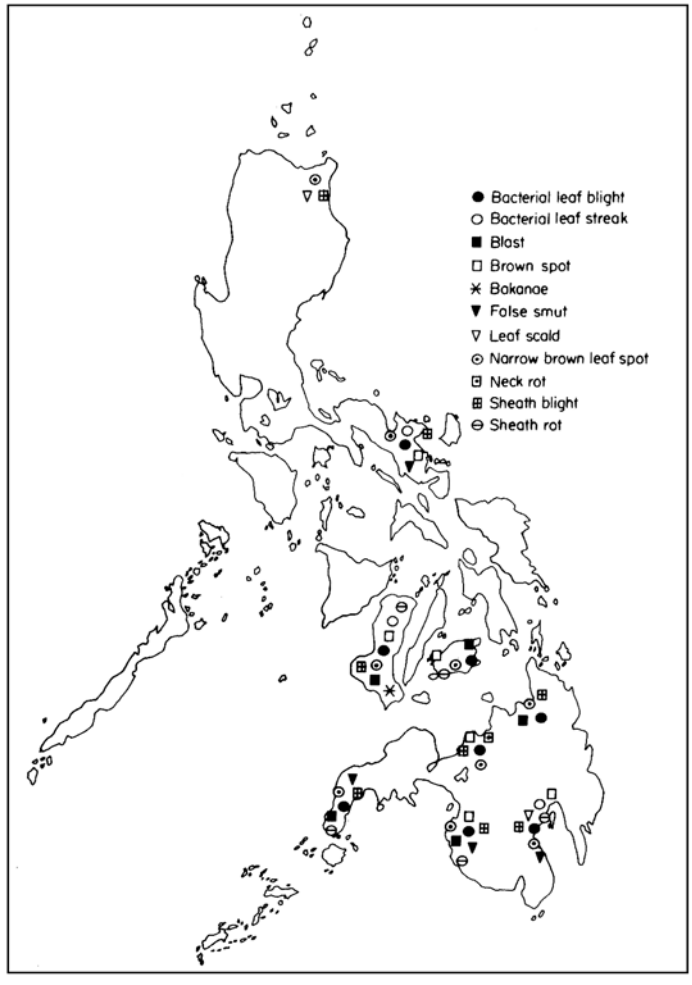


1. Healthy plant (left), and stunted plants infected with RGSV 2 (middle) and RGSV 1 (right). IRRI, 1982.

Positive reactions were obtained from sap of plants infected with the unknown virus up to 1:1,280. The sap from RGSV-infected plants gave positive reaction up to 1:5,120. Positive results were also obtained from the sap of 19 of 24 naturally infected plants showing RTV-like symptoms collected from the field. The results indicate that the RGSV in Japan is closely related serologically to RGSV in the Philippines and also to the unknown virus. Therefore, the unknown virus was identified as a RGSV strain because of the close serological relationship and similarity in symptomatology and virus-vector interactions. The new strain was designated RGSV 2 and the ordinary type RGSV 1.

MONITORING RICE DISEASES

General situation. The 1982 bacterial and fungal disease monitoring conducted by IRRI and cooperating personnel of the Philippine Regional Crop Protection Center (RCPC) covered 94 fields in 9 provinces (Fig. 2). The fields were planted to six IRRI varieties (IR5, IR36, IR42, IR50, IR54,



2. Occurrence of rice diseases in surveyed areas in the Philippines (Nov-Dec 1982).

and IR56), two UPLB varieties (C4 and C44.77), four local varieties (Katsuri, Mestiza, Wagwag, and Malagkit) and six other selections (SN47, TBTB, SN4, SN15, 11 ib, 20-1). The common variety planted is IR36 with growth stages ranging from seedling to mature stage.

Blast, bacterial blight, bacterial leaf streak, brown spot, false smut, leaf scald, narrow brown leaf spot, neck rot, sheath blight, and sheath rot caused disease in 19 varieties in surveyed fields. Brown spot, narrow brown leaf spot, and sheath blight were severe and more prevalent than the other diseases. Sheath blight was the most destructive in Cotabato.

Tungro. In 1981, IRRI and the Philippine Bureau of Plant Industry (BPI) organized a project to monitor RTV. Initially, eight regions were covered by the project; in 1982 all 12 regions of the country were included. In May 1982, a training program was held at the Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, to show RCPC and Surveillance and Early Warning System personnel of the BPI how to monitor in their regions.

The 1982 monitoring showed a comparatively high incidence of RTV and its vectors in IR36 and IR42. The RTV incidence was confirmed by transmission tests using the vector insects collected from the field (Table 1).

Although some of the rice-growing areas had a serious problem because of varieties planted, staggered plantings, high vector population, and high RTV incidence, the situation, in general, was not as critical as that caused by the 1974 RTV outbreak in central Luzon.

Light trapping at IRRI farm, 1972-1982. Weekly light trapping of virus vectors at the IRRI farm and infectivity tests of a portion of the insects have been carried out since 1972.

During the last 11 yr, the highest number of RTV vectors (*Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis*) was collected in 1981 and the lowest in 1982. Generally GLH made up the highest percentage of the catch. The percentage of infective RTV vectors was generally low, from 0.32 to 2.86.

The number of BPH trapped varied tremendously during the last 11 yr (Fig. 3). The percentage of grassy stunt-infective BPH varied from 0 to 2.86. However, trapping of ragged stunt-infective BPH began only in 1977, when ragged stunt was included in the study.

Although the vector insects of the three rice virus diseases were trapped at the IRRI farm every month during the 11-yr study period, their numbers declined in December, January, and February (Fig. 4).

RTV disease incidence at the IRRI farm did not seem closely related to the number of insects trapped nor to the percentage of infective insects. Although the number of BPH trapped in 1981 was high (396,238), the incidence of grassy stunt was still low because only 0.05% of the insects were infective.

FUNGAL DISEASES

Sheath rot. *Infection.* Seedlings at germination and plants at tillering stage were inoculated with sheath rot (*Sarocladium oryzae*) under natural and room

Table 1. RTV incidence and vector insects in farmers' fields, 1982 RTV monitoring project, Jul-Sep 1982.

Province	Regions	Municipality	Sites (no.)	Variety name	Growth stage[a]	RTV incidence (%)	Insects	
							no./10 sweeps	Infective tested[b]
La Union	1	Balauan	8	IR36	E	0	2	0/10
				IR42	E	0	2	0/10
				IR42	L	0	0	–
				IR42	L	0	0	–
				IR36	E	0	3	0/1
				IR36	E	0	1	0/6
				IR42	E	0	0	–
				IR42	L	0	0	–

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Table 1 continued

Province	Region	Municipality	Sites (no.)	Variety name	Growth stage[a]	RTV incidence (%)	Insects	
							no./10 sweeps	Infective tested[b]
Pangasinan	1	Binalonan	5	IR42	E	0	1	0/17
				IR42	E	0	0	–
				IR42	E	0	0	–
				IR42	L	0	2	0/18
				Unknown	S	0	0	–
		Asingan	5	IR50	S	0	4	0/3
				Unknown	S	0	0	–
				Unknown	R	0	2	0/9
				IR54	S	0	4	0/4
				IR50	S	0	0	–
		Urdaneta	4	Unknown	S	0	20	1/28
				IR42	L	30	6	17/39
				IR42	L	5	3	9/34
				IR42	M	35	–	–
		Bugallon	2	Unknown	L	0	2	–
				Unknown	E	0	0	–
		Aguilar	2	Unknown	S	0	11	–
				Unknown	E	0	12	0/29
		Magatera	3	Unknown	E	0	0	–
				Unknown	E	0	0	–
				Unknown	S	0	5	0/32
Isabela	2	Burgos	5	IR36	F	60	63	7/39
				Malagkit	F	40	565	2/38
				IR36	M	40	172	6/33
				IR36	R	30	78	insects died
				IR36	E	80	30	10/36
		Aurora	2	IR56	E	0	1	–
				IR36	E	0	3	–
Nueva Viscaya	2	Bagabac	1	IR42	R	<1	11	1/38
		Villaberde	1	Unknown	S	0	4	–
Nueva Ecija	3	Gapan	2	IR42	L	30	3	7/24
				IR30	E	40	1	0/31
		Muñoz	1	IR36	E	0	6	0/40
Tarlac	3	Tarlac	4	IR42	E	*	13	0/22
				IR42	E	*	9	4/27
				IR42	E	*	12	0/23
				IR36	E	*	17	0/28
		La Paz	1	Unknown	E	0	6	0/23
		Capas	1	Unknown	E	0	14	1/9
Bulacan	3	San Rafael	1	Unknown	E	0	0	–
	4	No monitoring.						
Camarines Sur	5	Bula	5	IR52	L	0	6	1/10
				IR50	S	0	2	1/30
				IR36	L	0	4	0/20
				Unknown	S	0	2	–
				IR36	E	0	0	0/16
		Ocampo	5	IR50	E	0	2	0/29
				IR50	E	0	0	–
				Unknown	L	0	4	0/6
				IR36	L	0	0	–
				Unknown	E	0	0	–

Continued on next page

Table 1 continued

Province	Regions	Municipality	Sites (no.)	Variety name	Growth stage[a]	RTV incidence (%)	Insects	
							no./10 sweeps	Infective tested[b]
Albay	5	Libon	3	IR50	L	0	0	–
				IR50	L	0	5	0/6
				IR36	L	0	1	0/19
		Polangui	3	IR50	L	0	4	0/20
				IR54	L	40	144	4/39
				IR54	L	0	12	0/34
		Malinao	2	IR42	B	50	18	13/25
				IR42	L	95	–	6/14
Antique	6	Bugasong	4	IR36	B	30	11	6/36
				IR36	L	40	24	8/37
				IR36	E	10	20	5/34
				IR36	E	70	35	15/35
Negros Occidental	6	Calatrava	2	IR36	L	1	3	0/24
				IR54	E	0	0	–
		Mao	4	IR36	L	20	17	3/36
				IR36	L	10	16	1/35
				IR36	E	5	4	2/39
				IR50	F	0	–	–
Bohol	7	Laboc	4	Unknown	S	0	9	0/10
				IR42	S	0	1	–
				IR42	E	0	2	0/3
				Unknown	S	0	14	0/27
		Bilar	3	Unknown	E	0	3	–
				Native	L	0	13	–
				Pang-anahaw	L	70	73	11/38
		Batuan	1	Unknown	S	0	7	–
		Carmen	2	IR36	S	0	10	0/5
				IR36	S	0	13	0/34
		Sagbayan	1	Lubang	S	0	9	0/25
Cebu	7	Carcar	4	Unknown	L	+50	1068	17/39
				Unknown	L	+35	956	9/40
				IR36	B	+60	89	18/39
				IR36	B	+70	149	19/39
		Asturias	3	IR54/IR46	S	0	20	0/25
				IR36	E	0	3	0/5
				IR36	S	0	9	0/11
		Balamban	1	IR36	S	0	5	0/16
Leyte	8	Abuyog	2	IR42	L	30	5	1/35
				IR42	E	10	0	–
		Hilongos	2	IR42	L	80	11	1/38
				IR50	E	0	0	–
Zamboanga del Sur	9	Molave	1	IR42	L	40	13	2/32
		Tanbulog	2	IR54	S	0	0	–
				IR36	R	10	43	3/36
		Ramon Magsaysay	1	IR42	E	10	16	2/34
		Kumalarang	1	IR42	L	0	16	0/37

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Table 1 continued

Province	Region	Municipality	Sites (no.)	Variety name	Growth stage[a]	RTV incidence (%)	Insects	
							no./10 sweeps	Infective tested[b]
		Tukuran	2	IR54	S	0	6	0/14
				IR36	R	20	10	1/18
		Labangan	2	IR52	L	0	2	0/18
				IR50	E	0	0	–
Bukidnon	10	Valencia	2	IR36	E	10	21	4/38
				IR36	L	60	24	9/36
Davao del Sur	11	Calinan	5	IR36	E	0	8	0/22
				SN15	S	2	4	–
				IR36	R	90	24	2/14
				IR36	E	25	35	0/14
				IR46	S	0	35	0/4
		Rizal	2	Unknown	L	0	2	–
				Unknown	B	10	40	2/19
		Magsaysay	4	Unknown	L	0	1	–
				Unknown	L	0	6	0/20
				IR54	B	25	8	3/34
				IR44	S	0	4	0/19
		Hagonoy	4	IR48	E	0	0	–
				IR36	E	0	0	–
				IR45 (line)	E	0	4	0/20
				IR45 (line)	L	10	1	8/39
Sultan Kudarat	12	Isulan	3	IR36	B	0	88	1/28
				IR45 (line)	E	10	56	1/30
				IR52	E	10	46	0/10
		Tacurong	3	PB6	L	15	140	4/35
				SN17	S	0	70	2/29
				IR54	E	1	3	0/9
		M. Marcos	3	Unknown	E	0	17	0/15
				MR var.	E	0	13	1/14
				Unknown	E	2	29	0/11
Cotabato	12	Tolonan	1	IR46	L	0	5	–
		Mlang	1	IR54	F	31	4	–
		Pikit	2	IR36	L	30	42	18/34
				IR25 (line)	S	0	2	–
		Pigcawayan	1	IR36	L	30	56	10/79

[a]S = seedbed, E = early tillering, L = late tillering, B = booting, F = flowering, M = maturing, R = ratoon. [b]Dash (–) indicates no insects collected for infectivity tests.

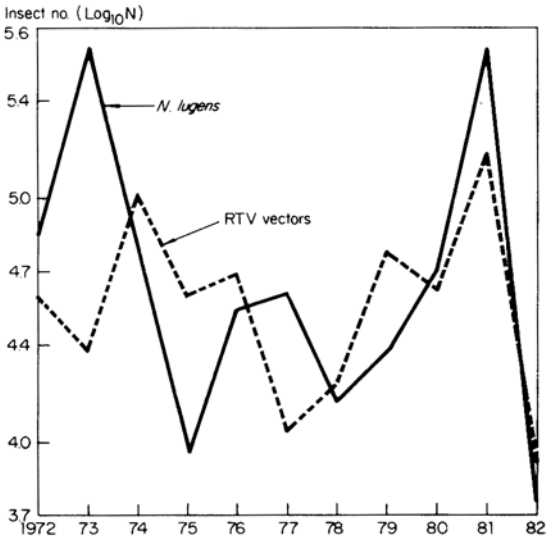
conditions using both intact plants and excised plant parts.

Inoculation caused a high percentage of infection on young wounded and unwounded seedlings of all the varieties tested. This indicates that wounding, although helpful, is not essential in infecting the host plant.

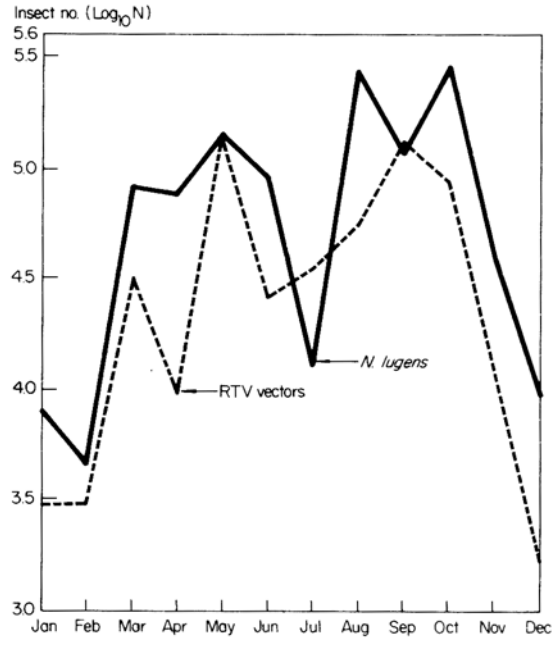
In plants at tillering stage, the infection percentage was highest on the oldest leaf sheath in most varieties. Excision of leaf sheaths of RGS-20 and IR36 caused a high percentage of infection on the fourth and youngest leaf sheaths, but not on the oldest, second, and third leaf sheaths.

The symptoms on young seedlings were brownish spots on the leaf sheath and numerous mycelial mats on the young emerging leaves. With moist conditions, whitish mycelial mats covered infected seedlings 7-10 DAI.

In plants at tillering stage, dark-brown lesions with numerous conidia appeared on the inoculated



3. Number of vector insects of rice virus diseases collected by light trap at IRRI farm, Aug 1972-Dec 1982.



4. Monthly collections of vector insects of rice viruses by light trap at IRRI farm, Aug 1972-Dec 1982.

areas (seen under the microscope) 3-4 DAI. The symptoms and signs on inoculated, excised plant parts were similar.

Host range. To determine if other plants can be infected by *S. oryzae* and serve as hosts, weed species from both wetland and dryland rice fields were collected and planted in clay pots in the greenhouse. When the weeds had fully recovered, they were injected with spore suspensions. Two weeks after inoculation, they were observed for symptoms and examined under the microscope.

Of the 20 species of weeds and wild rices tested, 13 were infected by the fungus. The infected weeds showed different degrees of response to the fungus, but all can be considered hosts of sheath rot (Table 2).

Transmission by seed. To determine whether sheath rot is transmitted through seeds, naturally infected seeds of TN1 and RGS-20 were planted in beakers of sterilized soil. Each beaker was then covered with another beaker and sealed with masking tape to prevent contamination. Each seedling was examined 10-12 DAS. Disease transmissibility by seed was high in both TN1 (75.3%) and RGS-20 (83.7%). In most cases, early symptoms were observed on the incomplete leaves. As the disease advanced, the second and third leaves also became infected. The seedlings with severe infection died.

Yield loss assessment. In a rice field during the 1982 WS, an experiment was conducted to assess the probable yield loss due to sheath rot and to determine the relationship between some yield components and disease severity.

Three susceptible breeding lines (IR442-2-58, IR1487-372-1-1, and IR1317-392-1-2) were used. IR1487 and IR1317 were badly damaged by rats and were dropped from the experiment.

At harvest, samples of healthy and infected panicles were taken from four plots. For each severity level of the disease scale (Table 3), 200 panicles were harvested at random. Evaluations were made on the effects of sheath rot on number of spikelets, percent filled spikelets, and 1,000-grain weight. Quantitative data on flag leaf sheath infection, panicle exsertion, grain filling, and grain discoloration were obtained to determine the reliability of the visual scale (Table 4).

Results showed a clear relationship between panicle yield components and disease severity. Yields decreased more intensely as disease severity

Table 2. Result of inoculation of the rice sheath rot pathogen on weeds and wild rices. IRRI, 1982.

Family	Species	Reaction of the pathogen[a]
Poaceae	*Digitaria ciliaris*	++++
Poaceae	*Echinochloa colona*	++++
Poaceae	*Echinochloa crus-galli* ssp. *hispidula*	++++
Poaceae	*Echinochloa glabrescens*	++++
Poaceae	*Oryza sativa* var. *rufipogon*	++++
Poaceae	*Oryza minuta*	+++
Poaceae	*Oryza australiensis*	+++
Poaceae	*Oryza brachyantha*	+++
Poaceae	*Eleusine indica*	++
Poaceae	*Paspalidium flavidum*	++
Poaceae	*Chloris barbata*	++
Poaceae	*Ischaemum rugosum*	+
Poaceae	*Leptochloa chinensis*	+
Poaceae	*Panicum repens*	−
Poaceae	*Paspalum*	−
Asteraceae	*Eclipta prostrata*	−
Cyperaceae	*Cyperus difformis*	−
Cyperaceae	*Cyperus rotundus*	−
Cyperaceae	*Cyperus brevifolius*	−
Pontederiaceae	*Monochoria vaginalis*	−

[a] − = no infection, + = brown lesions limited to point of wound inoculation, ++ = brown lesions extended from the point of wound inoculation, +++ = brown lesions more extensive, ++++ = lesions on the leaf sheath similar with those on rice.

increased (Table 5). The percentage of filled spikelets was affected most.

Influence of nutrition on bakanae incidence. Naturally infected seeds of IR42 were used to determine the effect of different nutrients on the incidence of bakanae disease. Seeds were grown in culture solution. The number of foot-rotted and elongated seedlings was recorded 1 wk after seed soaking and at weekly intervals thereafter. At the end of the experiments, the percentage of disease incidence was determined by considering as diseased both foot-rotted and elongated seedlings.

Nitrogen sources. The percentage of bakanae incidence increased as the rate of N was increased from 30 to 120 ppm in an ammonium nitrogen culture solution (Fig. 5). In seedlings in a 50% NH_4-N: 50% NO_3-N solution, the percentage of incidence tended to increase with N rate. The trend in the 20% NH_4-N: 80% NO_3-N solution was similar. Generally, bakanae incidence in seedlings was slightly higher in the 80% NH_4-N: 30% NO_3-N than in the other NH_4-N: NO_3-N combinations.

Potassium. K application did not greatly affect the incidence of bakanae infection (Fig. 6). The disease incidence slightly increased as the K rates were increased from 10 to 140 ppm, indicating that K application did not help prevent bakanae.

Silicon. N source in the absence of silicon (Si) greatly affected the disease. At 120 ppm N without Si, 100% bakanae infection was noted in the 20% NH_4-N: 80% NO_3-N solutions (Fig. 7). Disease incidence appeared to be lower in the presence of Si, especially at 30 ppm, than without it. However, disease incidence tended to increase at the 60 ppm Si rate regardless of rate or N source.

Calcium and magnesium. Naturally infected IR42 seedlings were grown in basal culture solutions with NH_4-N as the source. Bakanae incidence was always generally higher at 10 ppm and lower at 100 ppm calcium (Ca) concentration in all magnesium (Mg) concentration combinations. At 10 ppm Mg, bakanae incidence was reduced from 75 to 54% as the Ca concentration was increased from 10 to 120 ppm (Fig. 8). Trends were similar at 10-120 ppm Ca in combination with 40 and 80 ppm Mg.

BACTERIAL DISEASES

Bacteriocin-like substances produced by *X. campestris* **pv.** *oryzae.* Bacteriocins are highly specific proteinaceous antibacterial substances produced by many bacteria. *X. campestris* pv. *oryzae* produced bacteriocin-like substances on a solid medium (Fig. 9). Most of the 22 strains produced inhibition zones less than 2 mm from colony margins against *X. campestris* pv. *oryzae* strains, and 4-6 mm against *X. campestris* pv. *vascuolorum* strains. Inhibition zones were larger at 20° C than at 28° C, the optimum temperature for bacterial growth, on nutrient agar amended with 15 g/liter sucrose. The bacteriocin-like substances were heat stable (75°-80° C for 25 min) (Table 6, Fig. 10). The increase in antibacterial activity with $(NH_4)_2SO_4$ precipitation indicated that the substances were proteinaceous. The inhibition activity was not affected by ribonuclease, dioxyribonucleic acid, and proteinase, but was affected by protease and trysin.

Toxin produced by *X. campestris* **pv.** *oryzae.* Previous studies (Annual report for 1981) indicated that *X. campestris* pv. *oryzae* produced toxins. Further analysis suggested that the dialysable

Table 3. Disease severity scale for estimating yield loss due to sheath rot. IRRI, 1982.

Severity scale	Severity of flag leaf sheath infection	Panicle exsertion	Grain filling	Grain discoloration
0	No infection	Normal	Normal	No discoloration or very few grains discolored
1	Slight infection (small brown lesions covering about 1/10 of leaf sheath)	Apparently normal	Normal	Few grains discolored
2	Moderate infection (larger lesions that tend to coalesce and may cover less than half the leaf sheath)	About 65% or more panicle exsertion	Majority of grains filled	Moderate discoloration
3	Severe infection (lesions that have coalesced and may cover the entire leaf sheath)	No exsertion to slight exsertion of about 30% straight upward panicle	Almost 100% unfilled grain	Severe discoloration with whitish fungal growth

Table 4. Relationship of severity ratings with flag leaf sheath infection, panicle exsertion, grain filling, and grain discoloration. IRRI, 1982

Severity scale	Flag leaf sheath infection (%)	Panicle exsertion (%)	Grain filling (%)	Discolored grain (%)
0	0 d	96.7 a	95.0 a	4.3 c
1	11.84 c	86.2 b	90.7 a	7.3 c
2	34.63 b	61.0 c	59.8 b	36.9 b
3	72.06 a	30.4 d	2.7 c	87.9 a

Table 5. Yield components of panicles with various sheath rot severity ratings.[a] IRRI, 1982.

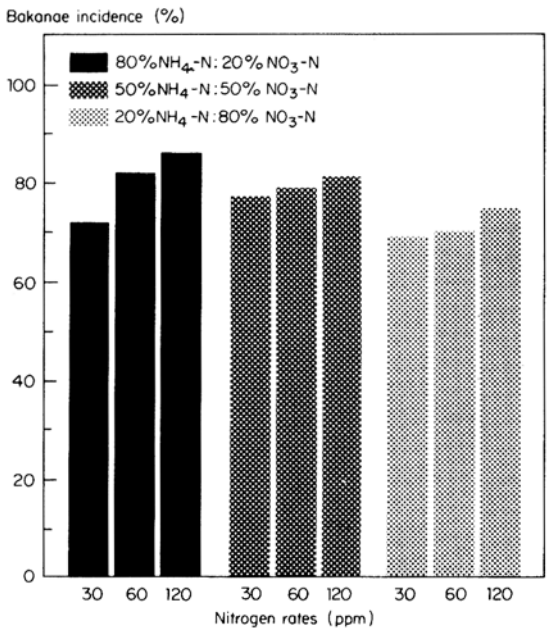
Severity rating	1000-grain wt (g)	Spikelets (no./ panicle)	Filled spikelets (%)	Relative yield (%)
0	24.9 a	164.2 a	95.0 a	100.0
1	24.3 a	178.5 a	90.7 a	88.3
2	22.3 b	171.4 a	59.8 b	62.2
3	14.8 c	144.5 b	2.7 c	1.3

[a]Healthy panicles and diseased panicles of IR442 selected from the field.

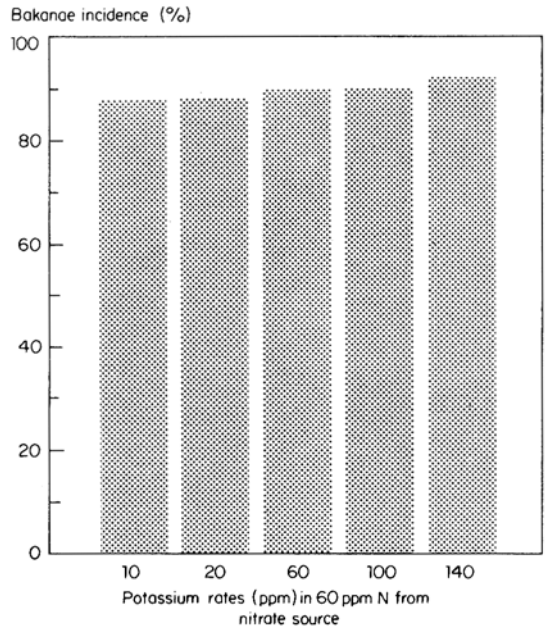
substances in culture filtrate of PXO 61 include succinic acid, fumaric acid, 3-methyl thiopropionic acid, trans-3-methyl thioacrylic acid, and phenyl acetic acid and three unidentified compounds, C_1, D_1, and D_2, with R_f values of 0.2, 0.29, and 0.35, respectively. The culture filtrate from the weakly virulent strain PXO 40 contained only succinic acid, fumaric acid, and a very small amount of the compounds D_1 and D_2 (Table 7). The biological activities of the unidentified compounds were tested. C_1, D_1, and D_2 showed high biological activity as indicated by wilting and yellowing of rice plants (Table 8). Biological activity of other compounds was also noted, but among them, phenyl acetic acid was most active in inducing wilting and yellowing.

In water extracts, dialysates, and ethyl acetate extracts of dialysates from extracts of bacterial blight-affected leaves, kresek plants showed more toxic activity than extracts from leaves with pale-yellow symptoms. The purified preparations from bacterial blight-affected leaves with PXO 61 showed the highest activity on test plants (Table 9). Other than extracellular polysaccharides isolated from rice leaves infected with PXO 61 and PXO 40, eight substances detected in culture filtrate were also detected in infected leaves with PXO 61 (Table 10). Succinic acid, fumaric acid, and the unidentified compounds D_1 and D_2 were detected from leaves infected with PXO 40. D_1 and D_2 were present in only small amounts on TLC chromatograms. When kresek plants were induced by PXO 40, all eight compounds were detected. The extract from pale-yellow leaves induced by PXO 61 contained large amounts of phenyl acetic acid and small amounts of C_1; other substances were not detected. Succinic acid, fumaric acid, D_1, and D_2 were present in healthy plants.

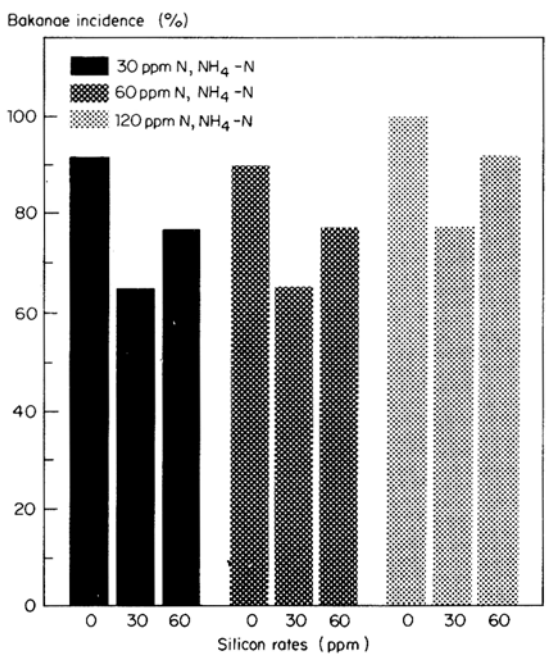
Response of bacterial blight differential varieties varied (Table 11). DV85 appeared to be more re-



5. Effect of source and N rates on bakanae incidence. IRRI, 1982.



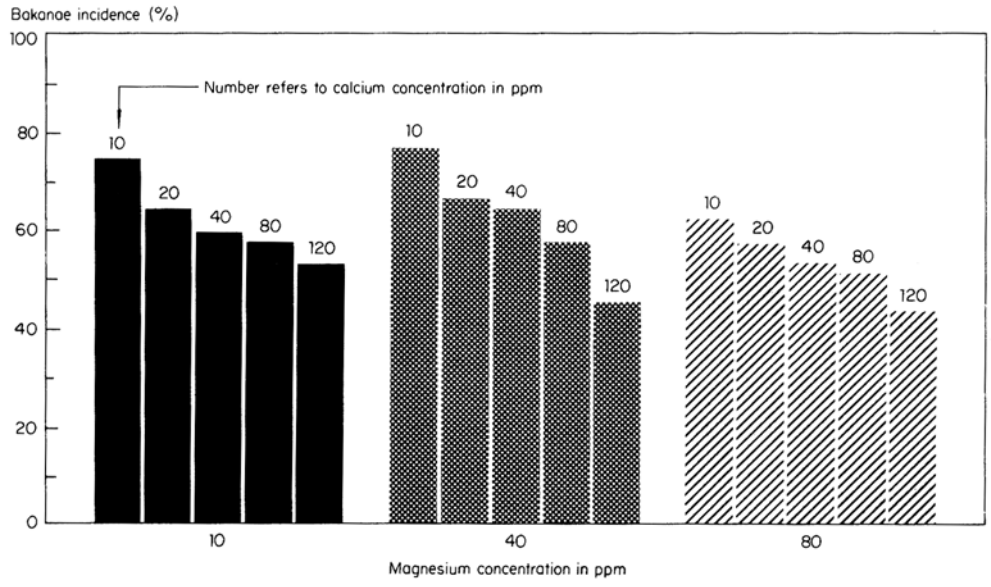
6. Effect of K rate on bakanae disease incidence. IRRI, 1982.



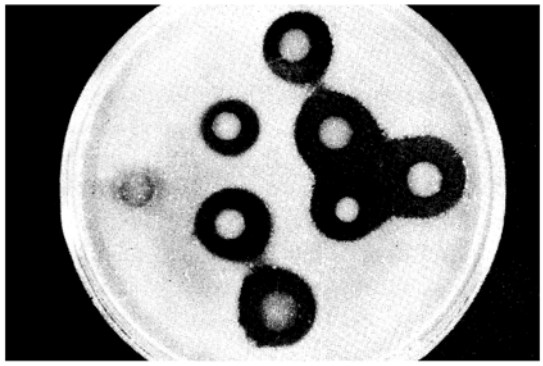
7. Effect of Si rate on bakanae disease incidence. IRRI, 1982.

sistant than others; Zenith seemed to be tolerant of all isolates. The culture filtrate appeared to delay seed germination. No clear-cut varietal difference was observed.

Numerical analysis of *Xanthomonas* sp. causing rice diseases — an IRRI-State University of Gent, Belgium, collaboration. In the past, there have been considerable data and conclusions regarding the bacteriological properties of *X. campestris* pv. *oryzae* and *X. campestris* pv. *oryzicola*, however, a numerical analysis of phenotypic features had not been applied. A study was conducted to apply numerical analysis of phenotypic features and modern molecular methods used in numerical taxonomy on a series of 36 *X. campestris* pv. *oryzae*, 12 *X. campestris* pv. *oryzicola*, and 6 brown blotch isolates from different ecological or geographical origins (Table 12). The latter group of isolates had been reported to have the general characteristics of members of the genus *Xanthomonas*, but they differ from *X. campestris* pv. *oryzae* in some physiological and biochemical characteristics. The numerical analysis of phenotypic features and modern molecular methods was applied to check homogeneity of *X. campestris* pv. *oryzae*, *X. campestris* pv. *oryzicola*, and brown blotch isolates (by numerical analysis of phenotypic features and polyacrylamide gel electrophoresis); determine taxonomic status of brown blotch isolates using phenotypic and genetic features (by



8. Effect of Ca-Mg combination on bakanae disease incidence. IRRI, 1982.



9. Bacteriocin-like substances produced by *Xanthomonas campestris* pv. *oryzae* on solid medium (nutrient agar + 15 g/liter sucrose). IRRI, 1982.

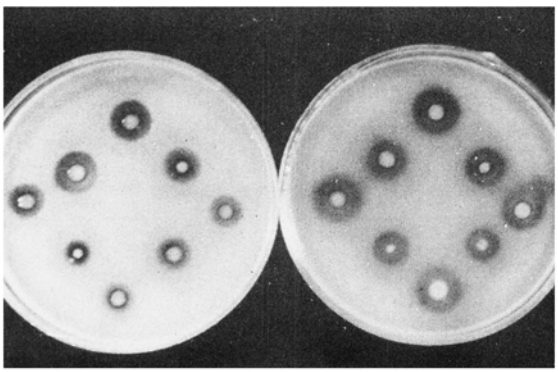
Table 6. Stability to heat of bacteriocin-like substances produced by *Xanthomonas campestris* pv. *oryzae* (75 - 80°C for 20 min). IRRI, 1982.

Producer	Inhibition[a] (mm) to indicator			
	Isa 148		BB 962	
	Heated	Non-heated	Heated	Non-heated
Isa 10	4.0	2.0	4.0	1.0
Isa 24	2.5	1.0	1.5	1.0
Isa 156	4.0	1.0	3.5	1.0
Isa 157b1	5.2	1.5	4.5	2.0
Isa 167	4.0	3.0	4.5	1.5
BB 912	4.5	2.0	3.0	2.0
PXO 83	2.5	1.0	2.5	2.0
PXO 61	5.0	2.0	5.0	2.0

[a]Diffusion of the bacteriocin-like substance perhaps occurred when the agar medium melted at the temperature.

determination of molar percentage of guanine + cytosine [% G + C] and DNA:rRNA hybridization); define the differentiation and similarities between *X. campestris* pv. *oryzae*, *X. campestris* pv. *oryzicola*, and brown blotch isolates; and find bacteriological differences between pathogenic races of *X. campestris* pv. *oryzae* (by phenotypic and polyacrylamide gel-electrophoretic analysis).

To screen as much of the bacterial genome as possible, a wide variety of features (unit characters) was chosen without putting emphasis (weight) on a certain character. About 131 phenotype traits were examined in the following sets of tests: cell morphology (five unit characters such as gram reaction, occurrence of chains, filaments); biochemical tests (26 unit characters such as esculin and arbutin hydrolysis, production of acetoin, hydrolysis of Tweens, egg yolk, pectinolysis, etc.); acid from carbon sources (19 unit characters such as acid from pentoses, hexoses, dissacharides, trisaccharides); growth on carbon-sources (45 unit characters such as growth on sugars or carbohydrates, polyphenols, glycosides, alcohols, organic acids); growth in different conditions (34 unit characters such as



10. Stability of bacteriocin-like substances produced by *Xanthomonas campestris* pv. *oryzae* on solid medium to heat (75-80°C for 25 min). (R = heated, L = unheated check) IRRI, 1982.

growth in different temperatures, growth in the presence of inhibitors-antibiotics, organic and inorganic compounds); reaction on carrot and potato slices (two unit characters).

The results of the numerical analysis of phenotypic features were expressed in a dendrogram that gave the similarity of each strain with the most similar strain and the overall similarity among strains. Figure 11 shows three phenons — Phenon 1, composed mainly of brown blotch isolates; Phenon 2 composed of *X. campestris* pv. *oryzae* with strains NCPPB 1152 and PXO 61 clustering somewhat lower than the other members of the groups; and Phenon 3, composed mostly of *X. campestris* pv. *oryzicola* with IRN235, a *X. campestris* pv. *oryzae* strain, NCPPB 1150 and NCPPB 1151, so-called *X. campestris* pv. *oryzae* strains. There were two subphenons each within Phenons 2 and 3. The two subphenons (A and B) in Phenon 2 could not be differentiated clearly, whereas the two subphenons (C and D) in Phenon 3 could be differentiated by two features. Subphenon C could hydrolyze arbutin and could grow in the presence of 0.0001% cadmium acetate while Subphenon D

Table 7. Substances isolated from ethyl acetate extracts of the culture filtrates of highly virulent (PXO 61) and weakly virulent (PXO 40) strains of *Xanthomonas campestris* pv. *oryzae*.[a] IRRI, 1982.

Substance	R_f	Extract from culture filtrate		Extract from dialysate of the culture filtrate	
		PXO 61	PXO 40	PXO 61	PXO 40
Succinic acid	0.08	+	+	+	+
Fumaric acid	0.14	+	+	+	+
Compound 1 (unidentified)	0.2	+	±	+	–
Compound 2 (unidentified)	0.29	+	–	+	–
Compound 3 (unidentified)	0.35	+	±	+	±
3-methyl thiopropionic acid	0.41[b]	+	–	+	–
trans-3-methyl thioacrylic acid	0.44	±	–	±	–
Phenylacetic acid	0.5	+	–	+	–

[a] + = present, ± = present in traces as indicated by faint spots, – = absent. [b] Spot made visible by iodine.

Table 8. Toxic effect of different substances isolated from culture filtrates of *Xanthomonas campestris* pv. *oryzae*. IRRI, 1982.

Substance	Biological activity[a]					
	Elute		2000 ppm		1000 ppm	
	W	Y	W	Y	W	Y
Compound 1 (C)	7.7	1.7	–	–	–	–
Compound 2 (D_1)	5.7	1.3	–	–	–	–
Compound 3 (D_2)	5.0	1.0	–	–	–	–
Phenyl acetic acid	4.7	2.0	4.0	2.0	2.0	1.0
3-methyl thiopropionic acid	–	–	3.0	0.7	1.3	0.8
trans-3-methyl thioacrylic acid	–	–	4.0	0.8	2.7	0.8
Succinic acid	–	–	0	0	0	0
Fumaric acid	0	0.3	0	0.3	0	0
Control (water)	0	0	0	0	0	0

[a] Mean of scores at 15, 24, and 36 h of treatment (av of four replications). W = wilting (0-9 scale: 0 = no wilting, 9 = severe wilting); Y = yellowing (0-3 scale: 0 = no yellowing, 3 = severe yellowing).

Table 9. Substances isolated from ethyl acetate extracts of dialysates of water extracts from healthy and infected rice plants showing different symptoms. IRRI, 1982.

Substance	R_f	Infected plants						Healthy plants	
		Blight		Kresek		Pale yellow	Wilt[a]		
		PXO 40	PXO 61	PXO 40	PXO 61	PXO 61	PXO 61	Whole plant	Leaves
Succinic acid	0.08	+	+	+	+	+	+	+	+
Fumaric acid	0.14	+	+	+	+	+	+	+	+
Compound 1 (unidentified)	0.20	±	++	+	+	±	+	–	–
Compound 2 (unidentified)	0.29	+	++	++	++	++	++	±	±
Compound 3 (unidentified)	0.35	–	+	+	+	–	+	±	–
3-methyl thiopropionic acid	0.41[b]	–	+	+	+	–	+	–	–
trans-3-methyl thioacrylic acid	0.44	–	±	+	+	–	+	–	–
Phenylacetic acid	0.50	–	±	+	+	++	+	–	–

[a]Wilting tillers from plants showing pale-yellow symptoms. [b]Spot made visible by iodine, + = present moderately, ++ = present in higher amount, ± = present in traces as indicated by faint spots, – = absent.

Table 10. Extracellular polysaccharides (EPS) isolated from *Xanthomonas campestris* pv. *oryzae*-infected rice plants showing different symptoms. IRRI, 1982.

Kind of sample	Strain	Score[a] (SES)/ incidence (%)	EPS (mg/g fresh wt of sample)
Inoculated leaves showing blight symptom	PXO 61	7	11.2
Inoculated leaves showing blight symptom	PXO 40	2	0.63
Kresek-affected plants	PXO 61	90	2.7 (1.665)
Kresek-affected plants	PXO 40	51	2.695 (1.069)
Leaves showing pale-yellow symptom	PXO 61	56	0.4
Wilting tillers from plants with pale-yellow symptom (basal 1/2 above-ground portion)	PXO 61	42	2.9

[a]Disease severity recorded as score for blight on clip-inoculated leaves and as incidence in case of kresek and pale-yellow symptoms reproduced by root dipping and clip inoculation, respectively. The figures in parentheses represent the amounts of EPS (in milligrams per gram fresh weight of total biomass) produced by the inoculated plants.

could not. All strains of Subphenon D were isolated in India in 1966 and 1967. IRN 234 is a *X. campestris* pv. *oryzae* based on pathogenicity test, but clustered with Phenon 3 because of its resistance toward antibiotics, which is typical to *X. campestris* pv. *oryzicola*.

Table 13 shows the differentiating phenotypic features for the three phenons.

The DNA base composition of the organism expressed as % G + C was determined to find the taxonomic status of brown blotch isolates. Table 14 showed the % G + C of the two strains of *X. campestris* pv. *oryzae*, *X. campestris* pv. *oryzicola* and brown blotch isolates. Because the % G + C of brown blotch was within the span of the genus *Xanthomonas*, this could be an indication that brown blotch might be a *Xanthomonas*, so further work on the DNA:rRNA hybridization is necessary to reveal the real taxonomic status of this organism.

Polyacrylamide gel electrophoresis (PAGE) was used to compare the numerical analyses of the phenotypic features of the three pathogen groups. To date, only six *X. campestris* pv. *oryzae* strains and five *X. campestris* pv. *oryzicola* strains have been examined. Visual comparison of the electrophoregrams showed three types of protein patterns. The first consisted of all *X. campestris* pv. *oryzae* strains; the second consisted mostly of *X.*

Table 11. Response of rice varieties to culture filtrates of isolates of *Xanthomonas campestris* pv. *oryzae*. Average symptom scores on seedlings at 15, 24, and 36 h.[a] IRRI, 1982.

Variety	PXO 40		PXO 61		PXO 71		PXO 79		PXO 86	
	W	Y	W	Y	W	Y	W	Y	W	Y
IR8	5.7	1.3	6.7	0.7	6.7	1.3	5.3	1.0	5.3	0.7
IR20	5.0	0.2	6.0	0.5	7.7	0.2	8.0	0.7	7.3	0.2
IR1545	5.0	0.0	4.3	0.0	4.7	0.0	5.7	0.0	5.7	0.0
Cas 209	6.0	1.5	7.3	1.3	7.0	1.5	6.7	1.3	6.7	1.5
DV85	2.3	2.0	2.3	1.5	3.3	1.8	4.3	1.7	2.3	1.5
Zenith	2.3	0.2	4.7	0.7	3.3	0.3	4.3	0.3	3.7	0.7

[a]W = wilting (0-9 scale), Y = yellowing (0-3 scale).

Table 12. List of isolates used in the numerical analysis of phenotypic features of bacterial blight, bacterial leaf streak, and brown blotch pathogens and their corresponding place and year of isolation, source, place in the dendrogram, and pathogenicity on rice variety TN1. IRRI, 1982.

Name as indicated by catalogue or author(s)[a]	Strain number[b]	Other strain designation(s)[b]	Isolation place, year	Source[c]	Place in the dendrogram	Pathogenicity on TN1[d]
X. c. pv. *oryzae*	NCPPB 1152	PDDCC 443	Japan	ex N. Okabe	2	2.44
X. c. pv. *oryzae*	NCPPB 1153	PDDCC 442	Japan	ex H. Muko	A	1.99
X. c. pv. *oryzae*	NCPPB 1154	PDDCC 440	Japan	ex H. Muko	B	1.96
X. c. pv. *oryzae*	NCPPB 1936	ICPB XO 110	India, 1963	ex D. N. Srivastava	A	20.03
X. c. pv. *oryzae*	NCPPB 2446		Japan, 1958	S. Yoshimura	A	3.65
X. c. pv. *oryzae*	T7174	E 698	Ooita, Japan	S. Wakimoto	B	3.37
X. c. pv. *oryzae*	T7133		Mie, Japan	S. Wakimoto	B	27.69
X. c. pv. *oryzae*	Q7472		Ooita, Japan	S. Wakimoto	A	14.89
X. c. pv. *oryzae*	Q7527		Miyazaki, Japan	S. Wakimoto	A	3.78
X. c. pv. *oryzae*	H75304		Miyazaki, Japan	S. Wakimoto	A	6.02
X. c. pv. *oryzae*	T7147		Japan	S. Wakimoto	A	0.60
X. c. pv. *oryzae*	IRN 198		Bolivia	H. Kauffman	B	4.82
X. c. pv. *oryzae*	IRN 235		Kogoni, Mali	H. C. Vuong	3	15.63
X. c. pv. *oryzae*	IRN 279		Nepal	T. W. Mew	B	21.69
X. c. pv. *oryzae*	IRN 325		Indonesia	T. W. Mew	B	28.86
X. c. pv. *oryzae*	PDDCC 3123		India, 1963	ex Y. P. Rao	B	4.03
X. c. pv. *oryzae*	PDDCC 3124		India, 1965	ex Y. P. Rao	B	3.90
X. c. pv. *oryzae*	PDDCC 3126		India, 1966	ex Y. P. Rao	B	3.95
X. c. pv. *oryzae*	PDDCC 3127		India, 1966	ex Y. P. Rao	B	1.81
X. c. pv. *oryzae*	PDDCC 3128		India, 1970	ex Y. P. Rao	B	16.55
X. c. pv. *oryzae*	PDDCC 4646		China	ex T. C. Huang	B	15.61
X. c. pv. *oryzae*	PXO 10		Philippines, 1972	M. P. Natural	B	24.01
X. c. pv. *oryzae*	PXO 40		Philippines, 1972	C. T. Rivera	A	5.11
X. c. pv. *oryzae*	PXO 61		Philippines, 1973	ex T. W. Mew	2	20.18
X. c. pv. *oryzae*	PXO 71		Palawan area, Philippines, 1974	ex T. W. Mew	B	4.31
X. c. pv. *oryzae*	PXO 79		Davao, Phil., 1975	ex T. W. Mew	B	4.95
X. c. pv. *oryzae*	PXO 82		Philippines, 1976	ex T. W. Mew	B	18.94
X. c. pv. *oryzae*	PXO 86		Philippines, 1977	ex T. W. Mew	B	17.70
X. c. pv. *oryzae*	CIAT 1185		Colombia	J. C. Lozano	B	15.93
X. c. pv. *oryzae*	CIAT 1186		Colombia	J. C. Lozano	A	18.73
X. c. pv. *oryzae*	E 698	TM 74	Japan	S. Wakimoto	A	3.76
X. c. pv. *oryzae*	21		West Java, Indonesia	Suparyono	A	7.79

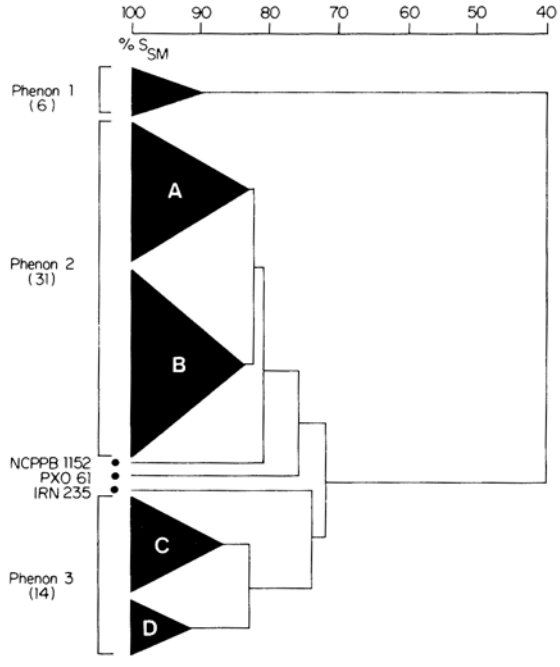
Continued on next page

Table 12 continued

Name as indicated by catalogue or author(s)[a]	Strain number[b]	Other strain designation(s)[b]	Isolation place, year	Source[c]	Place in the dendrogram	Pathogenicity on TN1[d]
X. c. pv. *oryzae*	37		Central Java, Indonesia	Suparyono	A	11.87
X. c. pv. *oryzae*	39		Central Java, Indonesia	Suparyono	B	16.99
X. c. pv. *oryzicola*	NCPPB 1150[e]	PDDCC 364	Philippines	ex F. T. Orillo	C	3.00
X. c. pv. *oryzicola*	NCPPB 1151[e]	PDDCC 363	Philippines	ex F. T. Orillo	C	1.00
X. c. pv. *oryzicola*	NCPPB 1585	PDDC 5743 ICPB XO 11	Malaysia, 1964	A. C. Hayward	C	5.00
X. c. pv. *oryzicola*	NCPPB 1632	ICPB XO 109	—	ex M. Goto	C	0.00
X. c. pv. *oryzicola*	PDDCC 1621	ICPB XO 104	Philippines, 1963	ex M. Goto	C	5.00
X. c. pv. *oryzicoia*	PDDCC 3122	ICPB XO 105	Philippines, 1963	ex M. Goto	C	0.00
X. c. pv. *oryzicola*	PDDCC 3129		India, 1967	ex G. S. Shekhawat	D	0.00
X. c. pv. *oryzicola*	PDDCC 3130		India, 1967	ex G. S. Shekhawat	D	0.00
X. c. pv. *oryzicola*	PDDCC 3131		India, 1967	ex G. S. Shekhawat	D	1.00
X. c. pv. *oryzicola*	PDDCC 3132		India, 1967	ex G. S. Shekhawat	D	1.00
X. c. pv. *oryzicola*	PDDCC 3133		India, 1967	ex G. S. Shekhawat	D	1.00
X. c. pv. *oryzicola*	PDDCC 3134		India, 1966	ex G. S. Shekhawat	D	3.00
X. c. pv. *oryzicola*	PDDCC 3135		India, 1968	ex G. S. Shekhawat	C	1.00
X. c. pv. *oryzicola*	PDDCC 3136		India, 1968	ex G. S. Shekhawat	C	0.00
X. c. pv. *oryzicola*	PDDCC 4654	CCM 2760	India, 1968	ex T. W. Mew	C	5.00
Brown blotch isolates	CIAT 1171		Norte, Panama, 1977	J. C. Lozano	3	nt[g]
	CIAT 1173		Monteria-Cordoba, Colombia, 1974	J. C. Lozano	3	nt
	CIAT 1187		Nataima-Tolima, Colombia, 1978	J. C. Lozano	3	nt
	CIAT 1191 (t_1, t_2)[f]		Monteria-Cordoba, Colombia, 1978	J. C. Lozano	3	nt
	CIAT 1192		Nataima-Tolima Colombia, 1978	J. C. Lozano	3	nt

[a]Names according to Dye et al (1980). [b]Abbreviations used: CCM = Czechoslavak Collection of Microorganisms; CIAT = Centro Internacional de Agricultura Tropical, Cali, Colombia; ICPB = International Collection of Phytopathogenic Bacteria, USA; IRN = Isolate Record Number, IRRI, Philippines; NCPPB = National Collection of Plant Pathogenic Bacteria, Marpenden, England; PDDCC = Plant Diseases Division Culture Collection, Auckland, New Zealand; PXO = Philippine *Xanthomonas oryzae,* IRRI, Philippines. [c]Names of isolators are underlined; names preceded by "ex" indicate individuals who successively maintained the culture before its deposition. [d]Pathogenicity for *X. campestris* pv. *oryzae* expressed as mean lesion length in centimeters; for *X. campestris* pv. *oryzicola* as mean visual score based on Standard Evaluation System for Rice (IRRI). [e]Strains NCPPB 1150 and NCPPB 1151 have been named *X. campestris* pv. *oryzae,* however, pathogenicity tests clearly showed that both strains are leaf streak organisms. Their PDDCC equivalents, i.e. PDDCC 364 and PDDCC 363, respectively, have not been examined. [f]CIAT 1191, showing two colony types (t_1, t_2) isolated from *Echinochloa colonum.* [g]Not tested.

campestris pv. *oryzicola* strains except for IRN 198 from Bolivia. NCPPB 1150, which was revealed by the phenotypic and pathogenicity test to be a *X. campestris* pv. *oryzicola* strain, was again confirmed by PAGE to belong to this group. IRN 235 from Mali, Africa, was a special case, showing a third protein pattern different from that of *X. campestris* pv. *oryzae* and *X. campestris* pv. *oryzicola*. A special PAGE procedure was necessary for brown blotch isolates because a clear-cut protein pattern was difficult to obtain in the presence of too many polysaccharides. This test was repeated to include all 54 strains used in the phenotypic test.



11. Phenons of *Xanthomonas* sp. causing rice diseases based on numerical analysis of 132 features. IRRI, 1982.

VIRUS DISEASES

Relationships between grassy stunt and rice stripe virus. Filamentous particles were purified from RGSV-infected rice plants, and antiserum was prepared at the Institute for Plant Virus Research (IPVR) Japan. The filament was ribonucleoprotein, 6 nm in diameter. Some of the filaments were circular with lengths of 1,000-1,300 nm. A titer of the antiserum against purified filaments was 1:1,280 in the precipitin ring interface test. The filaments and rice stripe virus are similar in morphology and somewhat serologically related. This indicates that the filaments may be a causal virus of RGSV. The antiserum was used in studies of serological relationships between RGSV in Japan and RGSV 1 and 2 in the Philippines. Both strains were closely related to RGSV in Japan.

Detection of viruses by serological tests. Two serological tests, the latex agglutination test and the enzyme-linked immunosorbent assay (ELISA), were used to detect viruses in rice leaves and vector insects. IPVR collaborators supplied antisera for rice tungro bacilliform virus (RTBV), rice tungro spherical virus (RTSV), rice ragged stunt virus (RRSV), and RGSV-associated filaments.

Table 13. Differentiating features among *Xanthomonas campestris* pv. *oryzae* (Phenon 2), *X. campestris* pv. *oryzicola* (Phenon 3), and brown blotch isolates (Phenon 1). IRRI, 1982.

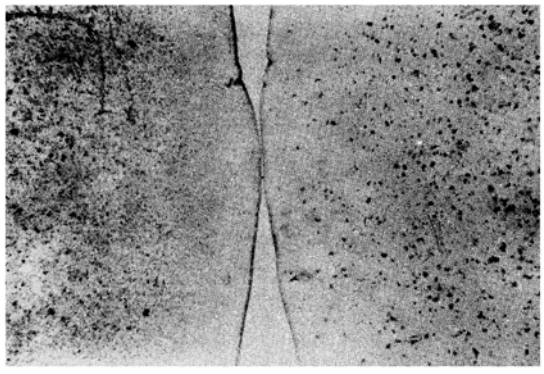
Feature	Brown blotch isolates (Phenon 1)	*X. c.* pv. *oryzae* (Phenon 2)	*X. c.* pv. *oryzicola* (Phenon 3)
Acetoin production	–	–	–
Strong peptonization in litmus milk	–	–	d
Phe-diaminase	–	–	d
H_2S from peptone	–	+	+
Hydrolysis of Tweens 60 and 80	–	+	+
Acid from D-galactose, cellobiose, and trehalose	–	+	+
Growth on:			
D-xylose, Na-L-Lactate	–	+	+
glycerol, propionic acid	+	–	–
L-alanine	+	–	+
Growth in the presence of:			
0.005% Methicillin	+	–	–
0.001% Ampicillin	d	–	+
0.001% Cu $(NO_3)_2$	+	+	–
0.001% 8-hydroxyguinolein	+	–	–

Table 14. DNA base composition, expressed as molar percentage of guanine + cytosine of *Xanthomonas campestris* pv. *oryzae*, *X. campestris* pv. *oryzicola*, and brown blotch isolates. IRRI, 1982.

Bacterium	Strain	Tm(e) (°C)	% G+C
Brown blotch isolate	CIAT 1171	95.3	63.2
	CIAT 1173	95.4	63.5
X. campestris pv. *oryzae*	NCPPB 1153	95.8	64.5
	T 7147	95.9	64.7
X. campestris pv. *oryzicola*	NCPPB 1585	96.0	65.0
	PDDCC 3135	96.0	65.0

Latex agglutination test. Latex particles (0.81 μm in diameter) treated with antiserum were mixed with extracts of virus-infected leaves or virus-exposed vector insects. Reactions were judged visually or under the light microscope base on clumping of latex particles (Fig. 12).

RGSV was detected efficiently from rice leaves and vectors by the latex test using RGSV antiserum. Reactions of extracts of leaves infected with RGSV 1 or RGSV 2 up to dilutions of 1:5,120, or



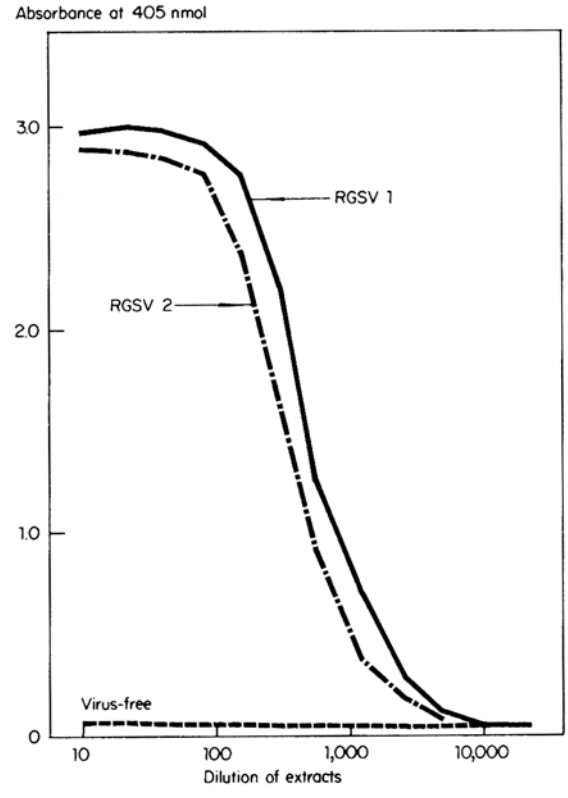
12. A light micrograph shows the clumping of latex particles indicating the presence of RGSV in leaf extract (right) and the absence of clumping in virus-free leaf extract (left). IRRI, 1982.

1:1,280, respectively, were positive. The dilution endpoint for positive reactions was 1:10,240 for RGSV 1 viruliferous BPH. Extracts of virus-free leaves and BPH gave no positive reaction even at 1:10 dilutions. The latex test can be adopted in the fields for the diagnosis of RGSV 1 and RGSV 2.

RTBV and RTSV were detected separately from tungro-infected rice plants by the latex test. This confirms that tungro is caused by a RTBV-RTSV complex. The dilution endpoint of tungro-infected leaf extracts was 1:80 for RTBV (when anti-RTBV γ-globulin was used, the endpoint was 1:160) and 1:320 for RTSV.

RRSV was not detected from infected leaves nor from viruliferous BPH.

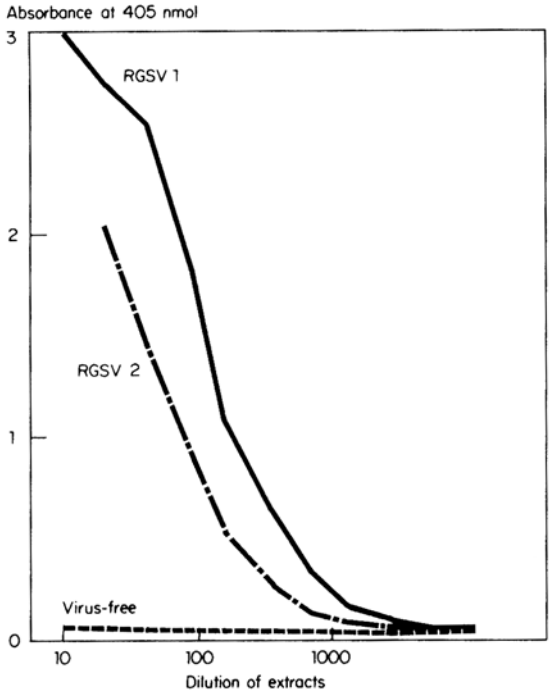
Enzyme-linked immunosorbent assay. A micro-ELISA plate (Dynatech) was coated with anti-RGSV or -RRSV γ-globulin; then the virus in the test sample was selectively trapped. Trapped virus was then reacted with further specific γ-globulin to which alkaline-phosphatase had been linked. Enzyme-labeled γ-globulin that had complexed with the trapped virus was detected visually or photometrically at 405 nm by adding an enzyme substrate. RGSV 1 and 2 were detected from infected leaf extracts up to a dilution of 1:5,120 (Fig. 13), while they were detected from BPH extracts up to 1:2,560 (Fig. 14). RRSV was detected from leaves up to a dilution of 1:640 (Fig. 15), and from BPH up to 1:1,280. This indicates that ELISA can detect RGSV and RRSV from individual BPHs.



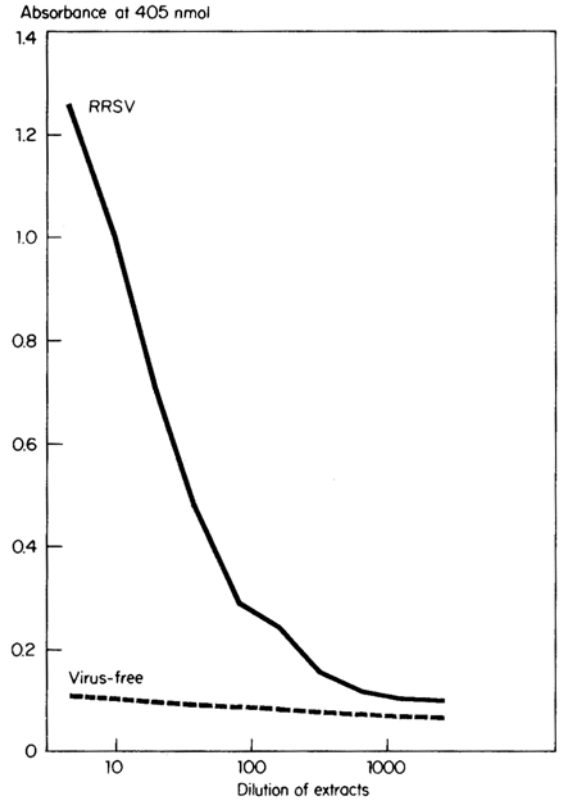
13. Reactions of extracts of rice leaves infested with RGSV 1 or RGSV 2 in enzyme-linked immunosorbent assay. IRRI, 1982.

Starch test for tungro diagnosis. Rice leaves infected with RTV often turn dark after treatment with iodine solution. This reaction could be used as an additional diagnostic test for RTV (Annual report for 1966). The usual procedure was boiling the infected leaves in ethyl alcohol to remove the chlorophyll and staining the boiled leaves with iodine potassium iodide (I_2KI) solution. This is time consuming, expensive, and difficult to apply in the field.

Procedure and reactions. A modified method consists of dipping a piece of diseased leaf about 10 cm long in a small amount of I_2KI in a small test tube for 15-30 min. The positive reaction is judged on the basis of the dark coloration (almost black) at the cut edge immersed in the solution and by dark streaks along the leaf veins. A negative reaction is indicated by a brownish color at the edges of the leaf pieces. Blank tests using artificially



14. Reaction of extracts of BPH exposed to RGSV 1 or RGSV 2 in enzyme-linked immunosorbent assay. IRRI, 1982.



15. Reaction of RRSV-infected and virus-free leaf extracts in enzyme-linked immunosorbent assay. IRRI, 1982.

inoculated TN1 plants gave good results. Using more leaves per diseased plant, particularly the second leaf showing discoloration, increased accuracy to 100%. In another test using naturally infected TN1 plants collected from the rice tungro nursery at IRRI, 82-91% of the discolored leaves gave positive reaction compared with only 9-17% of the green leaves. Moreover, the second leaf (starting from the youngest) gave 88% positive reaction compared with the youngest leaf (68%) and third leaf (32%). The healthy leaves (yellow, senescent) gave a negative reaction.

Comparison of the starch and transmission tests. The starch test and insect transmission test were compared to confirm reliability of the starch test. Fifty discolored leaves from TN1 plants naturally infected with RTV were collected in the field. Each leaf was cut in half. One half was used for the starch test and the other half for the RTV transmission test using the GLH. Five virus-free GLH were given access to diseased leaf in a test tube for 24 h. The viruliferous insects were used to inoculate healthy 7-d-old TN1 seedlings in the test tube (one insect/seedling) for 24 h. The inoculated seedlings were transplanted in pots and observed for RTV symptoms. Ninety-four percent of these leaves had a positive reaction to the starch test; 96% of the leaves used as the virus source had positive transmission results. None of the 40 plants inoculated by insects that fed on healthy senescent leaves developed RTV symptoms nor did the leaves have a positive reaction to the starch test. This indicates that the starch test is as reliable as the insect transmission test.

Significance and limitations of the starch test. The modified starch reaction test is simple, economical, and convenient in the field. Unlike the insect transmission test, which requires at least 7 d to obtain results, the modified starch reaction test needs about 30 min. Knowing that RTV is in a field 7 d sooner can be very important when the vector population is high.

However, the starch reaction test is not fool-

proof. First, the starch reaction is not highly specific to RTV disease because rice leaves infected with orange leaf also show positive reaction (Annual report for 1966). Also, discolored leaves of rice plants infected with RGSV 2 occasionally give a slight positive reaction, especially when dipping time is prolonged. Generally, rice leaves infected with ragged stunt did not give positive starch reaction except once when a leaf showed a slight positive reaction. The leaf might have been contaminated with RTV because the plants were kept outside.

Second, not all leaves of infected plants showed a positive reaction. However, this limitation could be overcome by testing more leaves per hill, particularly the discolored ones. The starch reaction test is therefore useful in detecting RTV-infected plants, particularly in the early stage of an epidemic when immediate control measures are needed. A positive starch reaction together with a high GLH population in the area would be a strong indication that RTV is present.

Effect of azolla on tungro incidence. IR36 (resistant to RTV in field and moderately susceptible in greenhouse) and TN1 (highly susceptible in field and in greenhouse) were raised in pots with and without azolla application. The pots containing the seedlings with and without azolla were arranged together and separately in inoculation cages to provide viruliferous insects with a choice of plants, as in the field. Uninoculated plants were the control. The percentage of infected seedlings were observed on day 12.

The occurrence of RTV-infected seedlings raised with and without azolla was almost the same for both varieties. The susceptible TN1 seedlings were severely infected: 85.4% infected in the cages with azolla and 89.3% without. IR36 was moderately infected: 45.6% infected in the cages with azolla and 44.7% without azolla.

In the field trial conducted in microplots, azolla application did not appear to influence the RTV incidence on either variety.

Effect of custard-apple and neem oils on green leafhopper and its transmission of tungro. Oils extracted from the seeds of custard apple (*Annona squamosa* L.) and neem (*Azadirachta indica* A. Juss) were sprayed on 10-d-old TN1 seedlings at 5, 10, 20, 30, and 50% concentrations with 0.1% Teepol as the emulsifier. Water with 0.1% Teepol was the control spray. GLH exposed to both oil sprays failed to survive beyond 3 d at 30 and 50% concentrations. A higher percentage of survival was observed at lower concentrations. However, insects survived beyond 5 d at all concentrations; insects that survived on control plant lived beyond 20 d.

The percentage of seedlings infected was reduced considerably on the second day of exposure to oil-sprayed plants and reached almost zero in custard apple oil spray at a 50% concentration. Very few insects survived after the third day and failed to transmit the disease beyond 3 d. The control plants became infected even beyond 5 d. Spraying before inoculation was effective in reducing the percentage of seedlings infected by RTV regardless of the oil concentration (Table 15).

CULTURAL AND BIOLOGICAL CONTROL

Influence of *Trichoderma* sp. from dryland rice fields on sheath blight fungus. The isolation of *Trichoderma* sp., a fungus antagonistic to the rice sheath blight pathogen from dryland rice fields, was reported in the Annual report for 1980. In 1982, the occurrence of the fungus in different rice cultural types was surveyed on the IRRI farm. Through the use of the dilution plate method on gallic acid agar medium, the *Trichoderma* sp. was isolated from dryland and rainfed wetland fields but not from irrigated fields with standing water (Table 16). On agar medium plates, the inhibition zone between *Trichoderma* sp. and *Thanatephorus cucumeris*, the sheath blight pathogen, was formed. The pathogen mycelium stopped growing when in

Table 15. Effect on RTV transmission of spraying oils at different times, before and after inoculations. IRRI, 1982.

Time (h) before inoculation	RTV infection (%)	Time (h) after inoculation	RTV infection (%)
0	18.89	0	83.35
0.5	19.72	0.5	78.57
1	16.00	1	82.63
2	12.39	2	79.28
3	16.17	3	83.95
4	16.06	4	79.65
24	23.22	24	86.25
0 (water spray)	72.44	0 (no spray)	84.46

Table 16. Isolation of *Trochoderma* sp. from soil in different fields. IRRI, 1982.

Type of field	Location	Field condition	Crop	Trichoderma/ g soil[a]
Irrigated	824	Standing water	Ratooned rice	0
	825	Standing water	Ratooned rice	0
	828	Standing water	Fallow	0
	829	Standing water	Rice at maturity	0
Dryland	UQ3	Dry	Fallow	42.8 ± 7.60
	UQ4	Dry	Mungbean	47.5 ± 27.3
	DH7	Dry	Fallow	56.0 ± 29.1
Rainfed-wetland	830	Dry	Rice at maturity	22.5 ± 19.0
	831	Wet	Rice at booting	9.6 ± 3.2

[a]Determined by dilution plate using gallic acid medium.

contact with *Trichoderma* (Fig. 16). Microscopic examination of the hyphae of the two organisms showed that *Trichoderma* frequently coiled around the aerial hyphae of *T. cucumeris*. The cytoplasm vacuolated and coagulated and then the hyphae of the fungal pathogen burst.

Bacteria from rice fields antagonistic to sheath blight development. Many bacteria of different colony morphology from rice fields showed strong antagonistic activity against the rice sheath blight pathogen (Annual report for 1981). To determine the effect of the bacteria on sheath blight development, two isolates (In-b-17 and In-b-24) were tested for their influence on infectivity of the sclerotia. The bacteria affected the viability of the sclerotia (Fig. 17) on the detached flagleaf; they also prevented sheath blight lesion initiated from these sclerotia. Sclerotia mixed with In-b-17 for 2 wk were no longer viable (Table 17). On potted IR36, when the bacterial suspension was applied to the stem of the rice plants 1 d before inoculation of the sheath blight inoculum, both disease incidence and severity were reduced. Field experiments are in progress.



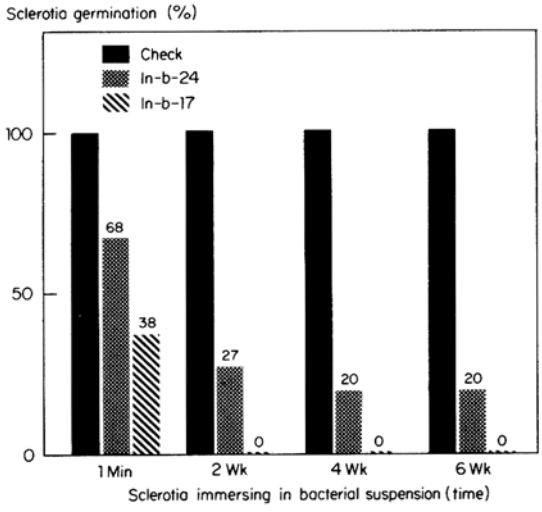
16. Reaction of healthy leaf (left), and leaves infected with RGSV 2 (middle) and RTV (right) to iodine test. IRRI, 1982.

CHEMICAL CONTROL

Blast. *Seed treatment*. Systemic compounds for seed treatment were evaluated in the blast nursery and the field. Treated and untreated seeds were either planted in plastic trays filled with soil or planted in the blast nursery and field plots. The test plants were continuously exposed to blast inoculum.

CGA49104 (50% WP) and PP389 (50% WP) were each applied at 4 and 8 g/kg seed. Hoe 00550 (75% WP) was applied at 16 and 32 g/kg seed. In the blast nursery, all three chemicals effectively protected seedlings in plastic trays against leaf blast up to 6-8 WAS.

Similarly, when treated and untreated seeds were planted directly in the blast nursery plots, CGA49104 and Hoe 00550, at the rates mentioned, consistently provided effective seedling protection against leaf blast infection for 6-8 WAS. When both compounds were applied to the seeds as



17. Influence of antagonistic bacteria from rice field on the viability of sclerotia of the rice sheath blight pathogen. IRRI, 1982.

slurries and dry powders using the same rates of application, the slurry preparations were more effective than the dry powders. However, the slurry preparations of Hoe 00550 reduced the percentage of seed germination more than did the dry powders. During previous years, the slurry treatment of CGA49104 had similar effects.

Among the other systemic compounds evaluated, only tricyclazole (75% WP), at 5.3 g/kg seed, provided moderate blast protection. However, tricyclazole with CGA49104 at 8 g/kg seed sometimes slightly reduced seed germination, especially with closer seed spacings and higher seeding rates in plastic trays. Earlier tests showed no reduction in germination of seeds treated with CGA49104 at 8.0 g/kg seed planted in rows 25 cm apart in dryland fields at seeding rates similar to those in the plastic trays and blast nursery.

When PP389 was applied at 10, 20, and 40 g/kg seed and CGA49104 at 2, 4, and 8 g/kg seed on seeds planted directly in rows 25 cm apart, both compounds effectively controlled blast up to 8 WAS. However, only the two higher rates of PP389 and the highest rate of CGA49104 markedly reduced neck blast infection on IR50 at harvest over the untreated check (Table 18). The computed grain yields were higher in all treatments, especially at the higher application rates than in the untreated check.

Table 17. Influence of antagonistic bacteria from rice field on sheath blight development in IR50. IRRI greenhouse, 1982.

Treatment[a]	Sheath blight[b]	
	Incidence (%)	Severity
Antagonist + pathogen (In-b-17)	30	0.61
Antagonist + pathogen (In-b-24)	75	1.27
Pathogen alone	100	2.00

[a]Bacterial suspension (1×10^6 cells/ml) was sprayed onto the rice plants 1 d before inoculation of the pathogen (sclerotia).

[b]Incidence = $\frac{\text{No. of tillers infected}}{\text{Total no. of tillers (3 hills)}}$

Severity sheath blight lesion (cm).

Seed soaking. When evaluated as suspensions for 24-h seed soaking, CGA49104 and PP389, at 1, 2, and 4 g/liter of suspension, effectively protected seedlings up to 8 WAS. The treated seeds were planted directly into the dapog beds and plastic trays (Table 19). However, when seedlings were transplanted in plastic trays and the chemically-soaked seeds were planted directly in the blast nursery beds, only the highest concentration (4 g/liter) provided slight to moderate protection up to 9 WAS (Table 20).

Seedling root dipping. CGA49104 and PP389 at concentrations of 1, 2, and 4 g/liter of suspension were evaluated as dapog seedling root dips. Dipping durations were 12 and 24 h. CGA49104 effectively protected the seedlings up to 7 WAS (Table 21). CGA49104 treatments resulted in more remaining green leaves and taller plants. CGA49104 is definitely superior to PP389 at the same concentration.

Foliar sprays. Some fungicides were evaluated as sprays, usually with three replications at weekly intervals. Edifenphos (50% EC), applied at 1 liter/ha, was consistently effective against leaf blast. Other tested fungicides with efficacies varying from slight to moderate are dispersible sulfur (80% ai) at 4 kg, thiabendazole (45% flowable) at 2 liters, and copper oxychloride (35% Cu) at 4 kg formulation/ha per application.

Thiophanate-methyl (70% WP), a commercially-available systemic fungicide, worked effectively at higher rates up to 8 WAS (Table 22). No phytotoxic

Table 18. Effect of seed treatment with systemic fungicides on leaf and neck blast control in IR50 in dryland fields.[a] IRRI, 1982.

Chemical	Rate (g formulation/kg seeds)	Lesions[b] (no./seedling) 4 WAS	6 WAS	8 WAS	Leaf blast control[c] (%)	Neck blast infection[d] (%)	Sheath blight infection[e] (%)	Computed grain yield[f] (kg/ha)
PP389	40.0	0.4	0.4	0.8	97.9	27.1	5.0	437.5
(50% WP)	20.0	1.2	1.7	2.6	93.1	42.7	5.0	407.5
	10.0	6.5	8.2	11.1	70.5	68.4	6.0	278.3
CGA49104	8.0	2.8	3.5	4.1	89.1	48.8	4.5	376.7
(50% WP)	4.0	4.4	5.6	7.1	81.1	67.2	5.5	273.7
	2.0	10.6	13.8	15.3	59.3	76.1	7.5	246.2
No chemical (check)	0.0	27.4	32.6	37.6	–	68.4	6.5	227.9

[a]Treated and untreated seeds were seeded in rows (with 25-cm distance between furrows) in plots (12.0-m^2 plot/replication per treatment). [b]Mean of four replications; in each replication, 25 seedlings were picked at random, marked, and used for leaf blast disease readings. [c]Based on leaf blast infection at 8 WAS. [d]Infection count, made on the total number of panicles harvested from 6-m^2 center portion of each treatment plot/replication. [e]Based on scales 0 to 9 of natural infection: 0 = no infection and 9 = lesions reaching top of tillers (severe infection on all leaves and some plants killed). [f]Mean of four replications; each replication with 6.0 m^2 harvested area; yield at 14% MC.

effects were observed on test plants.

On a field planted to IR52, natural infections of leaf blast and sheath blight were observed at the late booting to early flowering stages. Fungicide combinations were immediately sprayed on the plants. To avoid possible fungicide incompatibility the first chemical in the combination intended to control sheath blight was applied 2 to 3 d ahead of the other fungicide intended to control leaf and neck blast. Each chemical was sprayed three times at weekly intervals.

The three combinations provided excellent protection against neck blast and moderate protection against sheath blight (Table 23).

Table 19. Effect of presprouting treatment of seeds with systemic fungicides on leaf blast control in trays and in dapog seedlings in the blast nursery. IRRI, 1982.

Chemical	Concn (g formulation/liter suspension)	Leaf blast control[a] (%) Dapog	Tray
CGA49104 (50% WP)	4.0	98.4	100.0
CGA49104 (50% WP)	2.0	85.7	100.0
CGA49104 (50% WP)	1.0	80.4	98.9
PP389 (50% WP)	4.0	90.0	88.1
PP389 (50% WP)	2.0	66.8	74.3
PP389 (50% WP)	1.0	61.4	64.3
No chemical (check)	0.0	–	–

[a]Based on disease reading of infection taken at 8 WAS.

Table 20. Effect of presprouting treatment of seeds with systemic fungicides on leaf blast control in the blast nursery. IRRI, 1982.

Chemical	Concn (g formulation/liter suspension)	Leaf blast control[a] (%)	Green leaves[b] (%)	Plant ht[c] (%)
CGA49104 (50% WP)	4.0	65.2	71.7	46.0
CGA49104 (50% WP)	2.0	35.0	69.5	43.1
CGA49104 (50% WP)	1.0	27.5	67.8	37.8
PP389 (50% WP)	4.0	12.3	57.4	38.2
PP389 (50% WP)	2.0	11.9	54.4	34.0
PP389 (50% WP)	1.0	9.8	53.3	37.1
Untreated seeds	0.0	–	29.3	25.0

[a]Based on infection at 9 WAS; most of the test seedlings in the untreated seeds (check) treatment had been killed by blast. [b]Based on the 6th to 9th upper leaves of the 25 seedlings picked at random, marked, and used for disease readings; determined at 9 WAS. [c]Measurements taken at 9 WAS from the survivors of the original 25 seedlings picked at random, marked, and used for disease readings.

Table 21. Effect of 12- and 24-h root-dipping in systemic fungicide suspensions before transplanting of 10-d-old dapog-raised seedlings on leaf blast control in the blast nursery.[a] IRRI, 1982.

Chemical	Concn (g formulation/liter suspension)	12-h suspension			24-h suspension		
		Leaf blast control[b] (%)	Green leaves[c] (%)	Plant ht[d] (cm)	Leaf blast control[b] (%)	Green leaves[c] (%)	Plant ht[d] (%)
CGA49104 (50% WP)	4.0	93.7	92.1	30.0	96.1	100.0	30.4
CGA49104 (50% WP)	2.0	92.9	91.7	32.8	95.2	99.2	32.4
CGA49104 (50% WP)	1.0	80.6	83.5	30.6	73.2	97.5	30.3
PP389 (50% WP)	4.0	39.4	63.6	32.1	18.3	66.6	29.7
PP389 (50% WP)	2.0	25.0	65.4	32.3	22.9	63.7	27.5
PP389 (50% WP)	1.0	22.4	62.6	31.7	17.1	62.5	27.5
Untreated seedlings	0.0	–	57.0	29.6	–	55.1	26.1

[a]After their root systems had been dipped, the seedlings were transplanted in rows in plastic trays (five rows/tray; 20 seedlings/row) filled with soil and exposed continuously to blast inoculum. [b]Based on disease reading of infection taken at 7 WAS. [c]Based on the 2nd to the 6th upper leaves per seedling at 7 WAS of 25 seedlings picked at random. [d]Based on measurement per seedling taken at 7 WAS from 25 seedlings picked at random.

Table 22. Effect of thiophanate methyl 70% WP foliar sprays at different rates of application on leaf blast control in the blast nursery. IRRI, 1982.

Rate (kg formulation/ 2,000 liters suspension per application)	Lesions/seeding[a] (no.)			Blast control[b] (%)
	4 WAS	6 WAS	8 WAS	
5.0	0.0	0.1	0.9	99.2
4.0	0.0	0.0	1.9	98.2
3.0	0.0	1.1	5.0	95.4
2.0	1.7	7.0	21.8	79.9
1.0	7.4	15.4	27.2	74.9
0.5	8.4	29.9	44.4	59.0
0.25	23.9	50.6	70.4	35.0
0.0	35.9	81.3	108.3	–

[a]Mean of three replications; each replication with 25 seedlings picked at random (from five rows of seedlings/plastic tray containing soil) marked and used for disease readings. [b]Based on the last disease reading taken 8 WAS.

Sheath blight. *Foliar sprays.* NTN19701 (25% WP), sprayed three times at weekly intervals at various rates, provided effective sheath blight protection up to 9 WAS (Table 24). Control increased with the application rate without any phytotoxic effect on the plants.

A tin compound triphenyltin acetate (60% WP), sprayed at different rates, resulted in similar control (Table 25). However, very slight to moderate phytotoxicity was observed on leaf blades 4 d after the first sprays were applied at 3 WAS. No toxic effects of the second and third sprays were observed, indicating, that as the plants grow older, the leaf blades tend to become insensitive to triphenyltin acetate. Triphenyltin acetate may be used on adult plants in the field at the rates of 0.5-1.0 kg formulation/ha per application. Tests indicated that triphenyltin acetate was the best among the evaluated compounds (Table 26). The compound had no phytotoxic effects.

Bakanae. *Artificial seed infection.* Bakanae has resurged as a problem in farmers' fields planted to IR42, one of the highest yielders among IRRI varieties. The disease is seed transmitted. At the flowering stage, *Fusarium moniliforme* spores enter the open florets and may be present on the seeds even after harvest. In spite of the heavy bakanae incidence in some farmers' fields, it was difficult to obtain naturally infected seeds. So artificial field infection of seeds has become indispensable to proper evaluation of chemical effectiveness.

IR42 seeds were sprayed with spore suspensions in the field for a maximum of 5 consecutive days and a minimum of 3 times a week within a 5-d period. Motorized and knapsack sprayers were used. The two volumes of spore suspensions used were 1,000 and 2,000 liters/ha per application. The first-trial results indicate that the daily inoculations using the motorized sprayer exhibited the highest percentages of infected seeds (76.1% at the 1,000-liter rate and 79.8% at the 2,000-liter rate). At the 2,000-liter rate, the 3 weekly inoculations produced

Table 23. Effect of fungicide combinations as foliar sprays on neck blast and sheath blight control in IR52 in the field.[a] IRRI, 1982.

Chemical	Rate (kg or liter formulation/2,000 liters suspension per application)	Neck blast infection[b] (%)	Sheath blight disease rating[c]	Filled grains[d] (%)	Grain yield[e] (g)
Edifenphos (50% E. C.) and triphenyltin acetate (60% WP)	1.0 1.0	8.7	4.7	81.8	988.7
CGA49104 (50% WP) and triphenyltin acetate (60% WP)	1.0 1.0	11.8	5.3	77.8	960.1
Benomyl (50% WP) and triphenyltin acetate (60% WP)	1.0 1.0	12.0	5.2	78.4	1 023.4
No chemicals (check)	0.0	75.2	6.8	65.8	747.6

[a]In all treatments except the check (no chemical), triphenyltin acetate was sprayed on the rice plants starting at the early booting stage; 2-3 days ahead of the other fungicides. All chemicals were sprayed three times at weekly intervals. [b]Mean of four replications; each replication with 600 panicles picked at random from a 7.5 m-plot at harvest and used for neck blast infection count. [c]Rated on a 0-9 scale; 0 = no infection; 9 = lesions reaching top of tillers, all leaves and some plants killed. [d]Based on countings of 50-cc seed samples/replication. [e]From 600 panicles used for neck blast infection count/replication.

Table 24. Effect of NTN 19701 25% WP fungicide sprays at different application rates on sheath blight control in rice seedlings.[a] IRRI, 1982.

Application rate (kg formulation/2,000 liters suspension/application)	Infection[b] (%)				Sheath blight control[c] (%)
	4 WAS	5 WAS	7 WAS	9 WAS	
4.0	4.8	6.5	6.8	6.3	88.4
3.5	10.5	7.3	8.7	6.5	88.0
3.0	9.7	13.0	12.2	11.5	78.8
2.5	12.0	13.3	11.3	10.6	80.4
2.0	14.0	16.8	15.0	15.3	71.8
1.5	35.7	24.0	21.2	19.2	64.6
1.0	31.5	33.5	27.2	23.0	57.6
0.5	21.7	31.2	28.5	26.8	50.6
0.0 (check)	73.5	76.0	63.5	54.2	–

[a]The first spray was applied at 3 WAS; subsequent sprays were applied at weekly intervals; the test plants were artificially inoculated 1 d after the first spray application. [b]Mean of three replications; each replication with five rows of seedlings; based on the average infection of leaf sheaths and leaf blades of 25 IR1317-392-1-2 seedlings picked at random at every disease reading. [c]Based on infection at 9 WAS.

about 68% infected seeds. Continuous roguing of infected plants starting at the maximum tillering stage resulted in a very low (about 5-10%) infection of the harvested seeds.

Presprouting or soaking of naturally infected seeds. Benomyl (50% WP) and thiophanate-methyl (70% WP) provided very effective bakanae control from the dapog bed to field transplanting (Table 27). Both chemicals exhibited grain yields higher than the two checks.

The continuous roguing of bakanae-infected tillers from infected hills (plants), from maximum tillering to heading stage, remarkably reduced the amount of infected seeds to less than 4%. This confirmed the result obtained from the roguing treatment of the artificial infections.

Table 25. Effect of triphenyltin acetate 60% WP fungicide sprays at different rates of application on sheath blight control in rice seedlings.[a] IRRI, 1982.

Rate of application (kg formulation/2,000 liters suspension per application)	Infection[b] (%)			Mean infection[c]	Sheath blight control[d] (%)
	5 WAS	7 WAS	9 WAS		
3.00[e]	5.5	5.5	5.7	5.6	90.7
2.50[e]	8.2	8.8	8.3	8.4	86.1
2.00[e]	8.8	9.7	7.8	8.8	85.4
1.50[f]	21.7	18.8	16.3	18.9	68.7
1.00[g]	23.5	21.0	19.8	21.4	64.6
0.50[g]	35.7	28.8	25.2	29.9	50.5
0.25	38.1	31.7	24.3	31.4	48.0
0.00 (check)	68.8	53.8	58.7	60.4	–

[a]The first spray was applied at 3 WAS, two subsequent sprays were applied at weekly intervals; the test plants were artificially inoculated 1 day after the first spray application. [b]Mean of three replications; each replication with five rows of IR1317-392-1-2 seedlings; based on the average infections of leaf sheaths and leaf blades of 25 seedlings picked at random every disease reading. [c]Based on the average of three disease readings at 5, 7, and 9 WAS. [d]Based on the mean infection. [e]Phytotoxic effect, observed as many brown spots on many leaves; few leaves with about 50% of leaf area affected; observed 4 d after the first spray only. [f]Mild toxic effect, few brown spots appeared on many leaves; small leaf areas only were affected; observed 4 d after the first spray only. [g]Very mild toxic effect, very few spots appeared only on very few leaves; very small areas of leaf blades were affected; observed 4 d after the first spray only.

Table 26. Effect of fungicide sprays on sheath blight control in rice seedlings.[a] IRRI, 1982.

Chemical	Rate (kg or liter formulation/2,000 liters suspension/application)	Infection[b] (%)				Mean infection[c] (%)	Sheath blight control[d] (%)
		4 WAS	5 WAS	6 WAS	7 WAS		
Triphenyltin acetate (60% WP)	0.6	1.4	1.4	2.0	1.8	1.7	96.7
	0.5	0.4	1.0	1.4	4.1	1.7	96.7
Thiophanate-methyl (70% WP)	1.0	23.1	23.1	22.9	31.9	25.3	50.3
Copper oxychloride (35% Cu)	3.0	35.2	26.0	22.6	28.9	28.2	44.6
Dithianon (75% WP)	2.0	30.8	30.8	30.0	39.7	32.8	35.6
Copper oxychloride (35% Cu)	1.5	36.6	36.6	32.0	30.3	33.9	33.4
Dithianon (75% WP)	1.0	37.0	37.0	29.9	39.7	35.9	29.5
Pyrazophos (30% E.C.)	2.0	38.6	38.6	37.9	39.2	38.6	24.2
	1.0	39.9	39.9	40.1	37.2	39.3	22.8
No chemical (check)	0.0	50.2	50.2	53.0	50.1	50.9	–

[a]The first spray was applied at 3 WAS, two subsequent sprays were applied at weekly intervals; the test plants were artificially inoculated 1 day after the first spray application. [b]Mean of three replications; each replication with five rows of IR1317-392-1-2 seedlings; based on the average infections of leaf sheaths and leaf blades of 25 seedlings picked at random every disease reading. [c]Based on the average of four disease readings at 4, 5, 6, and 7 WAS. [d]Based on the mean infection.

Brown spot. *Foliar sprays.* Some fungicidal sprays against brown spot were evaluated in the screenhouse, using Sekiguchi Asahi, a highly susceptible variety, which produces unusually large, commonly coalescing brown spot lesions.

Evaluated chemicals and rates are listed in Table 28. Mebenil and Mancozeb, although not very effective, appeared best.

Seed discoloration. *Foliar sprays.* Fungicide sprays were applied seven times at weekly intervals

Table 27. Effect of presprouting treatment with benomyl and thiophanate-methyl of naturally infested seeds and roguing of bakanae-infected plants for bakanae control. IRRI, 1982.

Chemical	Concn (g formulation/liter suspension)	Dapog bed 8 DAS[b]	Seed infection[a] 10 DAS[b]	Infection (%) Dapog seedbed[c]	Tillers[d]	Tillers[e]	Hills[e]	infected seeds[f] (%)	Computed grain yield[g] (t/ha)
Benomyl (50% WP)	1.0	0.8	23.8	0.3	6.4	0.01	0.1	3.3	2.44
Thiophanate-methyl (70% WP)	2.0	0.8	25.8	0.3	4.0	0.01	0.1	4.8	2.31
No chemical + roguing of infected plants	0.0	281.0	1,358.8	14.4	14.8	3.06	20.5	3.8	2.02
No chemical (no roguing of infected plants)	0.0	363.8	1,441.3	15.3	14.6	3.94	26.5	39.8	2.06

[a]Mean of four replications; each replication with 250 g presprouted seeds grown in a 0.45- × 0.375-m dapog bed; test variety, IR42. [b]8 DAS = no. of infected seedlings with abnormal elongation symptoms only; 10 DAS = no. of infected seedlings with abnormal elongation and foot rot symptoms. [c]Based on number of infected seedlings counted at 10 DAS. [d]Based on number of infected (abnormally elongated) tillers/infected plant (hill) counted 2 MT from a 5.0- × 5.0-m treatment plot replication. [e]Based on counts made on a 5.0- × 5.0-m plot/replication of healthy and infected (abnormally elongated) tillers and plants (hills) at 2 MT. [f]Based on laboratory determination using Komada's medium to plate 100 surfaced-disinfested seeds; counting of infested seeds made 10 DAS. [g]From a harvest area of 16.0-m^2/replication; grain yield at 14% MC.

Table 28. Effect of fungicide sprays on brown spot control on variety Sekiguchi Asahi.[a] IRRI, 1982.

Chemical	Rate (kg formulation/2,000 liters suspension/application)	Lesions/seedling[b] (no.) 4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS	Brown spot control[c] (%)
Mebenil (75% WP)	1.0	5.2	23.7	46.9	54.3	77.7	88.9	54.3
Mancozeb (80% WP)	1.0	5.2	25.7	39.2	44.3	65.3	69.9	41.6
Chlorothalonil (75% WP)	1.0	4.0	13.6	35.1	51.4	76.3	82.8	30.8
Triphenyltin acetate (60% WP)	1.0	9.4	46.6	61.4	71.2	81.1	88.2	26.3
Tricyclazole (75% WP)	0.7	9.2	41.7	74.0	103.9	131.8	146.1	24.8
BAS 3302F (82% WP)	1.0	10.4	39.8	79.7	102.3	136.4	148.5	23.6

[a]The first spray was applied to the test plants 3 WAS, two subsequent sprays were applied at weekly intervals; the plants were artificially inoculated 1 day after the first spray application; Sekiguchi Asahi is extremely susceptible to brown spot, with unusually large lesions. [b]Mean of 25 seedlings picked at random from each treatment (five rows of seedlings/plastic tray), marked and used for disease readings; nonreplicated trial. [c]Based on infection at 9 WAS.

to IR10781-143-2-3 plants from early booting to early ripening stage in the field. Glume discoloration, as well as narrow brown leaf spot (NBLS), sheath rot, sheath blight, and neck blast, appeared naturally on the test plants. The effect of the chemical sprays on such diseases was also evaluated.

In spite of a generally low disease incidence, Benomyl (50% WP) was especially effective in reducing seed discoloration and other infections (Table 29). Benomyl-treated seeds were the cleanest. Mancozeb (80% WP) and chlorothalonil (75% WP), although apparently inferior to benomyl, provided similar grain discoloration control. Chlorothalonil also showed effective NBLS control.

Table 29. Effect of fungicide foliar sprays[a] on seed discoloration and fungus diseases of rice. IRRI, 1982.

Chemical	Rate (kg formulation/2,000 liters suspension/ha per application)	Disease severity[b]				Neck blast infection[c] (%)
		SD	NBLS	ShR	ShB	
Benomyl (50% WP)	1.0	2.2	0.6	0.5	0.1	5.6
Mancozeb (80% WP)	1.0	2.9	2.3	0.6	0.4	5.8
Chlorothalonil (75% WP)	1.0	3.0	1.1	0.7	0.3	7.7
No chemical (check)	0.0	3.8	3.8	0.9	0.5	9.2

[a]Seven weekly spray applications at early booting until early ripening stage on IR10781-143-2-3 in the rice field. [b]Mean of four replications; each replication with 8.05-m^2 plot, SD = seed discoloration; NBLS = narrow brown leaf spot; ShR = sheath rot; ShB = sheath blight; based on degree of affected and/or infected areas using scales 0 to 9; 0 = no lesion or infection; 1 = less than 1%; 3 = 1-5%; 5 = 6-25%; 7 = 26-50%; 9 = 51-100%; data taken at harvest time from 1,000 panicles picked at random from each treatment plot. [c]Mean of four replications; infection count made on 1,000 panicles picked at random/treatment at harvest.

Table 30. Effect of soil incorporation of rice grain-hull *Sclerotium rolfsii* inoculum at two volume ratios on Sclerotium seedling blight disease.[a] IRRI, 1982.

Treatment[b] (seeding time)	Volume ratio of inoculum to soil	Seedling stand reduction[c] (%) based on		Volume ratio of inoculum to soil	Seedling stand reduction[c] (%) based on	
		Check 1	Check 2		Check 1	Check 2
Immediately after infection	1:5	55.5	60.8	1:10	45.5	50.1
3 d after infection	1:5	72.7	78.0	1:10	63.4	68.0
7 d after infection	1:5	53.8	59.1	1:10	36.0	40.6
Check 1 (sterilized rice grain-hull, mixed with soil)	1:5	–	5.3	1:10		4.6
Check 2 (nothing added to soil)	0:5	–	–	0:10		–

[a]Soil infected with 1- to 2-wk inoculum was put in plastic trays and sown to IR42 in 10 rows at 20 seeds/row; uninfested soils were seeded similarly to the same variety. [b]Mean of three replications; each replication with 200 seeds equally distributed and seeded among the 10 rows/tray. [c]Based on seedling stand count taken 21 DAS.

Sclerotium seedling blight. *Seed treatment.* Sclerotium seedling blight is commonly encountered in seedbeds, dapog beds, and direct-seeded dryland fields. It may cause substantial loss of seedlings for transplanting in rice fields and may seriously reduce the seedling stand in dryland fields. Sclerotial bodies of the causal fungus are commonly mixed with the seeds at harvest. Once the seeds are sown, the sclerotia germinate and attack the germinating seeds and seedlings, resulting in seedling stand reduction in seedbeds and in the field.

Two efficient inoculation methods for evaluating chemicals are soil incorporation of rice grain-hull *Sclerotium rolfsii* inoculum and the spreading of the inoculum over the seeded rows. With soil incorporation, the 1:5 and 1:10 volume ratios of inoculum to soil and 3-d incubation in the infected soil are best (Table 30). Spreading about 100 cc of 1- to 2-wk-old rice grain-hull inoculum over 10 seeded rows per plastic tray is also efficient for evaluating fungicides for seed treatment.

Using the inoculum spreading method, carboxin (75% WP) and triphenyltin acetate (60% WP)

Table 31. Effect of treating the seeds with fungicides by slurry and dry powder methods on the control of Sclerotium seedling blight.[a] IRRI, 1982.

Chemical	Rate (g formulation/kg seed)	Seedling stand count[b] (%)			
		Slurry		Dry powder	
		7 DAS	14 DAS	7 DAS	14 DAS
Carboxin (75% WP)	5.0	95.3	92.7	93.0	90.8
	1.0	92.5	89.7	87.2	85.2
Triphenyltin acetate (60% WP)	6.3	85.0	82.7	88.5	87.5
	1.3	87.7	86.0	88.8	86.5
NK-191 (10% dust)	37.5	9.2	9.0	7.0	8.0
	7.5	2.0	2.0	7.7	8.3
No chemical (check)	0.0	5.7	5.7	15.0	15.7

[a]Treated and untreated IR42 seeds were seeded in rows in plastic trays filled with soil (10 rows/tray; 20 seeds/row); 100 cc of 1- to 2-wk-old rice grain-hull inoculum was uniformly spread over the 10 seeded rows, which in turn were covered with soil. [b]Mean of three replications; each replication with 200 seeds sown and equally distributed among the 10 rows/tray filled with soil.

Table 32. Percentage of seedborne fungi on IR varieties grown in IRRI fields during the 1982 DS (harvested Mar 1982). Based on blotter test 200 seeds, 12 h NUV/12 h darkness, 8 d. IRRI, 1982.

IR variety	Seedborne fungi[a] (%)															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
IR5	19	9	15	1	10	17	1		3				3	1	1	
IR8	19	8	24	2	1	70	1	1	1	2	1		5	3	3	
IR20	18	5	13	2		14				1	10			2	7	
IR22	20	4	14	4		21		1			3					
IR24	24	2	6	1	2	10				1	4		1			
IR26	44	5	17	2	10	13					1	4	1	1		
IR28	30	3	8	2	11	16		1			13			1		
IR29	37	3	18	3	19	16		1						3		
IR30	18	7	5		3	6					2					
IR32	11	1		1	3			1			1				1	
IR36	12	7	34	5	2	56		5	3					5	10	
IR38	18	7	28		13	15					2		1	2	2	
IR40	23	3	34	3	3	23		1	1	1	5			2	1	
IR42	18	3	11	1	7	10				6						
IR43	16	9	18	5	4		1	2						1	21	
IR44	10	6	3	6	5	5								3		
IR45	40	7	3	1	1	14	3	1	1				1	2	1	
IR46	51	14	3	1	1	2	1		1				1	2		
IR48	37	6		3	1	9					2		1	4		
IR50	25	2	12	5	20	22		7		1	6			1	2	2
IR52	22	2	6	1	2	26			1	1	20			1	1	1
IR54	41	3	12	10	13	50	1		6	5	4		1	3	8	
IR56	13	8	12	12	2	21		1			1	7			1	
IR9752	24	4	15	3	5	18		1		1	2		1	2	5	
Total	590	128	311	74	138	454	8	23	17	19	77	11	16	39	64	3
Av	24.9	5.3	12.9	3.1	5.8	18.9	0.3	0.9	0.7	0.8	3.2	0.5	0.6	1.6	2.7	0.1

[a]A = *Trichoconiella padwickii*, B = *Curvularia* sp., C = *Nigrospora oryzae*, D = *Phoma* sp., E = *Alternaria longissima*, F = *Fusarium semitectum*, G = *Drechslera* sp., H = *Pithomyces* sp., I = *Fusarium equisite*, J = *Pyricularia oryzae*, K = *Cercospora oryzae*, L = *Sarocladium oryzae*, M = *Drechslera oryzae*, N = *Gerlachia oryzae*, O = *Fusarium moniliforme*, P = *Nakataea sigmoideum*.

Table 33. Percentage of seedborne fungi on IR varieties grown in IRRI fields during the 1982 WS (harvested Oct 1982). Based on blotter test 200 seeds, 12 h NUV/12 h darkness, 8 d. IRRI, 1982.

IR varieties	Seedborne fungi[a] (%)															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
IR5	12	35	4	5	6	36		1			1	1	6	2		
IR8	34	12	2	16	31	26			1		1	4	1	8		2
IR20	24	7	1	24	8	34			1			8	1	12		
IR22	19	9		22	5	22		1				3	1	8	1	1
IR24	19	13	1	20	6	29				1	2	9	2	13	1	3
IR26	34	16	1	13	8	29				1	1	12	1	10	1	1
IR28	63	20	1	16	3	9						30	1	12	1	
IR29	64	17	1	14		10		1				1	1	6		
IR30	57	11		8	1	12						9		3	1	
IR32	10	15	3	4	3	10		1				3	1	2		1
IR34	27	17	5	14	4	24		2					1	15	1	
IR36	62	16	1	9	3	9						24		1		
IR38	37	7	1	14	1	13		1				2		13		
IR40																
IR42	43	15	4	6	6	10		3					3	3	1	
IR43	28	8	1	9	15	33					1	4	1	16	1	1
IR44	51	8	2	8	2	9		1	1			1	1	12	1	
IR45	41	17	1	14	5	12	1			1			3	9		1
IR46	53	18	2	4	3	5	1					2	1	6		
IR48	20	16	5	7	1	7							2	3	1	
IR50	48	13		12	2	6					1	8		8	1	1
IR52	44	10	1	28	4	11					1		1	18		1
IR54	29	13	1	7	7	18	1			2	3	2		16	1	1
IR56	67	4	1	8	3	3				1		6		8		1
IR9752	34	27	1	16	1	6			1		1	5	1	2		
Total	920	344	40	298	128	383	3	11	4	6	12	134	29	206	12	14
Av	38.3	14.3	1.7	12.4	5.3	15.9	0.1	0.4	0.1	0.2	0.5	5.6	1.2	8.6	0.5	0.6

[a] A = *Trichoconiella padwickii*, B = *Curvularia* sp., C = *Nigrospora oryzae*, D = *Phoma* sp., E = *Alternaria longissima*, F = *Fusarium semitectum*, G = *Drechslera* sp., H = *Pithomyces* sp., I = *Fusarium* sp., J = *Pyricularia oryzae*, K = *Cercospora oryzae*, L = *Sarocladium oryzae*, M = *Drechslera oryzae*, N = *Gerlachia oryzae*, O = *Fusarium moniliforme*, P = *Nakataea sigmoideum*.

provided very effective protection against seedling blight in both the slurry and dry powder treatments (Table 31).

SEED PATHOLOGY

The fungal seed microflora of IR varieties grown in IRRI fields during the 1982 DS and WS were studied. The results showed that the most common seed fungi for both seasons were *Trichoconiella padwickii* and *Fusarium semitectum* (Table 32, 33).

In the DS crops, *Cercospora oryzae* (NBLS) caused 3.2% average seed infection; *Fusarium moniliforme* (bakanae), 2.7%; *Gerlachia oryzae* (leaf scald), 1.6%; and *Pyricularia oryzae* (blast), *Drechslera oryzae* (brown spot), *Sarocladium oryzae* (sheath rot) and *Nakataea sigmodium* (conidial state of the stem rot fungus, *Leptosphaeria salvinii*) less than 1%. In the WS crop however, *G. oryzae* caused 8.6% seed infection on the average; *S. oryzae*, 5.6%; *D. oryzae*, 1.2%; and *N. sigmoideum*, *C. oryzae*, *F. moniliforme*, and *P. oryzae*, less than 1%.

Control and management of rice pests

Insects

Entomology Department

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TAXONOMY

Correct names of rice field insects. A researcher's knowledge of the correct scientific names of rice insect pests and their natural enemies facilitates locating relevant scientific literature in abstracting journals, determining phylogenetic affinities, or choosing the parasite species to introduce against insect pests. Often, the host range of a parasite is specific to closely related species.

Insects collected from rice fields or reared from rice pests are maintained in the reference collection of IRRI's Entomology Department. They are cataloged and sent to specialists throughout the world for authoritative determinations. The following list identifies 139 species determined by 27 specialists.

COLEOPTERA (beetles)

Carabidae
Anoplogenius microgonus Bates
Batoscelis ceylonicus Matsumura
Cicindela lacrymosa Fabricius
Drypta geniculata (Klug)
Drypta japonica Bates
Ophionea ishii Habu
Ophionea nigrofasciata Schmit-Goebel

Chrysomelidae
Altica cyanea Weber
Chaetocnema basalis Baly

Coccinellidae
Coccinella repanda Thunberg
Synharmonia octomaculata (Fabricius)

Elateridae
Aeleoderma brachmana (Candeze)

Scarabaeidae
Adoretus luridus Blanchard
Adoretus ranunculus Burmeister
Anomala sulcatula Burmeister
Holotrichia flachi Breuske
Leucopholis irrorata Chevrolat

DERMAPTERA (earwigs)

Carcinophoridae
Euborellia stali (Dohrn)

Labiidae
Auchenomus hincksi Ramamurthi

DIPTERA (flies)

Agromyzidae
Pseudonapomyza asiatica Spencer

Chironomidae
Chironomus crassiforceps Kieffer
Chironomus javanus Kieffer
Chironomus kiiensis Tokunaga
Clynotanypus claripennis Kieffer
Cricotopus bicinctus Meigen
Cryptochironomus javae Kieffer

Chloropidae
Anatrichus pygmaeus Lamb
Chlorops stigmatella Becker
Conioscinella griseicollis (Becker)
Conioscinella inaequalis (Becker)
Conioscinella similans (Becker)
Elachiptera umbrosa Becker
Mepachymerus ensifer Thomson
Mepachymerus singularis (Becker)

Ephydridae
Actocetor beckeri de Meijere
Brachydeutera longipes Hendel
Discomyza maculipennis (Weidemann)
Hydrellia griseola (Fallen)
Notiphila latigenis Hendel
Notiphila similis de Meijere
Notiphila spinosa Cresson
Paralimna aequalis Cresson
Paralimna lineata de Meijere
Paralimna picta Kertesz
Psilopa flavimanus Hendel
Psilopa pollinosa (Kertesz)
Psilopa sorella Becker
Polytrichophora brunneifrons (de Meijere)
Scatella callisicosta Bezzi

Muscidae
Atherigona falcata (Thomson)
Atherigona oryzae Malloch
Atherigona punctata Karl

Phoridae
Megaselia scalaris (Loew)

Pipunculidae
Pipunculus javaensis Meijere
Pipunculus mutillatus Loew
Tomosvaryella oryzaetora (Koizumi)
Tomosvaryella subvirescens (Loew)

Stratiomyidae
Evaza atripluma James
Evaza scenopinoides (Walker)
Hermetia illuscens (Linnaeus)
Oplodontha rubrithorax (Macquart)

Tachinidae
Argyrophylax nigrotibialis (Baranov)
Palexorista lucagus (Walker)

Sarcophagidae
Pierretia litsingeri Shinonaga & Barrion

HEMIPTERA (hoppers, true bugs)

Cicadellidae
Macrosteles striifrons Anufriev

Delphacidae
Coronacella sinhalana (Kirkaldy)
Euidellana celadon Fennah
Harmalia anacharsis Fennah
Harmalia heitensis Fennah
Opiconsiva dodona Fennah

Lygaeidae
Elasmolomus sordidus (Fabricius)
Horridipamera nietneri (Dohrn)
Neocymodema sulcicollis (Bergroth)
Ninus insignis Stal
Nysius pacificus China
Nysius vinitor Bergroth
Pachybrachius inortatus (Walker)
Pachybrachius nigriceps (Dallas)
Pachybrachius puberulus (China)
Pamerarma nigritula (Walker)
Pamerarma ventralis (China)
Paraeucosmetus pallicornis (Dallas)
Pseudopachybrachius guttus (Dallas)

Miridae
Creontiades pallidifer (Walker)
Orthotylellus rufescens Usinger

Pentatomidae
Scotinophara coarctata (Fabricius)
Scotinophara latiuscula (Breddin)

HYMENOPTERA (ants, wasps)

Dryinidae
Echthrodelphax fairchildii Perkins
Pseudogonatopus flavifemur Esaki & Hashimoto
Pseudogonatopus nudus Perkins

Formicidae (ant)
Anoplolepis longipes (Jerdon)
Dolichoderus bituberculatus (Mayr)
Odontoponera transversa (F. Smith)
Paratrechina longicornis (Latreille)

Ichneumonidae
Amauromorpha accepta metathoracica Ashmead
Caenopimpla arealis Cushman
Campoplex pusilus Gupta & Maheshwary
Charops brachypterum (Cameron)
Eriborus terebrans Gravenhorst
Itoplectis narangae (Ashmead)
Leptobatopsis indica (Cameron)
Meloboris sinicus (Holmgren)
Temelucha philippinensis (Ashmead)
Temelucha stangli (Ashmead)
Trathala flavo-orbitalis Cameron
Trichomma cnaphalocrocis Uchida
Xanthopimpla flavolineata Cameron
Xanthopimpla punctata Fabricius
Xanthopimpla stemmator Thunberg

Mymaridae
Anagrus flaveolus Waterhouse
Anagrus optabilis (Perkins)
Gonatocerus cingulatus Perkins

Scelionidae
Gryon nixoni Masner

LEPIDOPTERA (moths)

Noctuidae
Spodoptera mauritia acronyctoides (Guenee)

ODONATA

Coenagrionidae (damselflies)
Agriocnemis femina femina Brauer
Agriocnemis pygmaea Rambur
Ischnura senegalensis Rambur
Pseudagrion pilidorsum pilidorsum Brauer

Libellulidae (dragonflies)
Diplacodes trivialis Rambur
Macrodiplax cora Brauer

Neurothemis terminata terminata Ris
Pantala flavescens Fabricius

ORTHOPTERA (grasshoppers, crickets)

Acrididae (grasshopper)
Ailopus thalassinus tamulus (Fabricius)
Gesonula mundata (Walker)
Heteropternis obscurella (Blanchard)
Oxya hyla intricata (Stal)
Oxya japonica japonica (Thunberg)
Trilophidia annulata (Thunberg)

Gryllidae (cricket)
Euscyrtus concinnus (Haan)
Gryllus bimaculatus De Geer
Loxoblemmus haani Saussure
Plebeiogryllus plebejus (Saussure)
Teleogryllus occipitalis (Serville)
Velarifictorus aspersus (Walker)

Pyrgomorphidae
Atractomorpha psittacina psittacina (Haan)

STREPSIPTERA (twisted wingflies)

Elenchidae
Elenchus yasumatsui Kifune et Hirashima

Halictophagidae
Halictophagus spectrus Yang

THYSANOPTERA (thrips)

Thripidae
Haplothrips aculeatus (Fabricius)
Stenchaetothrips biformis (Bagnall)

Nomenclatural changes. Some recent changes in nomenclature include: the rice mealybug *Brevennia* (=*Heterococcus*) *rehi* (Lindinger), rice white leafhopper *Cofana* (= *Tettigella* = *Cicadella*) *spectra* (Distant), rice leaf folder *Cnaphalocrocis* (= *Cnaphalocrosis*) *medinalis* (Guenee), gall midge parasite *Propicroscytus mirificus* (=*Obtusiclava oryzae)* (Girault), rice yellow stem borer *Scirpophaga* (= *Tryporyza*) *incertulas* (Walker), and rice white stem borer *S. innotata* (Walker).

A new species of the sacrophagid fly, *Pierretia litsingeri* Shinonaga et Barrion, was reared from the egg mass of the argiopid spider *Argiope catenulata* (Doleschall).

ECOLOGY

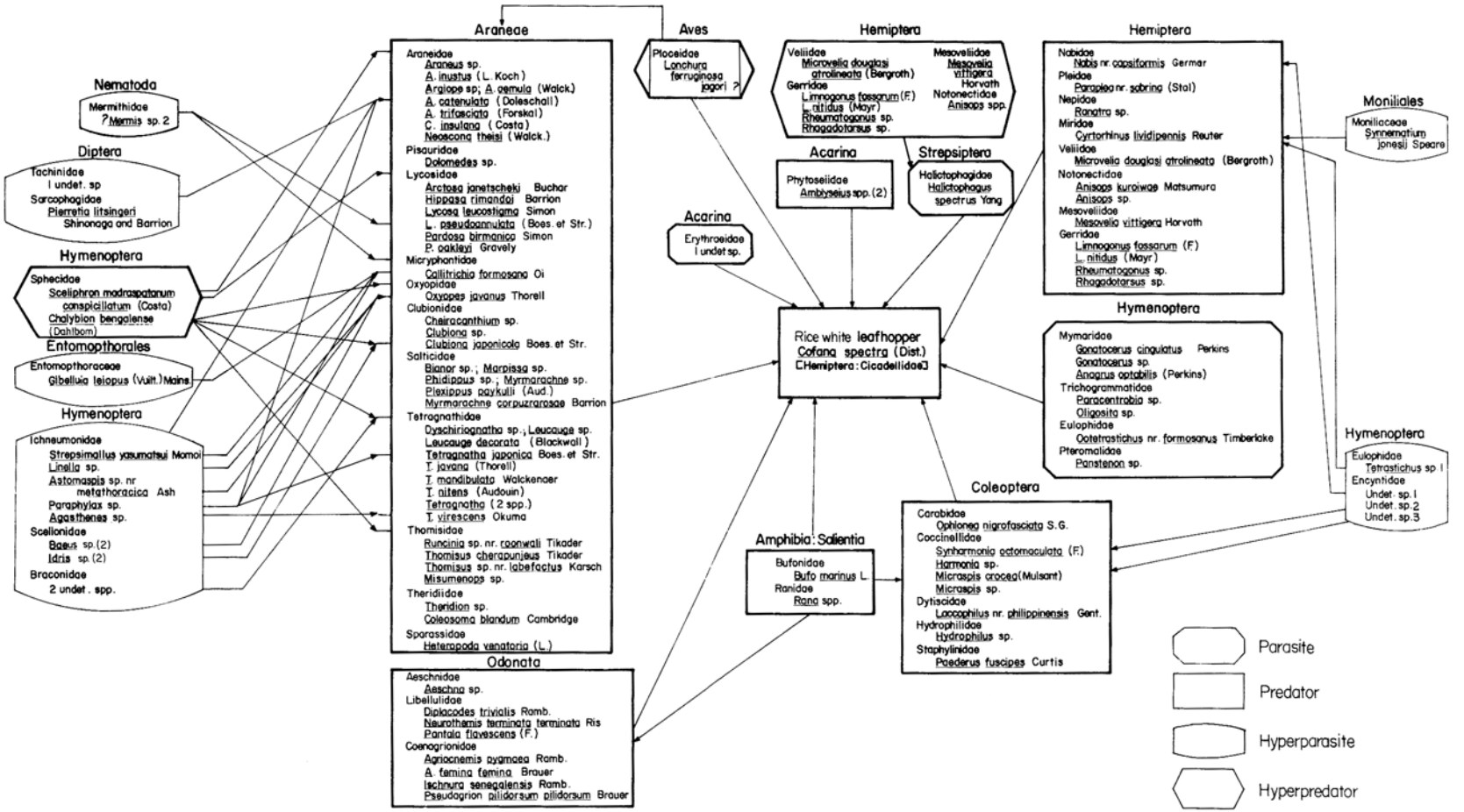
Foodweb of the rice white leafhopper. The foodweb of the rice white leafhopper (RWL) *Cofana spectra* was determined and 107 species were found to comprise the host-parasite/predator/pathogen relationships (Fig. 1). Species of predators (76) outnumbered the parasites (9) and the secondary natural enemies (30). Spiders (43 species) were the dominant predators, followed by aquatic hemipterans (12), odonatans (8), aquatic beetles (8), mites (2), amphibians (2), and an avian (1). The dominant parasite, a strepsipteran *Halictophagus spectrus* Yang, attacked the nymphs and adults. *Gonatocerus cingulatus* Perkins was the dominant egg parasite. Unlike the GLH, BPH, and WBPH, no dryinids and pipunculids were reared from the RWL.

Two species of phytoseiid mites *Amblyseius* sp. were found to prey on RWL eggs. Until this record, only the mirid bug *Cyrtorhinus lividipennis* Reuter had been known as a hopper egg predator.

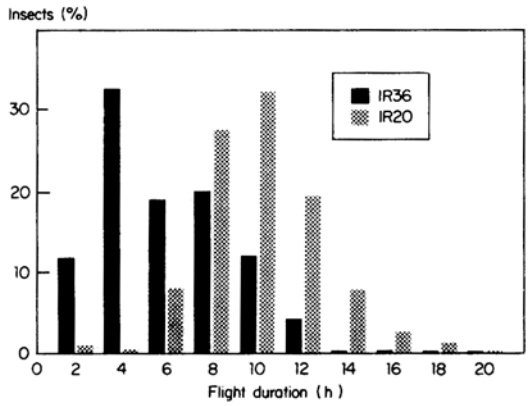
Twenty species of hyperparasites, most of them taken from spiders, were recorded. Thirteen species belong to the families Scelionidae, Ichneumonidae, Braconidae, Tachinidae, and Sarcophagidae. Two species were fungi — *Gibellula leiopus* (Vuillemin) Mainsley, from the micryphantid spider *Callitrichia formosana* Oi; and *Synnematium jonesii* Speare, from the mirid bug *Cyrtorhinus lividipennis* Reuter. Likewise, chalcidoid wasps were reared from pupae of coccinellids and eggs of *Cyrtorhinus lividipennis*.

Brown planthopper migration. Previous studies have established that BPH flight activity shows strongly marked diurnal periodicity. There is a well-defined peak takeoff from the crop at dusk and a smaller peak at dawn. A clear seasonal periodicity is also associated with the cropping pattern. Work in 1982 concentrated on clarifying the normal BPH flight range in the tropics.

Mature insects normally emigrate from the crop 2-3 DE. The take-off flight is vertical and carries the insects into air streams where they are passively transported for as long as they maintain altitude by continued flight. Vertical air movements may increase or decrease lateral displacement. Once the insects are airborne, the dispersal range is determined by flight duration and meteorological



1. Food web of the rice white leafhopper *Cofana spectra* (Distant).



2. Potential flight duration of BPH reared on susceptible (IR20) and resistant (IR36) rice, calculated from the lipid and glycogen levels of adult insects. IRRI, 1982.

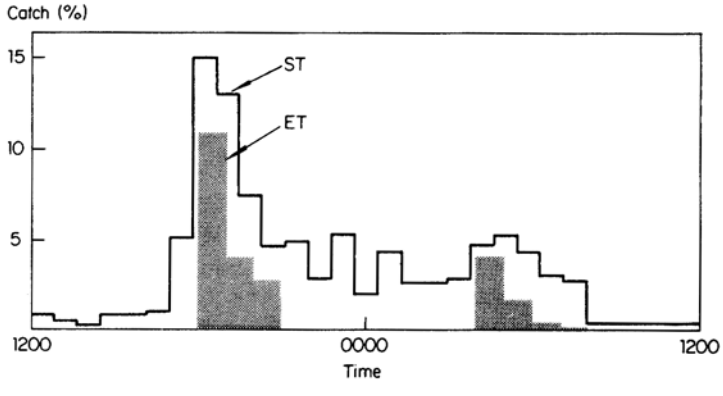
conditions. Flight physiology and biochemistry studies show that flight durations, based on lipid and glycogen reserves and their utilization rates can range from 2 to 20 h (Fig. 2).

Energy reserves of adult insects vary according to the host plant on which the insects were reared; insects reared on resistant varieties have lower reserves and, therefore, reduced flight potential. Durations of tethered flights in the laboratory are extremely variable among individuals; they range from a few minutes to 12 h and average 4 h for insects 2-4 d old. For other species, tethered flights of insects deprived of tarsal contact are frequently longer than free flight and it is likely that most flights are short. Considerable information on the nature of flight activity and on dispersal range can be derived by comparing timed catches in different traps. Suction traps at 1.5 m show flight activity occurring at times when emigration is not taking place (Fig. 3). Most of this activity occurs at night.

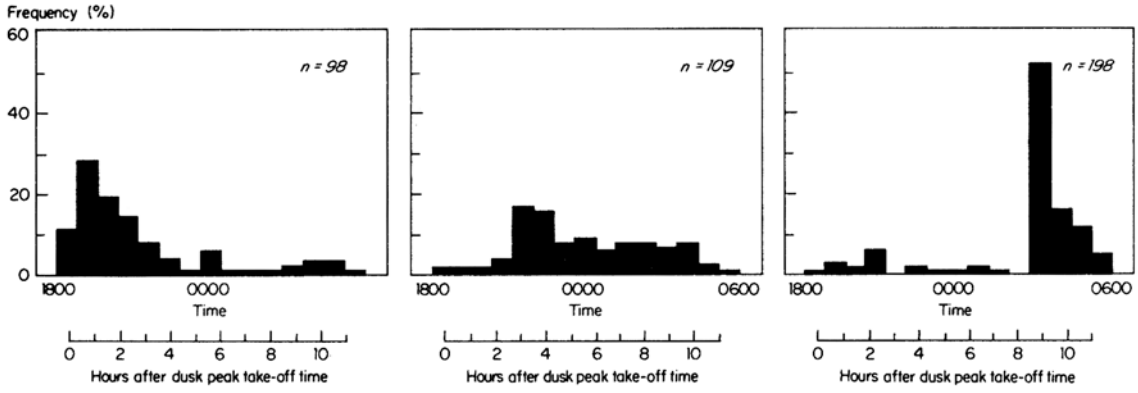
Yellow pan traps were used to monitor immigration. When catches were divided according to the major flight activity periods, they showed that the highest rate of catch occurred during the evening take-off peak followed by substantial catches at night. Because yellow traps are more attractive during the day, this suggested that most immigration occurs at night. If it does, light trapping may be a good way to monitor immigration.

A segregating light trap was constructed to investigate immigration timing. Under all circumstances, it may not monitor actual immigration to the site because it can attract insects that otherwise would not terminate their flights. If they respond to the light, however, they must be behaviorally disposed to discontinue flying. The periodicity of catch varied considerably from night to night (Fig. 4). Assuming the insects have taken off at dusk, the approximate flight duration can be determined. By combining this information with detailed meteorological data, simulations of BPH flight tracks can be constructed. Figure 5 uses data from pilot balloon studies in conjunction with timed light trap catches. Wind speed and direction vary considerably with altitude and it is important to establish BPH flight height to obtain reliable dispersal estimates. Radar studies are planned for 1983 to investigate vertical distribution.

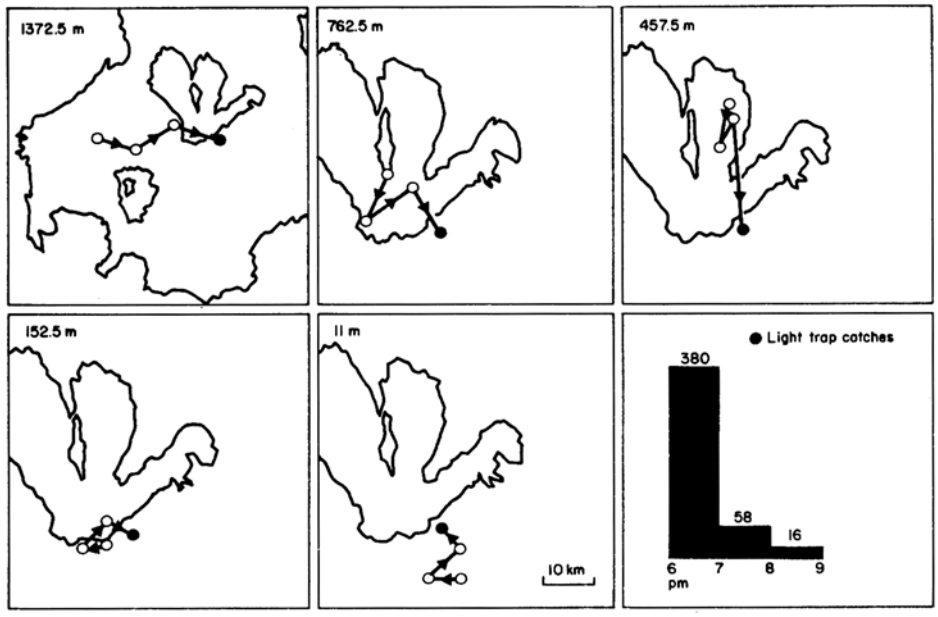
In temperate countries, BPH population devel-



3. Frequency distribution of emigration (ET) and suction trap (ST) catches for BPH at Liliw, Laguna, Philippines, 1982.



4. Periodicity of BPH catch in a segregating light trap on selected occasions shows variability from night to night. Liliw, Laguna, Philippines, 1982.



5. Simulated flight paths for BPH caught at Hanggan, Laguna, Philippines, on 6 Sep 1982 assuming different flight altitudes. The distance between the open circles represents 1 h flying time. Even at high altitudes, most insects caught in the first hour would have travelled no more than 20 km.

opment is largely determined by the initial rate of immigration into the crop. Immigration occurs over a limited period and can be measured to predict whether damaging populations will result. In the tropics, rice is available throughout the year within the potential BPH dispersal range and immigration is possible at any time. Studies to quantify the relationship between immigration rate and subsequent population changes have been conducted at a number of sites in Laguna. Variability among sites is high, suggesting considerable local influence and there is very poor correlation between trap catches and observed populations. These results show the importance of regulatory mechanisms rather than immigration rate in population development.

Sampling for hoppers. A reliable high-technology technique based on suction sampling has been developed to provide good estimates of absolute population densities for planthoppers and

leafhoppers. To estimate their efficiency in determining population levels, visual count and sticky paddle techniques were compared to suction sampling. Samples were taken on eight occasions 41-90 DT from 80 hills in each of three treatments. Suction sampling involved placing a mylar enclosure over the hill, which was then sampled with D-Vac followed by FARMCOP (Annual report for 1978). Visual counts involved briskly tapping the hill five times and counting the insects falling on the water. The sticky-paddle technique involved placing a 30- × 30-cm board coated with sticky material at a 45° angle to the base of the rice hill. The hill was then tapped toward the board five times and the insects adhering to the coating were counted. The relationship between population estimates for the visual count and sticky-paddle techniques, and the suction technique was examined. Correction factors were calculated to convert the estimates obtained from visual and sticky-paddle techniques into absolute population (Table 1). For most anthropod categories, the sticky paddle gave more efficient estimates although visual counts were much better for delphacid nymphs. There was little loss in precision, measured as the standard error in relation to the mean. This suggests that these two simple techniques are promising methods for obtaining reliable population data.

BIOLOGY OF THE RICE GREEN SEMILOOPER

High yield losses result from multiple insect infestation of rice plants at the vegetative stage. One vegetative-stage pest, the rice green semilooper (RGS) *Naranga aenescens* Moore (Noctuidae), was considered a minor pest, but has now been elevated in importance. It occurs in Japan, Korea, Taiwan, and the Philippines.

A mass rearing method was developed to facilitate insecticide and rice germplasm screening and host range and damage studies. The noctuid moths are yellow with light red markings. The spherical eggs, yellow when newly laid, singly or in groups, develop purple markings at maturation in 3-4 d. The light-green larvae with narrow white stripes running lengthwise along their bodies pass through five instars in 10 d. Young larvae scrape leaf mesophyll tissue between the leaf veins, leaving the thicker upper epidermis, which turns the leaves greyish white. Older larvae, feeding from leaf margins, consume all but the midribs and make characteristic notches. The mature larvae fold the leaf tips twice over to form a triangular chamber for the pupae. Pupation takes 4 d and the moths have a life-span of 5-6 d. Adults survive better and lay more eggs in fully aerated rather than in enclosed oviposition cages. Honey for adult sustenance does not increase egg production.

Four parasitic wasps have been reared from field-collected larvae: *Charops brachypterum* (Cameron) and *Itoplectis narangae* (Ashmead), (Hymenoptera: Ichneumonidae); *Cotesia* (=*Apanteles*) flavipes (Cameron), and *C. ruficrus* (Haliday) (Hymenoptera: Braconidae).

CULTURAL CONTROL

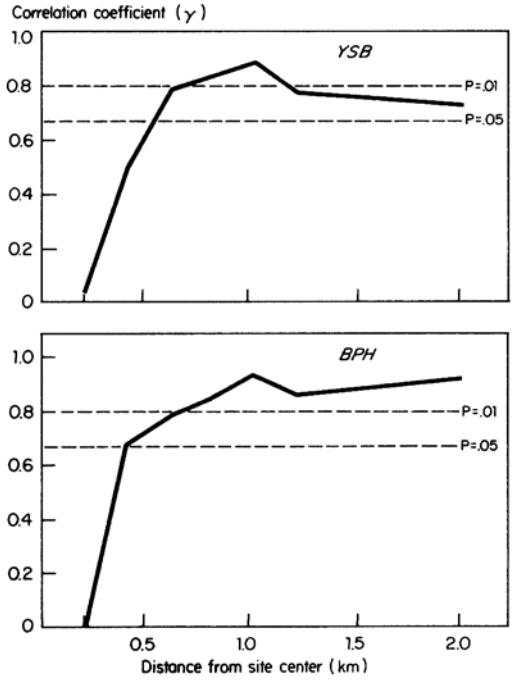
Synchronous planting. Work on the feasibility of promoting synchronized cultivation among

Table 1. Calibration of two low technology hopper sampling techniques.[a] IRRI, 1982.

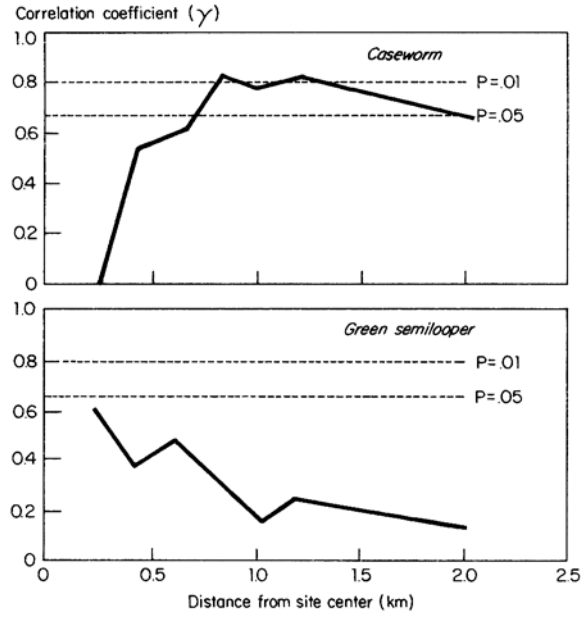
Arthropod category	Range of population density (no./hill)	Correction factor ± SE	
		Visual count	Sticky paddle
BPH adult	0.7 – 7.8	4.36 ± 0.48	2.21 ± 0.40
WBPH adult	0.1 – 6.5	1.35 ± 0.39	3.73 ± 1.16
Delphacid nymphs	1.1 – 22.1	1.71 ± 0.13	10.00 ± 3.03
GLH adult	3.1 – 18.7	7.62 ± 1.04	2.25 ± 0.21
GLH nymphs	4.6 – 41.2	4.81 ± 0.72	4.00 ± 0.57
Cyrtorhinus A + N	12.6 – 106.3	8.08 ± 1.67	4.20 ± 0.49
Microvelia A + N	3.3 – 36.4	4.25 ± 0.75	5.05 ± 0.97
Spiders A + J	7.5 – 28.7	16.52 ± 2.99	8.85 ± 1.06

[a]Data from eight sampling occasions, 41-90 DT.

farmers as a cultural method of insect control in irrigated rice culture continued in Zaragoza, Nueva Ecija. Forty-six light traps are tended by farmer-cooperators in 23 areas naturally varying in degree of planting synchrony. The total seasonal catch of a pest species is used as an index of its local abundance and the variance of planting dates within a specified radius of the light traps as a measure of asynchrony. Figure 6 shows preliminary results obtained from one transect of traps during the 1981 DS. The correlation between total seasonal catch and planting-date variance for the yellow stem borer (YSB) *Scirpophaga incertulas* rises to a highly significant peak at a radius of 1 km and declines thereafter, indicating that most dispersal occurs within this range. When separated by distances greater than 1 km, the insects are unable to use the additional food resources that staggered plantings offer. For BPH, the greatest correlation is obtained at a radius of 2 km, suggesting that it is capable of considerably greater dispersal. Peak correlations at significant levels are also obtained



6. Correlation coefficient between seasonal light trap totals and the variance of planting dates as a function of the distance within which this variance is calculated: YSB and BPH. Nueva Ecija, Philippines, 1981 DS.



7. Correlation coefficient between seasonal light trap totals and the variance of planting dates as a function of the distance within which this variance is calculated: RCW and green semilooper. Nueva Ecija, Philippines, 1981 DS.

for the RCW *Nymphula* sp. and the RGS (Fig. 7), but at distances less than 1 km.

Corroborative evidence for the relatively short range of average dispersal these results indicate has been obtained by analyzing the catches in light traps set at increasing distances from isolated sources of naturally dispersing insects. In February 1982, when an old-field area at the downstream end of an irrigation system was plowed for the first time in 6 yr, large numbers of BPH were recorded in the farmer-tended light traps over a 2-wk period. When these were plotted against distance from the edge of the area, a negative exponential decay provided a good fit (Fig. 8). By integrating this curve and resolving it around the origin, an estimated 80% of the insects dispersing moved less than 5 km.

Light traps were also placed at distances of 0-485 m from a 1.5-ha field planted out of season when surrounding fields were fallow. The densities of several species declined markedly over this range. Figure 9 illustrates the pattern for male and female YSB. On the average, males appeared to disperse significantly further. Even without discounting the low level of moth emergence from the

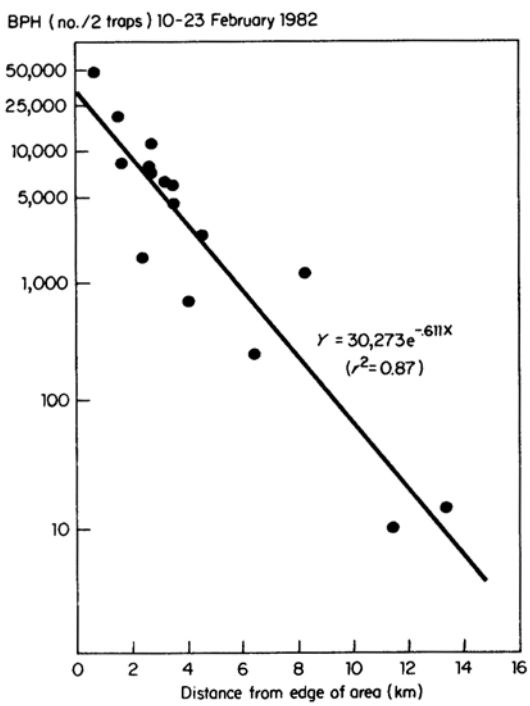
stubble in the fallow fields, which tends to inflate the estimated dispersal range, it is reckoned by integration that 80% of females moved less than 1.6 km.

The data suggest that synchronized cultivation may reduce the potential for insect pest buildup. Because of the limited dispersal of a majority of the insects, synchronization is required across a relatively short distance. If the maximum range of planting dates is restricted within an area to a span corresponding to the generation of a species, there will be no more adult insects than those in fields all planted the same day. Thus the most stringent synchronous cultivation criterion for BPH control is that, within a radius of 5 km, the range of planting dates should be restricted to 3 wk. Considerably less rigid standards are needed to control the lepidopterous pests, such as stem borers, which generally have longer generation lengths and weaker dispersal abilities.

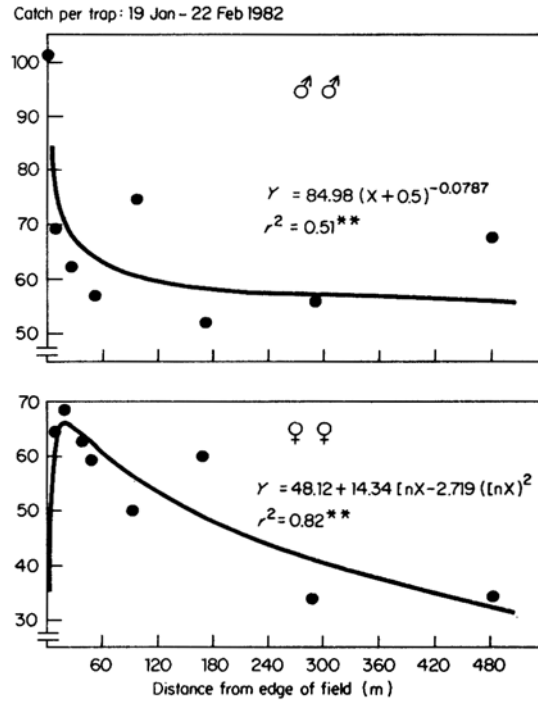
Imposing too strict a schedule over a wide area may have several harmful consequences. Hire rates for transplanting labor and tractors for land preparation may be driven up by the concentrated demand and the synchronized harvest may cause the price of the marketed surplus to slump. Canal capacity may be inadequate to supply the required water. Finally, within the typhoon belt that covers most of the Philippines, excessive synchronization may put a wide area of crops at risk, and the traditional sharing and loan arrangements within villages affected by a storm may no longer be possible because there will be few who will escape.

The most efficient means to implement synchronous planting on an irrigation system-wide scale is to vary the planting dates gradually from one end to the other. Farmers could rely on a scheme of tail-first irrigation that has been advocated as more equitable (Fig. 10).

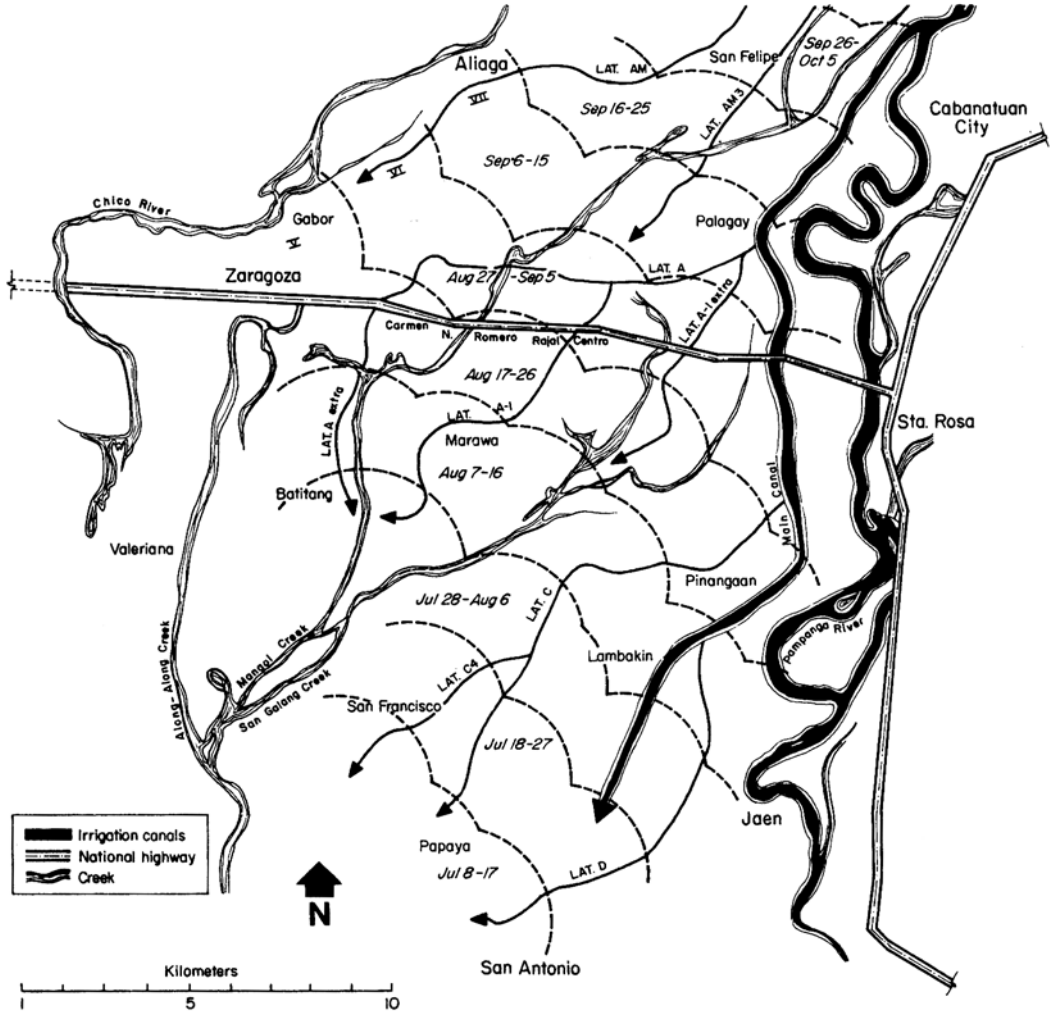
Synchronous planting removes the food from the pests and can be made more effective if early maturing varieties are grown and if at least a 3-wk rice-free period between crops is created by plowing down the rice stubble or allowing it to dry up.



8. Catches of BPH in paired kerosene light traps as a function of distance from a newly plowed old-field area. Batitang, Zaragoza, Nueva Ecija, Philippines, 1982 DS.



9. Catches of male and female YSB in kerosene light traps as a function of distance from an isolated source field. Carmen, Zaragoza, Nueva Ecija, Philippines, before the 1982 DS.

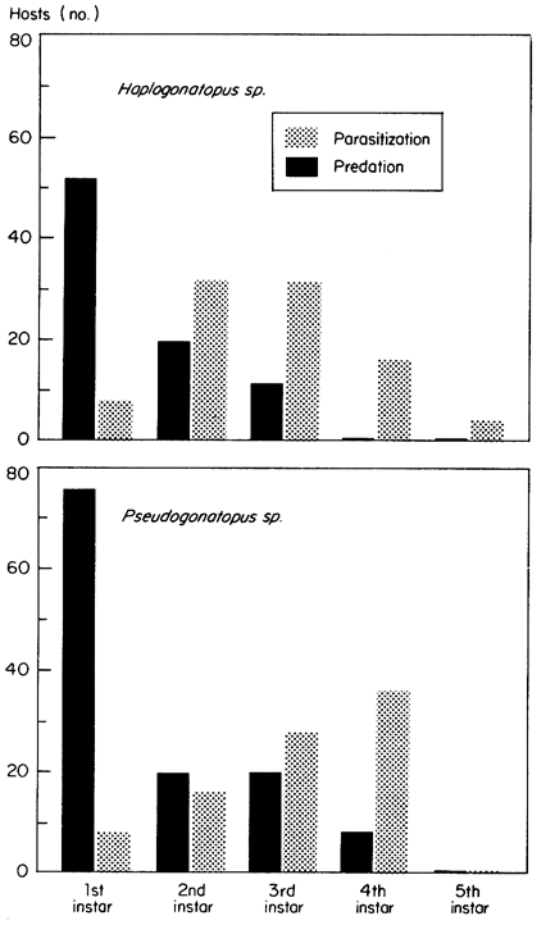


10. Suggested plan for synchronous cultivation during the WS relying on tail-first irrigation for the 17,000 ha of Zones II and III of District III in the Upper Pampanga River Integrated Irrigation System, Nueva Ecija, Philippines. The plan is based on the biological characteristics of the BPH; areas planting more than 3 wk apart should be separated by at least 5 km to reduce the number of generations that a given amount of rice will support. The tail-end of the irrigation system would be planted first over a 10-d interval 8-17 Jul. Each successive area would be planted 10 d later than the preceding area. The width of each planting area is 2.5 km.

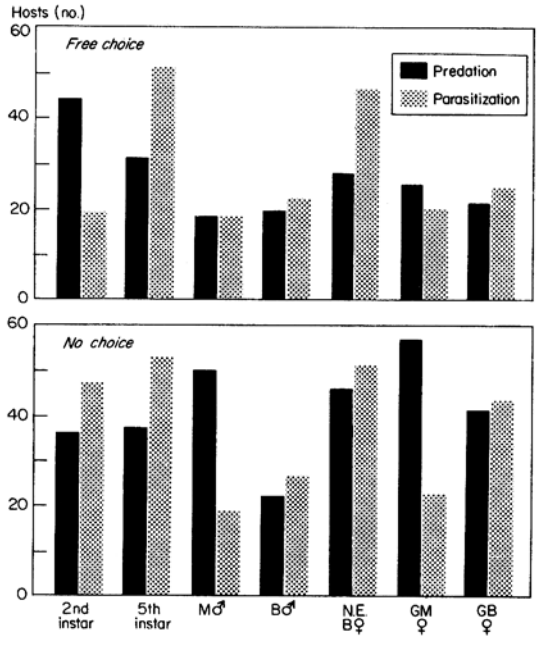
BIOCONTROL

Hopper parasites. *Dryinids.* Experiments have been conducted on the predation and parasitization preferences of dryinid parasites to determine at which stage they are most effective. *Haplogonatopus* sp. and *Pseudogonatopus* sp. both parasitic on GLH, showed marked feeding preference for early-instar nymphs in a free-choice situation. Figure 11 shows that parasitization preference was evident.

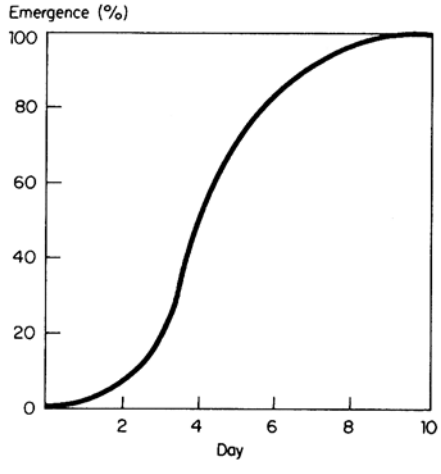
Investigation of the preferences of *Pseudogonatopus flavifemur* for various BPH stages showed that, in a free-choice situation, early-instar



11. Parasitization and predation efficiency of *Haplogonatopus* sp. and *Pseudogonatopus* sp. on different GLH instars. IRRI, 1982.



12. Preference of *P. flavifemur* on different BPH stages. IRRI, 1982. M = macropterous, G = gravid, B = brachypterous, N.E. = newly emerged.



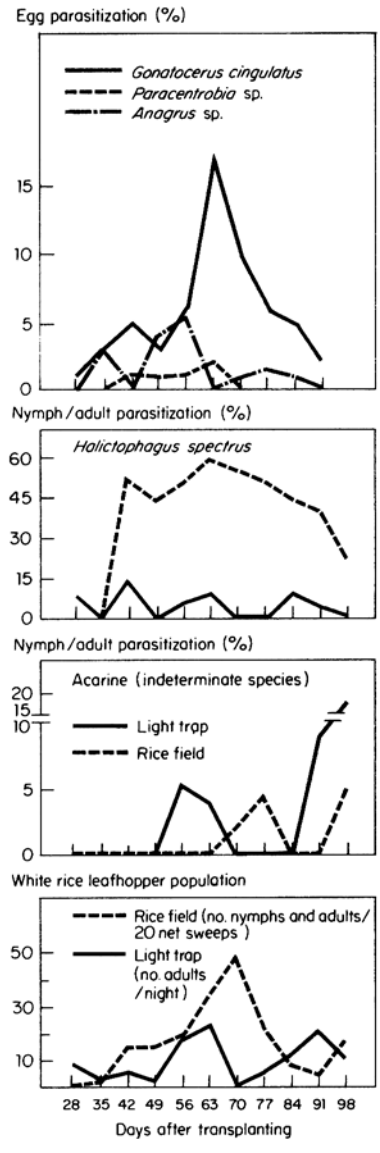
13. Emergence pattern of adult *Anagrus* from parasitized eggs of BPH. IRRI screenhouse culture, 1982.

nymphs were preferred for predation. When no choice was given, the insects were able to use other stages for feeding (Fig. 12).

Anagrus. Mass rearing techniques were developed for the egg parasite *Anagrus flaveolus* and studies were conducted on optimizing the productivity of cultures to provide insects for field-release experiments. Plants containing BPH eggs were exposed to adult *Anagrus* for 4 d, unparasitized hoppers were allowed to emerge, and then the plants were placed in parasite emergence cages. Figure 13 shows the emergence pattern.

Parasites of the rice white leafhopper. Parasites attacking the eggs, nymphs, and adults of the RWL were determined qualitatively and quantitatively during the 1982 WS at IRRI. Potted plants infested with hopper eggs laid by a greenhouse colony were set in a rice field each week from 28 to 98 DT. Four species of egg parasites were recovered and the most prevalent was a mymarid, *Gonatocerus cingulatus*, which parasitized up to 17% of eggs (Fig. 14).

Nymphs and adults were parasitized by a strepsipteran, *Halictophagus spectrus* Yang, and an



14. Abundance of rice white leafhopper *Cofana spectra* in rice field and light trap collections and parasitization by egg and nymphal/adult parasites. IRRI, 1982 WS.

unidentified mite in the family Erythracidae. The parasites were recovered from nymphs and adults collected by a sweep net in the field and from adults collected live in a walk-in trap cage. The strepsipteran parasitized from 40 to 60% of the nymphs and adults collected in the field and less than 15% of the adults collected from the light trap, indicating that parasitized hoppers may be less prone to fly. The mite occurred less consistently on hopper nymphs and adults, but parasitized up to 20% of adults collected in the light trap.

The most prevalent parasites recorded — *G. cingulatus, H. spectrus,* and an unindentified mite — do not attack the other commonly occurring rice leafhoppers and planthoppers. The parasites *A. flaveolus* and *A. optabilis* are most common on the BPH, and *Paracentrobia* sp. has a wide host range.

Effect of azolla on insect predators. Net samples of azolla, rice field water, and bottom mud were taken from transplanted rice fields, with and without azolla on 12 occasions from 6 Oct to 16 Dec 1982. Higher numbers of predators were found in fields with azolla (303) than in those without (191) (Table 2).

Species inhabiting the water surface, which preferred most the areas with azolla — *Microvelia douglasi atrolineata* (Bergroth) (Veliidae), *Paraplea sobrina* (Stal) (Pleidae), and *Lycosa pseudoannulata* (Boes. et Str.) (Lycosidae) were predators of rice hoppers. Spiders inhabiting the rice bund — *Pardosa birmanica* Simon, *Arctosa janetscheki* Buchar, and *Hippasa rimandoi* Barrion (Lycosidae) — moved into fields covered with azolla. The water-inhabiting species — notonectid waterboatmen and coegnagionid damselfly naiads — highly preferred azolla areas, libellulid dragonfly naiads preferred open water.

The surface-dwelling gerrid water striders were more common in open water. Other insect predators appeared unaffected by azolla or there were not enough of them to make comparisons.

Survey of insect fungal pathogens. A collaborative survey with the Boyce Thompson Institute for Plant Research, Ithaca, New York, is under way to identify fungal pathogens of rice insect pests in Asia. Collections from 1979 to 1982 in five countries have produced 135 fungal isolates from rice pests, including nine species infecting rice planthoppers and leafhoppers in the field (Table 3). Each isolate is cultured, characterized, and tested for virulence against the BPH, the principal target insect. The most virulent isolates will be field tested at IRRI to identify potentially useful pathogens.

Biological insecticides. Three formulations of *Bacillus thuringiensis* were tested in the greenhouse for toxicity against third- and fourth-instar larvae

of rice armyworm *Mythimna separata*. Larvae were released onto caged potted plants previously sprayed to run-off at three dosage rates. Dipel was effective at all rates, causing high mortality after a 3-d exposure, even at the lowest rate. Bactospeine was effective above 10 g/liter. Thuricide gave poor control at all rates.

Sex pheromones. Collaborative research with the Tropical Products Institute (TPI), London, on the identification and use of sex pheromones of lepidopterous rice pests continued.

Pheromone identification. The YSB was confirmed to produce a female sex pheromone. Virgin female moths, laboratory-reared from field-collected pupae, were used to bait sticky traps (Annual report for 1981). Single female moths caught up to 12 males/trap per night and were attractive for at least 3 nights. Large numbers of virgin female moths were used in entrapment equipment designed to collect female pheromone for subsequent chemical identification at TPI.

Mating disruption for insect control. After the

Table 2. Effect of azolla on rice insect predator populations in a rice field. IRRI farm, 6 Oct-16 Dec 1982.

Rice field	Predators[a] (no./family)																			Total
	Hemiptera								Coleoptera						Odonata		Araneae			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
With azolla	57	38	28	26	4	2	2	1	24	18	14	11	8	6	17	0	42	2	1	2	303
Without azolla	31	20	16	10	3	2	13	2	18	20	9	10	4	6	2	7	16	1	0	1	191

[a]Total of 12 net samples. A = Veliidae, B = Pleidae, C = Notonectidae, D = Mesoveliidae, E = Ochteridae, F = Nepidae, G = Gerridae, H = Belostomatidae, I = Dytiscidae, J = Hydrophilidae, K = Hydraenidae, L = Gyrinidae, M = Carabidae, N = Staphylinidae, O = Coenagrionidae, P = Libellulidae, Q = Lycosidae, R = Theridiosomatidae, S = Theridiidae, and T = Tetragnathidae.

Table 3. Nine species of fungi infecting rice planthoppers and leafhoppers, identified from 1980 to 1982 from five Asian countries.

Fungus	Host	Origin
Hirsutella citriformis	BPH	Philippines
		Malaysia
		Indonesia
		China
Erynia delphacis	BPH	Indonesia
		China
		Philippines
	GLH	Philippines
	WBPH	Indonesia
Metarhizium anisopliae	BPH	Philippines
		China
	ZLH	Malaysia
	WBPH	Philippines
Beauveria bassiana	BPH	Philippines
		China
	GLH	Philippines
		China
Verticillium lecanii	BPH	Philippines
		Indonesia
Entomophaga australiensis	BPH	Indonesia
Hirsutella sp.	BPH	Malaysia
	WBPH	Indonesia
Tilletiopsis sp.	BPH	Thailand
Paecilomyces sp.	BPH	China

Table 4. Contact toxicity of insecticides applied with a Potter's spray tower for BPH, GLH, and WBPH adult control.[a] IRRI insectary, 1982.

Insecticide	Mortality[a]		
	BPH	GLH	WBPH
	Test 1		
Phosmet 50 WP			
Phenthoate + BPMC 35 EC			•
Heptachlor 3 E	•		•
Fenthion 50 EC	•		•
Carbaryl XLR 48 F			
Oncol 40 EC	•		
CGA 73'0240 40 EC	•		•
Kitazin P + malathion 70 EC		•	•
Carbofuran 12 F	•		•
	Test 2		
LAB 131 594 I 25 EC			
LAB 137 385 I 50 EC			
BAS 263 21 I 20 EC	•	•	•
WL 085871 5 WP			
Pyridaphenthion 50 EC			•
Ethoprop 6 EC	•	•	•
Dicarzol 500 50 WP	•		•
Carbamult 38 WP			
Diazinon 20 EC			
Carbofuran 12 F	•		•
Dicrotophos 20 EC	•		•

[a]• = ≥ 80% mortality.

successful use of stabilized microcapsule formulation of the synthetic pheromone of *Chilo suppressalis* to disrupt mating in cages (Annual report for 1981), trials were done in the open field. In such trials, the formulation caused greater than 90% communication disruption, as measured by the reduction in catches of pheromone-baited traps. As measured by overnight exposure and subsequent dissection (to determine mating status) of virgin female moths with clipped wings, mating disruption was lower (31% over 5 d).

CHEMICAL CONTROL

Insecticide screening. Coded and commercial insecticides were evaluated for effectiveness against the BPH, WBPH, GLH, rice bug *Leptocorisa oratorius*, leaf folder *Cnaphalocrocis medinalis*, and armyworm *Mythimna separata*.

Contact toxicity. Efficacy of insecticides as contact sprays was measured using the Potter's spray tower. The insects were sprayed with the insecticides and placed on untreated seedlings. Of 21 insecticides tested (Table 4), 13 were effective (≥ 80% mortality) against one or more of three hopper species (BPH, WBPH, and GLH). Only BAS 263 21 I and ethoprop (Mocap) were effective against all three. Heptachlor, fenthion, CGA 73'0240, dicarzol 500, and dicrotophos were effective against BPH and WBPH and comparable with carbofuran, the standard control.

Forty-three commercial and coded insecticides were tested by dipping the fifth-instar armyworm larvae into the insecticide solutions for 30 s. Triazophos, BPMC + chorpyrifos, azinphos ethyl, monocrotophos, and diazinon caused 100% mortality (Table 5). The most toxic new and coded compounds were methidathion, M 9918, phoxim, and DPX.

Insecticides effective for control of armyworm larvae were screened further for ovicidal activity (Table 6).

Foliar sprays. Insecticides were further screened to test their efficacy and residual activity as foliar sprays. Plants were sprayed with insecticides and infested with untreated insects. Promecarb and formetanate provided effective knockdown at 1 DAT against BPH and WBPH (Table 7). Ofunack had the longest residual activity against the WBPH,

Table 5. Contact toxicity of insecticides using the dipping method for armyworm larval control. IRRI insectary, 1982.

Insecticide[a]	Mortality at 48 HT[b] (%)
	Test 1
Triazophos 40 EC	100 a
BPMC + chlorpyrifos 31.5 EC	100 a
Azinphos ethyl 40 EC	100 a
Monocrotophos 30 EC	100 a
Diazinon 20 EC	100 a
Propoxur 20 EC	77 b
Carbophenothion 48 EC	63 bc
Methomyl 18 EC	57 bc
Acephate 75 WP	53 bc
Phosphamidon 50 EC	40 cd
Carbaryl 85 WP	40 cd
MTMC 50 WP	37 cd
BPMC 50 EC	37 cd
MIPC 50 WP	17 e
Endosulfan 35 EC	17 de
Control (water)	7 e
	Test 2
Methidathion 40 EC	100 a
M 9918 20 OE	100 a
Cypermethrin 5 EC	97 a
US SF-1 40 F	100 a
M 10604 20 OE	100 a
UC 54229 100 SP	100 a
RH 0308 48 EC	100 a
UC/MP 19779 48 EC	100 a
FMC 35001 (Marshal) 20 EC	97 a
UC 27867 50 WP	100 a
Monocrotophos 30 EC	100 a
Dioxacarb 50 WP	73 b
Methiocarb 50 WP	97 a
RH 0994 48 EC	100 a
Dioxathion 96 EC	17 c
Control (water)	0 c
	Test 3
Phoxim (Volaton) 50 EC	100 a
DPX 5188 20 EC	100 a
335 C[c]	97 a
NS 8265 75 EC	100 a
335 B[d]	97 a
Propoxur (Baygon) 20 EC	97 a
MTI 500 20 EC	100 a
JF 8251 10 EC	100 a
Pirimiphos methyl + Carbophenothion (Aktrion) 20 EC	100 a
U 57770 85 WP	63 b
Monocrotophos 30 EC	100 a
U 56295 85 WP	70 b
MTI 220 20 EC	100 a
NNI 750 50 WP	3 c
B. T. product (Backie)	3 c
Control (water	0 c

[a]Applied at 0.075% concentration. [b]Av of three replications. [c]deltamethrin + BPMC. [d]335B + neem oil 0.1% + EMCOL H500.

providing 90% control at 20 DAT.

Forty-three insecticides, applied as foliar sprays, were screened for effectiveness in controlling 5th-instar armyworm. Sixteen provided effective control (Table 8).

Table 6. Ovicidal effect of different commercial insecticides on the armyworm. IRRI insectary, 1982.

Insecticide[a]	Unhatched eggs (%)
	Test 1[b]
Azinphos ethyl	81 a
BPMC + chlorpyrifos	78 a
Diazinon	81 a
Monocrotophos	49 b
Triazophos	59 b
Propoxur	9 c
Control (water)	1 d
	Test 2[c]
UC/MP 19779 50 EC	100 a
Cypermethrin 5 EC	100 a
Methidathion 40 EC	99 a
Methomyl 18 EC	98 a
Carbosulfan 20 EC	96 ab
UC 27867 50 WP	93 ab
Azinphos ethyl 40 EC	91 ab
Methiocarb 50 WP	80 b
UC 54229 100 SP	81 b
Carbaryl 85 WP	18 c
Acephate 75 WP	12 c
Carbaryl 48 F	10 c
Control (water)	15 c

[a]Eggs were dipped in a 0.075% concentration of the insecticide for 30 S. [b]Av of four replications. [c]Av of three replications.

Among insecticides applied as foliar sprays, BPMC + chlorpyrifos and diazinon had high levels of fumigation activity against the adult armyworm (Table 9).

Insecticides applied as foliar sprays were evaluated for activity against the leaf folder. Plants were sprayed 2 wk after larvae were placed on them. The larvae were located in rolled leaves at the time of spraying. Eleven insecticides provided effective control (Table 10).

Granules. Of 11 granular insecticides screened, carbofuran 3G and diazinon 5G effectively controlled BPH and GLH up to 5 DAT when broadcast into rice field water.

Only carbofuran 3G effectively controlled armyworm at 14 DAT. The insecticidal activity of carbofuran 3G was evident at 24 HC on the treated plants. The efficacy of carbofuran 3G was indicated by the low rate of defoliation.

Seed treatment. Seeds were treated with carbosulfan and carbofuran, coated with calcium peroxide, covered with 1 cm soil in porcelain pots, and flooded with 5 cm water. Calcium peroxide provides O_2 to the submerged seedlings and the insecticide protects the young seedlings from early-season pests. In a laboratory test, carbosulfan at 200 g ai/ha controlled BPH and GLH up to 29 DAS. Carbofuran did not control the two hoppers. In a field test, hopper control by carbosulfan was very poor.

Pesticide combinations. In a test for contact

Table 7. Knockdown and residual activity of insecticides applied as foliar spray for BPH, GLH, and WBPH control. IRRI, 1982.

Insecticide[a]	BPH		GLH		WBPH	
	Knockdown mortality (≥80%)[b]	Residual mortality (≥60%)[c]	Knockdown mortality (≥80%)[b]	Residual mortality (≥60%)[c]	Knockdown mortality (≥80%)[b]	Residual mortality (≥60%)[c]
Promecarb 38 WP	•					
Formetanate 50 WP	•		•			•
Carbofuran 12 F	•			•		
Ofunack 50 EC					•	•
Dicrotophos 20 EC						
WL 08571 5 WP						
LAB 137385 I 50 EC						
Diazinon 20 EC						
BAS 263 21 I 20 EC						
LAB 131 594 I 25 EC						
Ethoprophos 6 EC						

[a]Applied at the rate of 0.75 kg ai/ha, except WL 08571 at 0.025 kg ai/ha. [b]1 DAT. [c]20 DAT.

Table 8. Effect of insecticides applied as foliar sprays on 5th-instar armyworm larvae caged 1 DAT. IRRI insectary, 1982.

Insecticide[a]	Mortality at 48 HC (>80%)	Defoliation[b] (≤3)
	Test 1	
Triazophos 40 EC	•	•
Monocrotophos	•	•
Azinphos ethyl	•	•
Carbaryl		•
Acephate	•	•
BPMC + chlorpyrifos		
Methomyl		•
Propoxur		
BPMC		
Phosphamidon		
Carbophenothion		
Diazinon		
Endosulfan		
MIPC		
MTMC		
	Test 2	
M 9918 20 OE	•	•
RH 0308 48 EC	•	•
M 10604 20 OE	•	•
Triazophos 40 EC	•	•
Methidathion 40 EC	•	•
RH 0994 48 EC	•	•
UC SF-1 40 F		
FMC 35001 (Marshal)	•	•
UC/MP 19779 50 EC		•
UC 27867 50 WP	•	•
UC 54229 100 SP		
Cypermethrin 5 EC		•
Methiocarb 50 WP		
Dioxacarb 50 WP		
Dioxathion 96 EC		
	Test 3	
MTI 220 20 EC[c]	•	•
MTI 500 20 EC[c]	•	•
U 57770 85 WP	•	•
U 56295 85 WP	•	•
335 B[d]		•
335 C[d]		•
JF 8251 10 EC		
Propoxur (Baygon) 20 EC		
Phoxim (Volaton) 50 EC		•
NS 8265 75 EC		
Carbaryl XLR 48 F		
Pirimiphos methyl + carbophenothion 20 EC		
Buprofezin 50 WP		
B. thuringiensis (Backie)[e]		
Triazophos 40 EC	•	•

[a]All rates 0.75 kg ai/ha unless otherwise noted. [b]Leaves checked for damage at 48 HT: 0 = no damage, 10 = 100% destruction. [c]0.05 kg ai/ha. [d]1 liter/ha. [e]0.4 kg/ha.

Table 9. Fumigant effect of commercial insecticides on the armyworm adults. IRRI insectary, 1982.

Commercial insecticide	Mortality at 48 HC (>80%)
Azinphos ethyl 40 EC	
BPMC + chlorpyrifos 31.5 EC	•
Diazinon 20 EC	•
Monocrotophos 202 R 30 EC	
Triazophos 40 EC	
Propoxur 20 EC	

Table 10. Toxicity of insecticides applied to the rice leaf folder *Cnaphalocrocis medinalis* as foliar spray. IRRI insectary, 1982.

Insecticide	Mortality (>80%)
	Test 1
335 B[a]	•
335 C[b]	
JF 8251[c]	•
MTI-500	
MTI-220	
Chlorphoxim (Volaton 500)	•
NS 8265[d]	
Cypermethrin 5 EC	•
Monocrotophos 16.2 EC	•
	Test 2
M 10604 20 OE	•
Methidathion 40 EC	•
RH 0308 48 EC	•
RH 0994 48 EC	•
Monocrotophos 30 EC	•
M 9918 20 OE	•
UC 27867 50 WP	
UC 54229 100 SP	
Dioxacarb 50 WP	

[a]deltamethrin + BPMC. [b]deltamethrin + BPMC + neem oil. [c]pirimicarb + pirimiphos ethyl. [d]phenthoate + BPMC.

toxicity against BPH, GLH, and WBPH, fungicide-insecticide combinations were applied in the Potter's spray tower and as foliar sprays in the laboratory. The mixtures of IBP (fungicide) and malathion showed synergism on BPH, GLH, and WBPH (Table 11). Combinations of edifenphos (fungicide) or IBP (fungicide) and carbaryl also showed a synergistic effect on BPH (Table 12). The combinations of these fungicides and diazinon, carbofuran, or BPMC showed no synergism.

Combinations of deltamethrin + BPMC and deltamethrin + BPMC + neem oil were tested for contact toxicity on BPH, WBPH, and GLH in the

Table 11. Evaluation on insecticide-fungicide (IBP) mixture applied in the Potter's spray tower for BPH, GLH, and WBPH control. IRRI insectary, 1982.

Treatment	Mortality (%) at 48 HT[a]		
	BPH	GLH	WBPH
25 parts malathion + 75 parts IBP	48.8 a	85.0 a	81.3 c
75 parts malathion + 25 parts IBP	30.0 b	65.0 b	92.5 ab
50 parts malathion + 50 parts IBP	56.3 a	85.0 a	92.5 ab
Malathion 50 EC	28.8 b	66.3 b	88.8 bc
IBP (Kitazin P) 48 EC	23.8 b	10.0 c	5.0 d

[a]Av of four replications.

Table 12. Synergistic effect of a mixture of fungicide and insecticide applied in the Potter's spray tower for BPH control. IRRI insectary, 1982.

Treatment[a]	Mortality 48 HT (%)
A = Carbaryl 85 WP	13 ij
B = Diazinon 20 EC	25 fghi
C = Carbofuran 12 F	95 ab
D = BPMC 50 EC	97 ab
E = Edifenphos 50 EC	13 ij
F = IBP 48 EC	17 hij
Untreated	7 j
7 parts A + 3 parts E	23 ghi
3 parts A + 7 parts E	37 fg
7 parts A + 3 parts F	70 e
3 parts A + 7 parts F	87 bcd
7 parts B + 3 parts E	43 f
3 parts B + 7 parts E	15 ij
7 parts B + 3 parts F	38 fgh
3 parts B + 7 parts F	33 fgh
7 parts C + 3 parts E	92 bcd
3 parts C + 7 parts E	92 abc
7 parts C + 3 parts F	98 a
3 parts C + 7 parts F	90 abc
7 parts D + 3 parts E	83 cde
3 parts D + 7 parts E	37 fg
7 parts D + 3 parts F	88 bcd
3 parts D + 7 parts F	78 de

[a]Formula in the computation of the parts of the compounds in the solution:

$$\text{Amt of formulated product needed in the spray fluid desired} = \frac{\text{\% recommended concn} \times \text{amt spray fluid required}}{\frac{\text{\% ai in commercial product}}{10}}$$

X parts needed.

Potter's spray tower. Only the mixture with neem was more effective against GLH than the standard check carbofuran 12F.

Insectistatics. The growth regulators LAB 141 305 I and buprofezin were tested in the laboratory on BPH, GLH, and WBPH. Buprofezin at 0.5 kg ai/ha was effective against the three hoppers. LAB 141 305 I was effective against none.

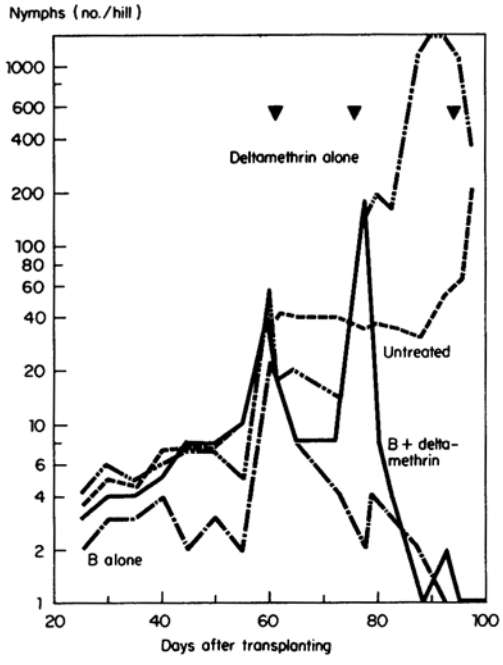
As a granular formulation, buprofezin provided >70% mortality of BPH and WBPH at 0.25-0.75 kg ai/ha at 15 DAT, but was not effective against GLH (Table 13). It had no effect on first-instar rice bug nymphs kept for 20 DAT on treated plants in the laboratory, nor was it toxic to natural enemies *Microvelia atrolineata* or *Cyrtorhinus lividipennis* when it was applied as a foliar spray in the laboratory.

In field studies, buprofezin, alone or combined with other insecticides, provided effective BPH control, but had no effect on leaf folder and stem borer. Yields were increased by the application of buprofezin alone and in combinations.

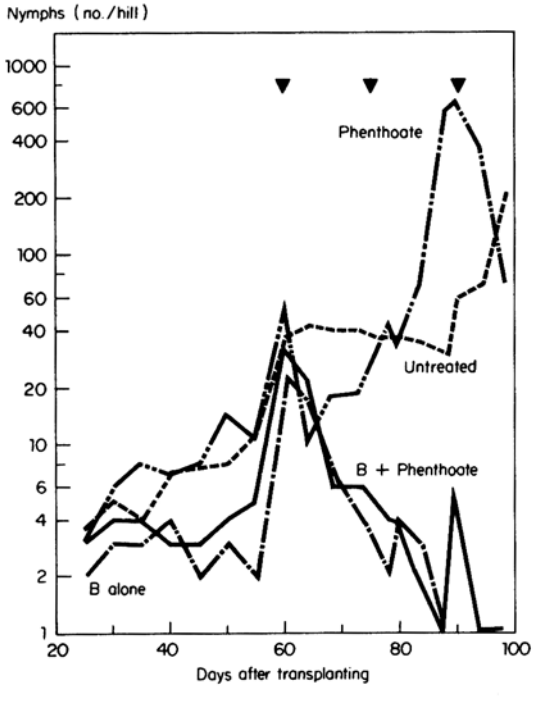
WS studies in Calauan, Laguna, showed that the BPH resurgence-inducing activity of an insecticide can be decreased by mixing it with buprofezin. Plants treated with combinations of buprofezin and deltamethrin (Fig. 15) and phenthoate (Fig. 16) had lower BPH populations than those treated with deltamethrin or phenthoate alone.

Table 13. Laboratory evaluation of buprofezin 2G for BPH, GLH, and WBPH control. IRRI insectary, 1982.

Rate	Mortality 15 DAT (%)
	BPH
0.750	72.5 b
0.500	87.5 a
0.250	72.5 b
0.125	50.0 c
0.000 (untreated)	7.5 d
	GLH
0.750	12.5 a
0.500	7.5 a
0.250	2.5 b
0.125	10.0 a
0.000 (untreated)	0.0 b
	WBPH
0.750	97.5 a
0.500	87.5 ab
0.250	77.5 b
0.125	20.0 c
0.000 (untreated)	17.5 c



15. BPH nymph population when buprofezin (B) was applied with deltamethrin. Calauan, Laguna, Philippines, 1982 WS. Triangles (▼) show time of application.



16. BPH nymph population when buprofezin (B) was applied with phenthoate. Calauan, Laguna, Philippines, 1982 WS. Trianggles (▼) show time of application.

Susceptibility of BPH biotypes to insecticides. The difference in the LD_{50} values of carbofuran and monocrotophos among the three BPH biotypes was not significant (Table 14).

LD_{50} values of insecticides for rice bug. Of the five insecticides tested, UC 54229 was highly toxic to both the rice bug nymphs and adults (Table 15).

Insecticide resistance. IRRI field-collected and greenhouse-reared fifth-instar BPH nymphs were placed on foliar-sprayed plants to determine their response to chlorpyrifos + BPMC, BPMC, and acephate. Mortality of the greenhouse-reared BPH was significantly higher than that of the field-collected BPH (Fig. 17). This indicates that BPH on the farm have some resistance to the test insecticides.

Botanical insecticides. Evaluation of chemicals derived from plants was continued.

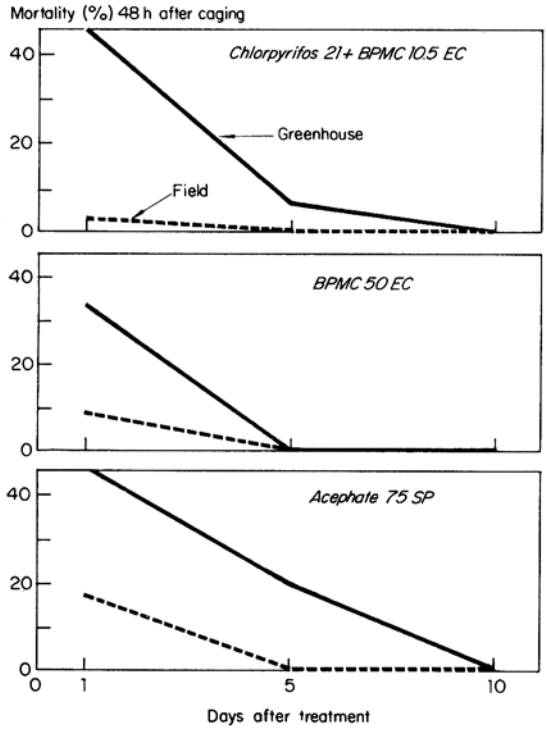
Effects of neem (Azadirachta indica), *chinaberry*

Table 14. Toxicity of carbofuran and monocrotophos to brachypterous female adults of the three BPH biotypes. IRRI insectary, 1982.

Biotype	LD_{50} (μg/g)	
	Carbofuran	Monocrotophos
1	21.6 a	18.7 a
2	16.4 a	16.4 a
3	27.8 a	13.2 a

Table 15. Toxicity of five insecticides to the rice bug. IRRI insectary, 1982.

Insect age	Insecticide	LD_{50} (μg/g)	95% fiducial limit	
			Lower	Upper
Third-instar nymph				
	Carbaryl	3.92 ab	2.39	6.99
	Diazinon	5.40 a	2.75	14.50
	Monocrotophos	0.79 abc	0.43	1.65
	UC 27867	4.18 ab	2.81	6.48
	UC 54229	0.62 bc	0.32	0.99
Adult				
	Carbaryl	0.48 c	0.25	1.43
	Diazinon	0.77 abc	0.36	3.57
	Monocrotophos	0.29 c	0.11	1.94
	UC 27867	0.89 abc	0.45	3.24
	UC 54229	0.29 c	0.20	0.47



17. Comparison in BPH mortality between greenhouse-reared, insecticide-free BPH populations and populations collected from the IRRI farm in Apr-Jun 1982, following insecticide foliar spray treatment at 0.75 kg ai/ha.

(Melia azedarach), *and custard-apple* (Annona squamosa) *seed oils on hoppers and their predators.* Oils were evaluated for toxicity to the GLH, BPH, and WBPH and two of their common predators, the mirid bug *Cyrtorhinus lividipennis* and spider *Lycosa pseudoannulata*. Custard-apple oil was most effective against BPH and WBPH, causing 71-100% mortality at doses of ≥5 μg/insect (Table 16). Neem oil and chinaberry oil were equally effective against WBPH. However, chinaberry oil was not as effective as neem oil against BPH. Neem oil and chinaberry were not effective against GLH. Custard-apple oil was moderately effective at high doses.

Neem and chinaberry oils were slightly toxic to the mirid bug at 50 μg/insect. Custard-apple oil was moderately to highly toxic at 10-50 μg (Table 17).

Survival of and tungro virus transmission by green leafhopper on rice treated with custard-apple and neem oils. Both custard-apple and neem oils reduced GLH survival (Table 18) and RTV transmission (Table 19). Less than 10% of the GLH survived 3 d after exposure to TN1 seedlings sprayed with the oils in both treatments. RTV infection was reduced to less than 1% in seedlings sprayed with 50% custard-apple oil after exposure to 2 d of inoculation feeding by viruliferous insects.

Effect of azadirachtin on brown planthopper and green leafhopper nymphs. Azadirachtin, a tetracyclic triterpenoid in neem seed, was tested to determine whether contact with fifth-instar BPH and GLH nymphs would prevent them from molting into the adult stage. Topical application of 1-15 μg azadirachtin/nymph resulted in a significant decrease in emergence of BPH adults at all doses (Table 20). At 15 μg, no BPH adults emerged and only 10% of the GLH adults emerged. Where adults emerged from treated nymphs, various degrees of adult abnormalities, such as retention of nymphal exuviae and distorted wings, were observed.

Insecticidal activity of an indigenous plant extract. The activity of a purified fraction isolated

Table 16. Mortality of BPH (biotype 1), WBPH, and GLH adults topically treated with seed oils of neem, chinaberry, and custard-apple. IRRI, 1982.[a]

Dose (μg/insect)	Mortality[b] at 24 HT (%)								
	Neem oil			Chinaberry oil			Custard-apple oil		
	BPH	WBPH	GLH	BPH	WBPH	GLH	BPH	WBPH	GLH
5	3 c	48 d	5 a	5 b	31 c	3 a	71 b	91 b	15 b
10	27 b	77 c	5 a	7 b	83 b	5 a	100 a	98 ab	22 b
20	67 a	90 b	8 a	15 ab	84 b	7 a	100 a	100 a	58 a
50	82 a	100 a	14 a	28 a	96 a	17 a	100 a	100 a	61 a

[a]Av of six replications, 10 insects/replicate. [b]Data corrected using Abbott's formula.

Table 17. Mortality of the mirid bug and the spider topically treated with seed oils of neem, chinaberry, and custard-apple. IRRI laboratory, 1982.[a]

Dose (μg/predator)	Mortality at 24 HT (%)					
	Neem oil		Chinaberry oil		Custard-apple oil	
	Mirid[b]	Spider	Mirid[b]	Spider	Mirid[b]	Spider
5	5 b	0	2 b	0	21 c	0
10	21 ab	0	15 ab	2	48 b	0
20	16 ab	2	15 ab	0	52 b	0
50	26 a	4	21 a	0	92 a	10

[a]Av of four replications, 10 insects/replicate. [b]Data corrected using Abbott's formula.

Table 18. Survival of GLH after exposure on TN1 seedlings sprayed with oil. IRRI insectary, 1981-82.

Oil concn (%)	Survival (%)					
	1 d		2 d		3 d	
	Custard-apple oil	Neem oil	Custard-apple oil	Neem oil	Custard-apple oil	Neem oil
5	25.0 b	57.5 b	5.0 b	23.5 b	0.0 b	7.0 b
10	27.5 b	36.5 cd	5.5 b	16.5 bc	0.5 b	5.5 b
20	22.5 bc	42.0 c	6.0 b	8.0 bc	1.0 b	0.0 b
30	16.5 bc	34.0 cd	1.5 b	2.5 c	0.0 b	0.0 b
50	1.5 c	26.6 d	0.0 b	2.5 c	0.0 b	0.0 b
0[a]	95.5 a		86.5 a		80.0 a	

[a]Control treatment was common to both oils. (Control: water + 0.1% liquid detergent.)

Table 19. RTV infection in TN1 rice seedlings sprayed with oils after exposure to viruliferous insects. IRRI insectary, 1981-82.

Oil concn (%)	RTV infection (%) of TN1 seedlings			
	1 d		2 d	
	Custard-apple oil	Neem oil	Custard-apple oil	Neem oil
5	25.0 b	27.0 b	6.9 b	13.6 b
10	19.0 bc	16.4 bc	4.2 b	11.2 b
20	19.0 bc	20.9 bc	2.4 b	10.2 b
30	20.4 bc	13.6 c	11.0 b	4.5 b
50	10.5 c	11.8 c	0.2 b	10.3 b
0[a]	60.4 a		35.5 a	

[a]Control treatment was common to both oils. (Control:water + 0.1% liquid detergent.)

from a plant indigenous to the Philippines was tested on BPH and WBPH. TN1 seedlings were dipped in different concentrations of a purified fraction in an acetone-water solution. BPH and WBPH mortalities were high at concentrations of ≥300 mg/kg (Table 21). Chemical synthesis and optimization of the purified fraction are in progress.

Application equipment. The knapsack sprayer, electrodyne sprayer (ICI, England), and Pulsfog K10/0 machine (Dr. Stahl & Sohn GmbH & Co. KG, Switzerland) were compared for effectiveness in controlling rice insect pests during the DS and WS. The electrodyne charges the spray droplets opposite to that of the rice plant. In the first test, the electrodyne and knapsack sprayers provided

Table 20. Adults emerging from fifth-instar BPH and GLH nymphs topically treated with azadirachtin. IRRI laboratory, 1982.[a]

Dose (μ/insect)	Adult emergence (%)	
	BPH	GLH
0	100 a	100 a
1	47 b	77 a
5	43 b	17 b
10	0 c	20 b
15	0 c	10 b

[a]Av of three replications, 10 insects/replicate.

Table 21. Mortality of first-instar BPH and WBPH nymphs on TN1 seedlings treated with different concentrations of a purified fraction isolated from the extract of an indigenous plant. IRRI insectary, 1982-83.[a]

Concn (mg/kg)	Mortality (%) at 24 h after infestation	
	BPH (biotype 1)	WBPH
0	0 d	0 d
100	0 d	5 d
200	30 c	33 c
300	70 b	75 b
400	93 a	97 a
500	100 a	97 a

[a]Av of six replications, 10 nymphs/replicate.

poor BPH control, but effective GLH control (Table 22). In the second test, the three machines equally controlled RWM and deadhearts caused by stem borer whereas the knapsack controlled whitehead damage most effectively (Table 23). The electrodyne (0.05 ml/s flow rate) and the knapsack provided the best leaf folder control. The data showed that neither the electrodyne or pulsfog is better than the knapsack sprayer.

YIELD LOSSES CAUSED BY INSECTS

Caseworm. The rice caseworm (RCW) usually attacks the rice crop early in the growing season and the plants appear to recover later on. The economic importance of RCW is not known because its effect on yield has not been determined. In 1982, screenhouse and field studies were conducted to assess RCW damage at nine infestation levels and at four plant ages (Fig. 18). Transplanting time was staggered to obtain the various plant ages at the same time so insect infestation could be done simultaneously. Plots were infested with second-instar larvae and covered with fiberglass netting immediately after transplanting. The netting was removed at 20 DI and the plants were sprayed with insecticide to protect them from insect damage.

Yields decreased with increases in the insect infestation level (Fig. 18). They declined most severely when the plants were infested at 5 DT. When infestation occurred at 30 DT in the screenhouse and at 17 and 30 DT in the field, yields were stable at all infestation levels. Early attacks had the most severe impact on yields.

Insect combinations. Previous studies showed that the RWM caused no yield losses. However, when RWM damage occurred simultaneously with other early season insect damage, yield losses occurred. In 1982, studies were conducted to determine the effect of four infestation levels of

Table 22. Comparison of electrodyne and knapsack sprayer using cymbush at five application times after transplanting for BPH and GLH control. IRRI, 1982 DS.

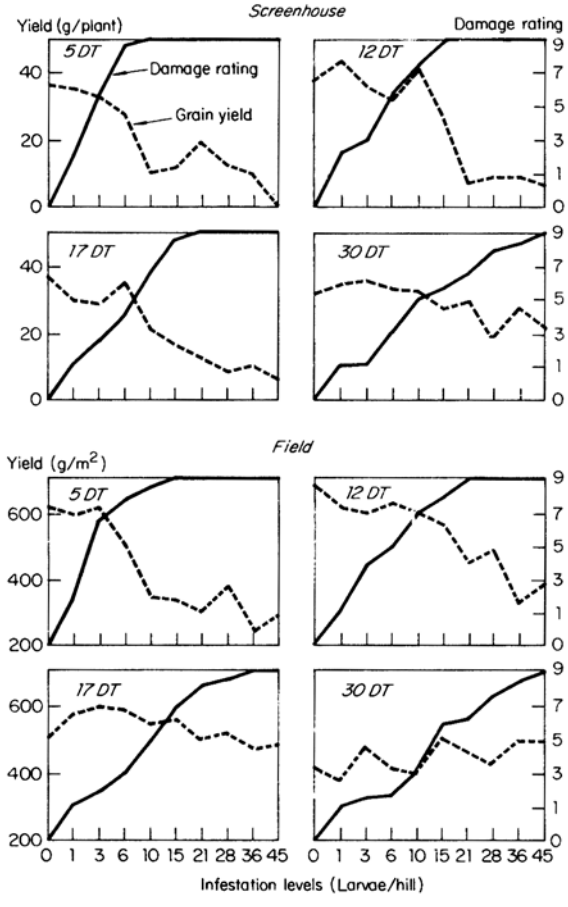
Treatment	Flow rate (ml/s)	Rate (g ai/ha)	Mortality[a] (%)									
			BPH					GLH				
			14 DT	27 DT	41 DT	56 DT	71 DT	14 DT	27 DT	41 DT	56 DT	71 DT
Electrodyne	0.05	25	24 a	23 a	6 a	–	–	100 a	74 a	51 a	–	–
Electrodyne	0.01	50	–	–	–	15 a	6 a	–	–	–	65 a	40 a
Knapsack	15.00	25	16 a	27 a	11 a	–	–	85 a	84 a	73 a	–	–
Knapsack	15.00	50	–	–	–	13 a	6 a	–	–	–	73 a	50 a
Untreated	–	–	5 a	16 a	3 a	6 a	2 b	85 a	21 b	5 b	4 b	3 b

[a]BPH caged at 2 h after spraying and GLH at 24 h after spraying. Mortality recorded at 24 HC for GLH and at 48 HC for BPH.

Table 23. Comparison of electrodyne, pulsfog, and knapsack sprayers using cypermethrin. IRRI, 1982 WS.

Treatment[a]	Flow rate (ml/s)	Pest control								
		RWM[b]		Deadhearts (%)			Whiteheads (%)	Leaf folder (% of leaves damaged)		Rice bug/m^2
		24 DT	35 DT	21 DT	42 DT	60 DT	5 DBH	50 DT	81 DT	93 DT
Electrodyne	0.05	2.0 b	3.9 a	0.3 a	0.5 a	0.7[a] b	0.9 a	0.0 b	2.0 a	1.8 a
Electrodyne	0.1	2.4 b	3.5 a	0.4 a	0.5 a	0.8 ab	0.5 ab	0.3 ab	2.3 a	0.5 a
Pulsfog	15	2.5 b	3.7 a	0.6 a	0.3 a[c]	0.7 ab[c]	0.9 a	0.6 ab	1.9 a	1.5 a
Knapsack	10	2.3 b	4.3 a	0.1 a	0.3 a	0.5 b	0.2 b	0.0 b	1.7 a	0.5 a
Untreated	–	3.3 a	3.8 a	0.5 a	0.5 a	1.4 a	0.6 ab	0.9 a	2.2 a	2.0 a

[a]Applied at 25 g ai/ha. [b]Based on a 0-9 scale: 0 = no change; 9 = more than 1/2 the leaves damaged with some leaves broken. [c]At 42 and 60 DT, no insecticide was applied.



18. The relationship of yield to RCW damage caused by different infestation levels at different ages of IR36 under screenhouse and field conditions. IRRI, 1982 WS.

RCW, RWM, and YSB and combinations of these pests on the yield of IR36. Plants were infested at 5-30 DT.

At levels 1 through 4, none of the insects by themselves caused yield losses (Table 24). However at level 4, all combinations significantly decreased yield below that of the control, whereas no yield decrease occurred in plots infected with only one species. When yield data were based on the means of all infestation levels, the treatments with insect combinations including YSB yielded lower than the treatments with only one pest (Table 25). The highest infestation level caused the lowest yield (Table 26). The results indicate that combinations of two or more pests, at subeconomic threshold levels individually, caused economic losses. Thresholds should be based on pest combinations rather than on each pest individually.

INTEGRATED PEST MANAGEMENT (IPM)

Integration of weed, insect, and disease control. The effects of two levels each of insect control, weed control, and fungal disease control on IR36 and IR22 were evaluated in a test conducted in a farmer's field. IR36 has multiple resistance to insects and diseases and IR22 is susceptible to both diseases and insects. Plots were continuously submerged, intermittently irrigated or saturated.

Insect populations were low and were not affected by water management. GLH populations were highest on susceptible IR22. Weed weight was affected by the level of herbicide and water management (Table 27). Continuously submerged plots and plots receiving Saturn D herbicide at 3 DT had the lowest weed populations. Insect control decreased weed weight because of the competition provided by the healthy rice plants, but differences were not significant.

Table 24. IR36 yield as affected by RCW, RWM, or YSB alone or in double or triple pest combinations at four infestation levels in field. IRRI, 1982 WS.

	Grain yield[a] (g/m^2) at infestation level			
	1[b]	2[c]	3[d]	4[e]
RCW	519.2 ab	539.3 ab	526.8 abc	474.0 abcdefghi
RWM	541.2 ab	554.8 a	508.4 abcde	451.4 cdefghij
YSB	473.5 abcdefghi	485.9 abcdefg	443.2 cdefghijk	426.6 efghijkl
RCW + RWM	481.3 abcdefgh	495.2 abcdef	343.3 lm	385.4 jklm
RCW + YSB	461.5 bcdefghij	434.9 defghijk	396.3 hijklm	360.5 klm
RWM + YSB	397.9 ghijklm	423.2 efghijkl	460.9 bcdefghij	392.9 ijklm
RCW + RWM + YSB	447.4 cdefghij	416.7 fghijkl	426.6 efghijkl	318.9 m
Control (unprotected)	487.6 abcdef	487.6 abcdef	487.6 abcdef	487.6 abcdef
Control (protected)	501.9 abcdef	501.9 abcdef	501.9 abcdef	501.9 abcdef

[a]Av of four replications. [b]Level 1 = 200 RCW, RWM, and YSB/2.25 m^2. [c]Level 2 = 400 RCW, 400 RWM, and 300 YSB [d]Level 3 = 600 RCW, 600 RWM, and 400 YSB. [e]Level 4 = 900 RCW, 900 RWM, and 500 YSB, 2nd-instar larvae, adults, and 1st-instar larvae, respectively.

Table 25. IR36 yield as affected by insect damage based on the means of the infestation levels. IRRI, 1982 WS.

Insect	Grain yield[a] (g/m^2)
RCW	514.8 a
RWM	513.9 a
YSB	457.3 b
RCW + RWM	426.3 bc
RCW + YSB	413.3 c
RWM + YSB	418.7 c
RCW + RWM + YSB	402.4 c

[a]Av of four replications.

Table 26. IR36 yield as affected by infestation levels[a] as based on means of all insect pest combinations. IRRI, 1982 WS.

Infestation level	Insects (no./2.25 m^2)			Mean yield (g/m^2)
	RCW	RWM	YSB	
1	200	200	200	474.6 a
2	400	400	300	478.6 a
3	600	600	400	443.6 b
4	900	900	500	401.4 c

[a]Av of four replications.

Table 27. Effects of different pest control levels and water management on weed dry weight. Victoria, Laguna, Philippines, 1982 DS.[a]

Pest control level[b]	Weed dry wt (g/0.72 m^2)		
	Continuously submerged	Intermittently irrigated	Saturated
IC + WC + FC	0.5 (b) b	3.6 (b) b	9.2 (b) a
IC + WC	0.3 (b) b	5.8 (b) a	7.1 (b) a
IC	6.1 (a) b	31.1 (a) a	46.6 (a) a
T + WC	0.5 (b) b	4.8 (b) a	13.7 (b) a
T	9.1 (a) b	44.3 (a) a	69.2 (a) a

[a]Values shown were the average of four replications and two varieties. Separation of means in a column of a row (in parentheses) by Duncan's multiple range test at the 5% level. [b]IC = insect control: seedbed protection = soil incorporation of carbofuran at 1.0 kg ai/ha before sowing and broadcast application 15 DE; vegetative protection: soil incorporation of carbofuran at 0.75 ai/ha 1 DBT. WC = weed control: broadcast application of 25 kg formulated product of Saturn D (thiobencarb + 2,4-D (G)) 3 DT. FC = Fungus control: foliar application of 1.0 kg formulated product of Benlate in 1,000 liters water at maximum tillering stage. T = based on the following insect and damage threshold levels: spray only if above the following: Defoliators > 15%, deadhearts > 15% the first 30-35 DT and > 5% thereon till flowering; GLH > 5 insects/10 sweeps, planthoppers > 20 insects/hill, leaf folders > 15% of flag leaves damaged/hill; rice bugs > 8/m^2.

The effects of water management and insect control and, consequently, weed competition on grain yield are in Table 28. Insect control, which resulted in a rapid canopy development helping to control weeds, increased yield in the intermittently irrigated and saturated plots. Evidently, even where economic thresholds were not reached, plant growth was not as luxuriant as in the plots that received early insect protection. The high level of weeds in these plots resulted in lower yields. There was an interaction between insect and weed control.

Teaching farmers integrated pest management. Starting in 1978, IRRI began teaching IPM to

Table 28. The economics of an IPM strategy for the control of pests in wetland rice. Victoria, Laguna, Philippines, 1982 DS.

Pest control level[a]	Yield[b] (t/ha)			Gross income[c] ($)			Pesticide cost[d] ($)	Labor cost[e] ($)	Net return[f] ($)			B:C[g]		
	C	I	S	C	I	S			C	I	S	C	I	S
							IR36							
IC + WC + FC	5.63	5.62	5.94	1001	999	1056	96	5.88	899	897	954	8.8	8.8	9.4
IC + WC	5.63	5.36	5.41	1001	954	972	41	3.11	957	910	928	21.6	20.6	21.0
IC	5.47	5.02	4.95	972	892	880	30	1.72	940	860	848	29.7	27.1	26.7
T + WC	4.32	3.96	4.57	768	704	812	11	1.39	756	692	800	60.9	55.8	64.6
T	5.21	4.19	3.52	926	745	626	0	0.0	926	745	626	–	–	–
							IR22							
IC + WC + FC	4.97	5.71	4.68	883	1015	832	94	5.88	783	915	732	7.8	9.2	7.3
IC + WC	5.01	5.19	4.95	891	923	880	41	3.11	847	879	836	19.2	19.9	19.0
IC	5.49	4.77	3.92	976	848	697	30	1.72	944	816	665	29.8	25.7	21.0
T + WC	4.59	4.51	3.12	816	802	555	23	4.16	789	775	518	29.1	28.5	19.4
T	5.15	2.84	2.77	915	505	492	12	2.77	900	490	477	61.0	33.2	32.3

[a]IC = insect control: seedbed protection = soil incorporation of carbofuran at 1.0 kg ai/ha before sowing and broadcast application 15 DE; vegetative protection: soil incorporation of carbofuran at 0.75 ai/ha 1 DT. WC = weed control: broadcast application of 25 kg formulated product of Saturn D (thiobencarb + 2,4-D (G)) 3 DT. FC = fungus control: foliar application of 1.0 kg formulated product of Benlate in 1,000 liters water at maximum tillering stage. T = based on the following insect and damage threshold levels: spray only if above the following: Defoliatiors > 15%, deadhearts > 15% the first 30-35 DT and > 5% thereon till flowering; GLH > 5 insects/10 sweeps, planthopper > 20 insects/hill, leaf folders > 15 of flag leaves damaged /hill; rice bugs > 8/m^2. The GLH threshold was reached in FR 22 and BPMC was applied once at 30 DT at 0.75 by ai/ha. [b]C = continuously irrigated; I = intermittently irrigated; S = irrigated at saturation point only. [c]Based on price of palay at $177.78/t. [d]Furadan at $20.00/16.7 kg bag of 3% ai; Saturn D at $11.11/bag of 25 kg; Benlate at $53.33/kg FP; BPMC (Hopcin at $7.88/liter FP. [e]$2.77/8 h. [f]Gross income minus cost of pesticide and labor. [g]Net return divided by the cost of pesticide and labor.

farmers in Nueva Ecija Province, an irrigated double rice crop area. At the start of the pilot project, farmers averaged six to seven insecticide applications per crop using low dosages averaging 0.2 kg ai/ha. Depending on the year and crop, the number of applications ranges from zero to three if economic thresholds are used.

The project has been centered on teaching farmers how to identify and quantify insect populations so they can base insecticide applications on pest abundance rather than follow normal calendar-based scheduling.

In the 2,000-ha project area encompassing eight villages, an IRRI research assistant assumed the role of extension technician. The teaching format has been to hold weekly classes during a crop season. A new topic was discussed during the 2-h weekly sessions that combined lectures, classroom demonstrations, question-and-answer periods, and field practice.

Classes are given only during one crop season in each village. During a 2-yr period seven villages were covered. Community development workers assigned in each village attended the classes and provided feedback on both the effectiveness of the teaching methods, which are continually revised, and the rate of IPM technology adoption by the farmers during the subsequent crops.

The community development workers found that the farmers were not able to assimilate the technology from classes during one crop season. Therefore during the 1980 WS crop, research assistants conducted weekly follow-up returns at two previously instructed villages starting at the time of seedbed preparation. The assistant met only with farmer leaders. The farmers agreed not to apply insecticides until after each weekly follow-up meeting. During each meeting, the leaders reported their observations and indicated whether they would apply insecticide as a result of their monitoring. Then, the group went to several fields where the pest problems were most evident and the assistant checked the farmers' observations.

The results of the follow-up meetings over 14 wk confirmed that classes alone were not sufficient to teach farmers IPM technology (Table 29). During seedbed preparation in week 3, the farmers wanted to apply insecticide when they saw stem borer moths and beetles without determining if an economic threshold had been reached. They also wanted to broadcast granular insecticide to counteract symptoms of excess N.

In week 5, the farmers wanted to apply insecticide to control RGS even though the economic threshold had not been reached. But the following week, they were able to diagnose the problem and to correctly decide to use insecticide. Because of their class instruction, they were able to diagnose RWM, stem borer deadhearts, and leaf folder in weeks 7 and 8.

Zn deficiency symptoms, a subject not covered in the classes, appeared in week 8 and the farmers wanted to apply insecticides as a remedy for yellowing plants.

Hoppers (*Sogatella furcifera*) were detected in week 9 and the farmers again wanted to spray insecticide unnecessarily. They had not learned to monitor their fields for hoppers by the following week, but by week 13, they showed the capability to assess a hopper problem and use economic thresholds.

First appearance of bacterial leaf streak symptoms during week 10 again prompted the impulse to apply insecticide. Again it took several weekly encounters before the farmers were able to grasp the problem. The farmers misdiagnosed a rat problem in week 15 and leaf folder in week 16.

It was apparent that the weekly follow-up meetings were essential to the farmers' learning process. The farmers were surveyed to compare the benefit of classes during the 1981 DS. Classes alone did not change farmers' insecticide-use practices (Table 30). Follow-up meetings with no classes significantly reduced the number of insecticide applications, but more IPM technology adoption occurred if classes and follow-up meetings were held. Even with follow-up meetings, farmers were still applying insecticides at rates lower than the recommended 0.75 kg ai/ha.

Although not sufficient by themselves as a means of teaching farmers IPM, classes are essential in creating interest in pest control problems so that farmers will attend the follow-up meetings. One technician can serve eight villages (each village has about 200 farm families) during the follow-up period, spending a half day a week in each.

Economic threshold values for farmers. The social scientists associated with the IPM project in

Table 29. Record of weekly follow-up contacts with farmer groups in two villages where the IPM classes had been taught. Nueva Ecija, Philippines, 1980 WS.

Week	Farmers' assessment		Technician's assessment	
	Pest problem	Decision	Pest problem	Decision
3	• Stem borer moths, caterpillars, beetles in seedbed	Apply insecticide	No economic threshold reached	Do not apply insecticide
	• Yellowing of seedlings	Broadcast fertilizer	N deficiency	Agree with farmers
	• Seedbed wilting in spots	Broadcast granular insecticide	Overdosage of fertilizer	Do not apply insecticide
4	• No problems	Do not apply insecticide	None	Agree with farmers
5	• Worms eating leaves	Apply insecticide	RGS	Do not apply insecticides until one-third of leaves eaten
6	• RWM	No economic threshold reached	RWM	Agree with farmers
	• RGS	Apply insecticide	RGS	"
7	• RWM	No economic threshold surpassed	RWM	"
	• RGS	No economic threshold reached	RWM	"
8	• RWM	"	RWM	"
	• Stem borer deadhearts	"	Stem borer deadhearts	"
	• Leaf folder	"	Leaf folder	"
	• Stunted plant growth and bronzing	Apply insecticide and fertilizer	Zn deficiency	Spray or broadcast zinc sulfate
9	• Hoppers	Apply insecticide	WBPH	Do not apply insecticide until more than 20 hoppers/hill reached
	• RWM	No economic threshold reached	RWM	Agree with farmers
	• Stem borer deadhearts	"	Stem borer deadhearts	"
	• Leaf folder	"	Leaf folder	"
	• Stunted plant growth	Apply zinc sulfate	Zn deficiency	"
10	• Yellowing of leaves	Apply insecticide	Bacterial leaf streak	Do not apply insecticide
	• Hopper	"	WBPH	Do not apply insecticide
11	• Leaf folder	No economic threshold reached	Leaf folder	Agree with farmers
	• RCW	"	Leaf folder	Do not apply insecticide
	• Yellowing of leaves	Apply insecticide	Bacterial leaf streak	Do not apply insecticide
12	• Leaf folder	No economic threshold reached	Leaf folder	Agree with farmers
	• Bacterial leaf streak	Do not apply insecticide	Bacterial leaf streak	"
13	• Hoppers	No economic threshold reached	WBPH	"
14	• None	"	None	"
15	• Rat damage	Bait with warfarin	Minimal rat problem	Do not bait (too late in season)
16	• Leaf folder	Apply insecticide	Leaf folder	Do not apply insecticide until nine leaves damaged per hill reached
	• Hoppers	No economic threshold reached	WBPH	Agree with farmers
17	• Leaf folder	"	Leaf folder	"

Table 30. Effect of farmers' classes and weekly technician follow-up with farmer groups on insecticide usage.[a] Nueva Ecija, Philippines, 1981 DS.

Insecticide applications	Weekly follow-up sessions[b]		No follow-up sessions[c]	
	Class	No class	Class	No class
Total (no.)	2.4 a	4.0 b	6.7 c	7.1 c
Seedbed (no.)	0.8 a	1.5 b	3.1 c	3.2 c
Vegetative stage (no.)	1.2 a	1.7 a	2.9 b	2.9 b
Reproductive stage (no.)	0.4 a	0.6 a	1.0 a	1.0 a
Ripening stage (no.)	0.1 a	0.2 a	0.3 a	0.3 a
Recommended insecticides (no.)	1.6 a	1.5 a	3.5 b	3.7 b
Spray mixtures (no.)	0.5 a	1.3 a	1.9 a	0.4 a
Dosage/spray (kg ai/ha)	0.19 a	0.19 a	0.22 a	0.15 a

[a]10 farmers interviewed per village. Separation of means in a row by Duncan's multiple range test at the 5% level. [b]Marawa and Malabon Kaingin, Jaen. [c]Ibabaw Bana, Cabanatuan, and Rajal Sur, Santa Rosa.

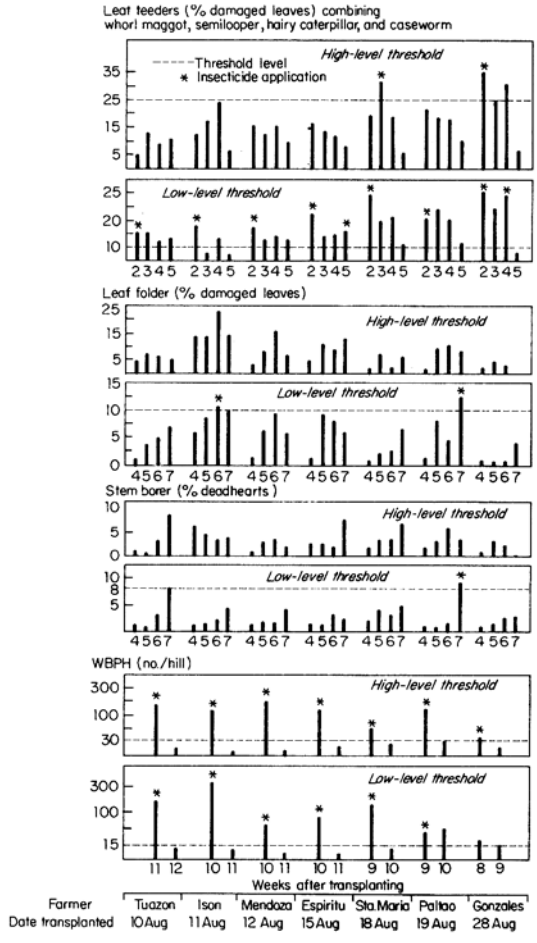
Nueva Ecija found that the farmers were having great difficulty grasping the technology because the economic threshold units (percentages and square meters) were incomprehensible to them. Changes are being made to simplify units within the experience of farmers but still produce reliable results.

The counting of vegetative stage leaf feeders was simplified with a combined damage count regardless of pest species. Percentages were replaced with sample sizes of 100 leaves or numbers of deadhearts in 10 hills. A total count of rice bugs in 10 hills replaced number per 5 m^2. Because the number of tillers per hill is highly variable, hopper counts are now based on numbers per tiller.

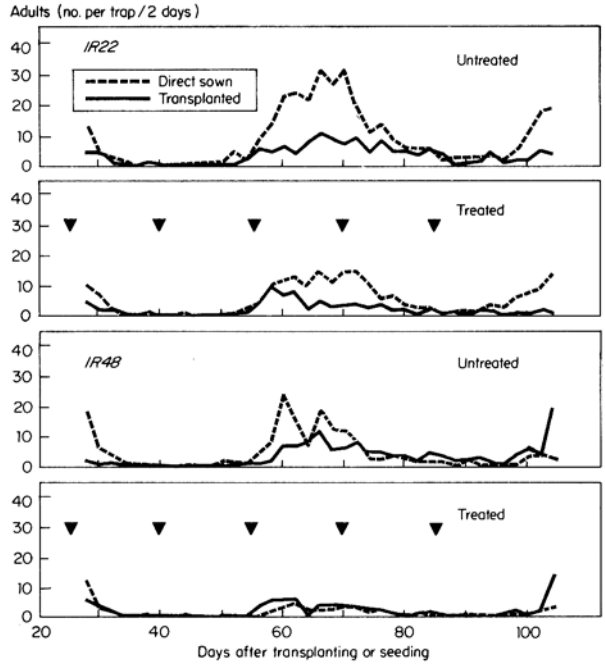
Development of integrated pest management technology. Economic thresholds need to be verified at each location. Low- and high-level thresholds were compared for each insect pest or pest group as separate treatments in the 1982 WS crop in Nueva Ecija replicated over seven farmers' fields. The low-level threshold treatment averaged 2.6 applications per field (Fig. 19) and produced a significant yield increase over the untreated control. But an average of 1.3 insecticide applications per field in the higher threshold treatment did not result in a significant yield gain.

WBPH populations surpassed the high- and low-level thresholds in six of seven fields. Vegetative-stage leaf feeders, mainly RWM and RGS, reached low-level thresholds. Leaf folder and stem borer reached the low-level thresholds in only one to two fields.

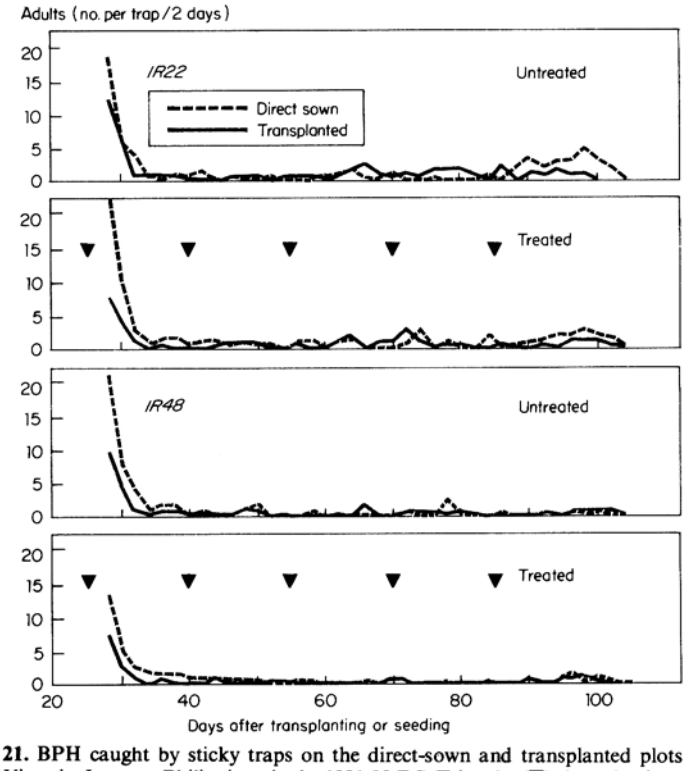
A yield loss of 0.93 t/ha was recorded in the untreated check of IR52, but because of unequal



19. Insect pest populations in the high and low economic threshold treatments showing the number and timing of insecticide applications by farmer replication when the threshold levels were reached. Nueva Ecija, Philippines, 1982 WS.



20. *Nephotettix* sp. caught by sticky traps on the direct-sown and transplanted plots at Victoria, Laguna, Philippines, in the 1981-82 DS. Triangles (▼) show the times of foliar spray applications.



21. BPH caught by sticky traps on the direct-sown and transplanted plots at Victoria, Laguna, Philippines, in the 1981-82 DS. Triangles (▼) show the times of foliar spray applications.

lodging and bacterial leaf streak, the growth stage(s) where the yield loss occurred could not be specified to determine the most important pest species. In future trials, IR42 will be used because of its higher disease resistance.

Yield losses between growth stages are partitioned to evaluate the benefit of each insecticide application in threshold treatments. This information is necessary for setting threshold values because both threshold treatments gave unfavorable economic returns. The low-dosage, complete-protection treatment (0.5 kg ai/ha) provided a level of control equal to that of the high-dosage treatment (0.75 kg.ai/ha). The low dosages are being used for economic threshold treatments to minimize costs.

INSECT POPULATIONS OF DIRECT-SEEDED AND TRANSPLANTED RICE

During the 1981-1982 DS, GLH (Fig. 20) and ZLH populations were higher in direct-seeded plots than in transplanted whereas both BPH (Fig. 21) and WBPH were almost the same in the two plots. Stem borer infestation was higher in direct-seeded than transplanted plots. During the 1982 WS, GLH, ZLH, BPH, WBPH, and RWM populations were low and there was no significant difference between direct-seeded and transplanted plots.

Control and management of rice pests

Weeds

Agronomy Department

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Research to identify herbicides that would complement other direct methods of control in rice continued at IRRI; at the Maligaya, Bicol, and Visayas research stations of the Philippine Bureau of Plant Industry (BPI); and in a farmer's field in Batangas Province. Screening trials and studies on the control of specific weeds and herbicide application and tillage techniques were conducted at IRRI.

Echinochloa crus-galli ssp. *hispidula, Echinochloa glabrescens, Monochoria vaginalis,* and *Cyperus difformis* were common at all wetland sites. *Echinochloa colona, Eleusine indica, Cyperus rotundus, Ipomoea triloba, Rottboellia exaltata, Calopogonium mucunoides,* and *Digitaria setigera* were dominant in the dryland fields.

Irrigated transplanted rice. *Preliminary screening.* All the herbicide-treated plots yielded significantly higher than the untreated check, but lower than the hand-weeded (Table 1). The oxyfluorfen and DPX 5384 treatments controlled weeds adequately, were safe on rice, and resulted in significantly higher yields than the thiobencarb - 2,4-D check.

Secondary screening. All the herbicide-treated plots yielded significantly higher than the untreated (Table 2). Because of intense weed pressure the untreated plots had no yield. Yields of all the treated plots, except that with the 7% formulation of chlornitrofen - 2,4-D, were similar to those of the hand-weeded, butachlor, and 2,4-D checks.

Advanced trials, IRRI and BPI. At IRRI, all the plots with herbicide treatments and the hand-weeded check gave comparable yields, which were significantly higher than that of the untreated check (Table 3). Yield with 2,4-D was significantly less than yields with the other herbicides, except pendimethalin. At Maligaya, yields did not vary significantly among the treatments. At Bicol, all the treatments gave significantly higher yield than the untreated control. Plots treated with oxyfluorfen, butachlor, pendimethalin, and 2,4-D yielded significantly less than the hand-weeded check.

In the WS, all the herbicide treatments at IRRI gave significantly higher yields than the untreated check, but markedly lower yields than the hand-weeded check (Table 4). At Maligaya, yields of all the herbicide-treated plots, except the 2,4-D plots, were comparable with the yield of the hand-weeded plots. Plots treated with piperophos - 2,4-D, pendimethalin and 2,4-D did not differ significantly in yield from the untreated check. At Bicol, all the herbicide treatments yielded significantly more than the untreated control, but some treatments yielded significantly less than the hand-weeded check. At Visayas, only the pendimethalin-treated plot yielded significantly higher than the untreated. However, among all the herbicides, only oxyfluorfen gave a yield significantly different from that of the hand-weeded check.

Herbicide combination. The effects of herbicides and herbicide combinations on weed control and rice yield were studied during the WS.

Table 1. Effect of herbicides on weed control, crop tolerance, and yield of irrigated transplanted IR42. IRRI, 1982 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Broadleaf Weeds	Grasses	Sedges		
Hand-weeded check	Twice	15 + 30	2 a	6 ab	52 bc	0	4.3 a
DPX 5384 G	0.2	8	0 a	0 a	13 a	0	3.3 b
DPX 5384 G	0.05	6	0 a	2 a	8 ab	0	3.2 b
DPX 5384 G	0.05	8	0 a	3 a	17 ab	0	3.2 b
Oxyfluorfen G	0.15	8	1 a	0 a	91 bc	0	2.4 c
M-8140 EC	2.0	8	0 a	6 ab	151 bc	1	2.0 cd
Butachlor EC	1.0	6	0 a	12 ab	98 bc	0	1.6 de
Thiobencarb – 2,4-D check	1.0 – 0.5	6	0 a	1 a	84 bc	0	1.2 e
Untreated check	–	–	4 a	21 b	153 c		0.2 f

[a] A spaced dash (–) means that two herbicides were formulated on the same carrier and applied as a single treatment. [b] Av of three replications. [c] Rated 2 wk after herbicide application on a scale of 0-10 (0 = no toxicity and 10 = complete kill).

Table 2. Effect of promising granular herbicides applied before weed emergence, 4 DT, on weed control and IR36 yield. IRRI, 1982 DS.

Treatment[a]	Rate (kg ai/ha)	Weed wt[b] (g/m^2)	Yield[b] (t/ha)
Butachlor check	1.0	1 a	5.3 a
Molinate – 2,4-D	2.1 – 0.45	18 bcd	4.9 ab
Hand-weeded check		33 cd	4.8 ab
2,4-D check	0.8	19 bcd	4.8 ab
Molinate – R-24216	2.0 – 1.0	6 b	4.7 abc
Chlornitrofen - 2,4-D (9%)	1.75 – 0.5	40 d	4.6 abc
EPTC – 2,4-D	1.8 – 0.45	16 bcd	4.3 abc
PPG 844	1.0	26 cd	4.1 bc
Chlornitrofen – 2,4-D (7%)	1.25 – 0.5	12 bc	3.5 c
Untreated check		659 e	0 d

[a]A spaced dash (–) means two herbicides were formulated on the same carrier and applied as a single treatment. Hand-weeded check = weeded 15 and 35 DT. [b]Av of three replications.

Except the dicamba and fluazifop - butyl plots, all the herbicide-treated plots yielded significantly higher than the untreated check (Table 5). The treatment butachlor followed by either dicamba or 2,4-D at 0.5 kg ai/ha provided reasonable weed control and the same yield as the hand-weeded checks. Similar weed control and grain yield were obtained from plots treated before weed emergence with 2,4-D at 0.8 kg ai/ha. Treatment with 2,4-D - fluazifop - butyl gave significantly lower yield than hand weeding.

Herbicide application with sprinkler bottle. During the DS, comparisons of the effects on weed control and grain of diluted and undiluted herbicide applied before and after transplanting were continued. The diluted herbicides were applied with a knapsack sprayer and the undiluted with a sprinkler bottle.

Regardless of the method and time of herbicide application, the yields of all the treated plots were significantly higher than the yield of the untreated control and comparable with that of the hand-weeded plot (Fig. 1). Yields of all the herbicide plots, except the butachlor plot, did not differ markedly between application methods (Table 6). Butachlor application at preplanting gave significantly more yield without dilution than with.

Results suggest that, diluted or not when applied, most herbicides would give the same control and grain yield increases.

Herbicide application at low spray volume. During the WS, experiments were conducted to compare the relative efficiencies of the micronherbi, an ultra-low-volume sprayer, and the knapsack sprayer. The micronherbi has a delivery rate of 15 liters/ha and the knapsack sprayer 300 liters/ha.

Regardless of the spray volume used, all the herbicides provided the same weed control as two hand weedings. Treated plots had only slightly higher yields than the untreated check.

Irrigated direct-seeded rice. *Preliminary screening.* The DPX 5384-treated plots showed adequate weed control and slight injury to rice, and yielded significantly higher than the untreated control (Table 7). Oxyfluorfen was moderately toxic to the crop.

Table 3. Effect of granular herbicides applied before weed emergence 4 DT on IR36 yield at three locations in the Philippines, 1982 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Bicol
Chlomethoxynil – 2,4-D IPE	2.1 – 0.75	4.5 a	5.2 a	6.4 ab
Hand-weeded check	–	4.1 abc	5.3 a	6.5 a
Naproanilide – thiobencarb	1.0 – 0.7	4.5 a	5.2 a	6.2 ab
Oxyfluorfen	0.15	4.3 ab	5.4 a	5.9 b
Piperophos – 2,4-D IPE	0.33 – 0.17	4.4 ab	4.9 a	6.0 ab
Bifenox – 2,4-D EE	2.0 – 0.66	4.4 ab	4.9 a	5.9 ab
Butachlor	1.0	4.6 a	4.7 a	5.2 c
Pendimethalin	0.75	3.5 bc	4.9 a	5.9 b
2,4-D	0.8	3.4 c	5.0 a	5.3 c
Untreated check	–	1.0 d	4.7 a	3.9 d

[a]A spaced dash (–) means that two herbicides were applied as a proprietary mixture. IPE = isopropyl ester. Hand-weeded check = weeded 15 and 35 DT. EE = ethyl ester. IPE = isopropyl ester. [b]Av of four replications/site.

Table 4. Effect of granular herbicides applied before weed emergence 4 DT on transplanted IR36 yield at four locations in the Philippines, 1982 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
Hand-weeded check	–	4.7 a	2.8 a	5.1 a	5.8 a
Bifenox – 2,4-D EE	2.0 – 0.66	3.6 b	2.7 ab	4.6 abc	4.9 abc
Butachlor	1.0	3.1 bc	2.5 ab	5.1 ab	4.7 abc
Naproanilide – thiobencarb	1.0 – 0.7	3.5 bc	2.7 ab	4.2 c	4.9 abc
Molinate – simetryn – MCPB	1.8 – 0.1 – 0.1	3.5 bc	2.5 ab	4.4 c	4.6 abc
Piperophos – 2,4-D IPE	0.33 – 0.17	3.2 bc	2.1 abc	5.0 ab	4.7 abc
Pendimethalin	0.75	2.7 bc	2.1 abc	4.6 abc	5.3 ab
2,4-D IPE	0.8	2.6 c	1.8 bc	4.5 bc	5.0 abc
Oxyfluorfen	0.15	3.5 bc	2.1 abc	4.3 c	4.0 bc
Untreated check	–	0.2 d	1.5 c	3.0 d	3.8 c

[a]Hand-weeded check = weeded 15 and 35 DT. A spaced dash (–) means two or more herbicides were applied as a proprietary mixture. EE = ethyl ester. IPE = isopropyl ester. [b]Av of four replications/site.

Table 5. Effect of different liquid herbicides and herbicide combinations on weed control and yield of irrigated transplanted IR42. IRRI, 1982 WS.

Treatment[a]	Application		Weed wt[b] (g/m^2) (at flowering stage of grasses)			Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DT)	Broadleaf weeds	Grasses	Sedges	
Hand-weeded check	Twice	15 + 30	2 ab	4 a	1 a	4.0 a
Butachlor fb dicamba	0.75 fb 0.5	5 fb 20	1 ab	1 a	13 a	3.8 ab
Butachlor fb 2,4-D	0.75 fb 0.5	5 fb 20	12 b	0 a	4 a	3.7 ab
Butachlor fb dicamba	0.75 fb 0.3	5 fb 20	0 a	0 a	2 a	3.4 abc
2,4-D	0.8	5	0 a	26 a	8 a	3.3 abc
Dicamba + 2,4-D	0.5 + 0.5	5	2 ab	31 a	6 a	2.8 abc
2,4-D – fluazifop – butyl	0.6 – 0.05	18	14 ab	17 a	10 a	2.6 bc
Dicamba	0.4	5	0 a	33 a	13 a	2.4 bcd
Fluazifop – butyl	0.05	18	2 ab	39 a	14 a	2.2 cd
Untreated check	–	–	8 b	96 a	3 a	1.1 d

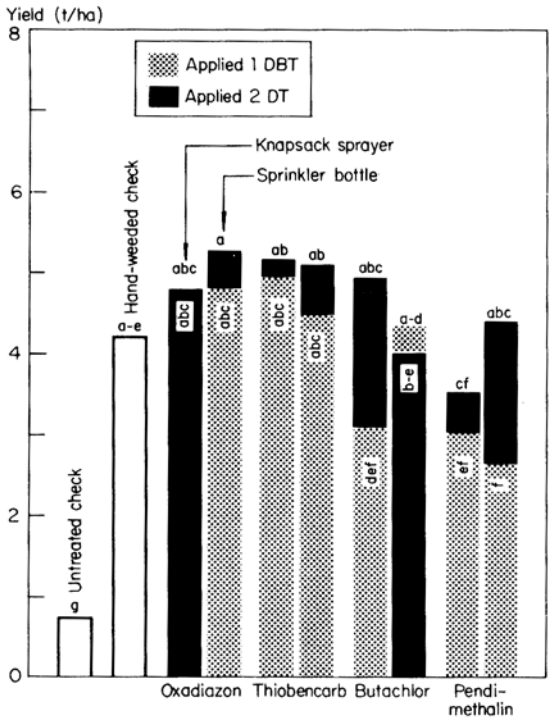
[a](+) means two herbicides were tank-mixed and applied as single treatment, a spaced dash (–) means that two herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of three replications.

Secondary screening. The molinate - R-24216, molinate - 2,4-D, and EPTC - 2,4-D treatments and the butachlor check gave similar yields (Table 8). All the other herbicide treatments did not differ in yield from the untreated control. EPTC - 2,4-D and chlornitrofen - 2,4-D were slightly to moderately toxic to rice.

Advanced trials, IRRI and BPI. All the herbicide treatments at IRRI (except the butachlor + 2,4-D and chlomethoxynil - 2,4-D plots) and Bicol yielded significantly higher than the untreated control (Table 9). At Maligaya, yields from the treated and the untreated plots did not differ significantly. Differences among some herbicide treatments at Maligaya and Bicol were significant.

In the WS at Maligaya and Bicol, all herbicide-treated plots yielded significantly more than the untreated check (Table 10). At Maligaya, herbicide treatments gave similar yields. At Bicol, plots treated with naproanilide - thiobencarb and thiobencarb - 2,4-D yielded significantly higher than plots treated with the other herbicides. At Visayas, yields of treated and untreated plots were similar.

Time and rate of herbicide application. During the WS, the effects of time and rate of application of bentazon, fluazifop - butyl, and propanil on weed control and phytotoxic reaction in IR36 were examined. Except in the fluazifop - butyl treat-



1. Yield as affected by time and method of herbicide application. IRRI, 1982 WS. Bars with a common letter are not significantly different at the 5% level by Duncan's multiple range test.

ment, two rates of each herbicide were used; these were split into applications at the 2- to 3-leaf and 5-to 7-leaf (pretillering) stages and the tillering stage.

All the herbicides provided better weed control when applied at the tillering stage than when applied at the pretillering stages (Table 11). Weed control by herbicide was comparable with weed control by hand weeding in the tillering-stage treatment, but was poorer in the pretillering treatment. The poorest weed control was obtained with fluazifop - butyl; the resulting yield was significantly lower than that from the hand-weeded plots. Regardless of the time and rate of herbicide application, tiller number did not generally differ between the herbicide-treated plots and the hand-weeded check.

Time of butachlor application and use of naphthalic anhydride. Pregerminated rice seeds are susceptible to injury by herbicides applied very soon after seeding. One way of protecting the seeds from herbicide damage is to coat them with safeners such as naphthalic anhydride (NA). During the 1981 WS, the effect of butachlor application time on weed control and on the rice seedlings with and without NA coating was studied in a field experiment. Pregerminated seeds of IR36 were coated with 0.5% NA (wt/wt) shortly before seeding.

Crop stand was related to time of butachlor application and use of NA. The stand was least when the herbicide was applied at 3 DAS and greatest when applied 10 DAS (Table 12). NA improved crop stand except when it was applied at 3 d before seeding (DBS) and at 10 DAS, in which cases differences in stand between NA-treated and untreated plots were not significant.

Weed weight was not affected by the NA treatment. Butachlor application at 3 DBS, at seeding, and at 3 DAS resulted in lower weed weights than application at 6 and 10 DAS. When

Table 6. Effect of method and time of application of four liquid herbicides on yield of irrigated transplanted IR36[a]. IRRI, 1982 DS.

Application method[b]	Herbicide[c]											
	Oxadiazon			Thiobencarb			Butachlor			Pendimethalin		
	Pre-planting	Post-planting	Dif-ference	Pre-planting	Post-planting	Dif-ference	Pre-planting	Post-planting	Dif-ference	Pre-planting	Post-planting	Dif-ference
Knapsack sprayer	4.9	4.8	0.1^{ns}	4.9	5.2	−0.3^{ns}	3.1	4.9	−1.8**	3.0	3.6	0.6^{ns}
Sprinkler bottle	4.8	5.3	−0.5^{ns}	4.4	5.1	−0.7^{ns}	4.3	4.0	0.3^{ns}	2.6	4.4	−1.8**
Difference	0.1^{ns}	−0.5^{ns}		0.5^{ns}	0.1^{ns}		−1.2*	0.9^{ns}		0.4^{ns}	−0.8^{ns}	

[a]Av of three replications. [b]Knapsack sprayer = diluted spray. Sprinkler bottle = sprayed without dilution. [c]Preplanting = 1 DBT. Postplanting = 2 DT.

Table 7. Effect of herbicide on weed control, crop tolerance and yield of irrigated wet-seeded IR42. IRRI, 1982 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		
DPX 5384 G	0.2	6	0 b	0 b	5 b	1	5.4 a
DPX 5384 G	0.05	6	0 b	0 b	4 b	0	5.0 ab
DPX 5384 G	0.2	8	0 b	0 b	2 b	1	4.8 ab
M-8140 EC	2.0	10	0 b	0 b	32 ab	1	4.0 ab
Thiobencarb – 2,4-D check	1.0-0.5	6	0 b	0 b	49 a	2	3.9 ab
Oxyfluorfen G	0.1	6	3 ab	0 b	41 a	4	3.8 abc
Oxyfluorfen G	0.15	8	5 a	1 b	32 ab	5	3.5 bc
Untreated check	–	–	17 a	11 a	36 a	0	2.2 c

[a]A spaced dash (–) means that two herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of three replications. [c]Rated 2 wk after herbicide application on a scale of 0-10 (0= no toxicity and 10 = complete kill).

Table 8. Effect of early postemergence (6 DAS) application of promising herbicides on weed control, crop tolerance, and yield of wet-seeded flooded IR36. IRRI, 1982 DS.

Treatment[a]	Rate (kg ai/ha)	Weed wt[b] (g/m²)	Visual toxicity rating[c]	Yield[b] (t/ha)
Molinate – R-24216	2.0 – 1.0	0 a	0	3.8 ab
EPTC – 2,4-D	1.8 – 0.45	29 ab	3	3.7 ab
Molinate – 2,4-D	2.1 – 0.45	12 ab	0	3.6 abc
Chlornitrofen – 2,4-D (7%)	1.25 – 0.5	130 ab	3	2.8 bcd
PPG 844	1.0	92 ab	0	2.4 cd
Chlornitrofen – 2,4-D (9%)	1.75 – 0.5	70 b	5	2.3 d
Butachlor check	1.0	0 a	0	4.2 a
Untreated check		130 ab	0	2.2 d

[a]A spaced dash (–) means two herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of three replications. [c]Rated, 1 wk after herbicide application, on a 0-10 scale (0 = no toxicity and 10 = complete kill).

Table 9. Effect of early postemergence (6 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at three locations in the Philippines, 1982 DS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		IRRI	Maligaya	Bicol
Naproanilide – thiobencarb	1.0 – 0.7	4.2 a	5.5 a	5.0 bc
Bifenox – 2,4-D EE	2.0 – 0.66	4.4 a	5.2 ab	4.8 c
Piperophos – 2,4-D IPE	0.33 – 0.17	4.0 a	5.6 a	4.2 d
Butachlor	1.0	4.4 a	4.0 bc	5.2 ab
Pendimethalin	0.75	3.8 a	4.3 abc	5.4 a
Thiobencarb – 2,4-D IPE	1.0 – 0.5	3.9 a	5.5 a	4.1 d
Oxyfluorfen	0.15	4.1 a	3.6 c	4.6 c
Butachlor + 2,4-D	0.75 + 0.5	3.4 ab	3.8 bc	3.4 e
Chlomethoxynil – 2,4-D IPE	2.1 – 0.75	3.1 ab	4.3 abc	2.7 f
Untreated check	–	2.3 b	4.4 abc	2.2 g

[a]A spaced dash (–) means that two herbicides were applied as a proprietary mixture. EE = ethyl ester. IPE = isopropyl ester. A plus (+) means the chemicals were applied separately at about the same time. [b]Av of four replications/site.

Table 10. Effect of early postemergence (6 DAS) application of granular herbicides on yield of direct-seeded, flooded IR36 at three locations in the Philippines, 1982 WS.

Treatment[a]	Rate (kg ai/ha)	Yield[b] (t/ha)		
		Maligaya	Bicol	Visayas
Naproanilide - thiobencarb	1.0 – 0.7	3.6 a	3.7 a	4.0 a
Butachlor + 2,4-D IPE	0.75 + 0.5	3.9 a	2.9 c	4.4 a
Piperophos – 2,4-D IPE	0.33 – 0.17	3.8 a	3.3 b	4.1 a
Butachlor	1.0	3.9 a	2.8 c	4.4 a
Thiobencarb –2,4-D IPE	1.0 – 0.5	3.4 a	3.7 a	4.0 a
Bifenox – 2,4-D EE	2.0 – 0.66	3.4 a	2.9 c	4.2 a
Oxyfluorfen	0.15	3.3 a	3.3 b	3.8 a
Pendimethalin	0.75	3.1 a	3.0 c	3.9 a
Untreated check	–	1.9 b	2.0 d	3.9 a
Molinate – simetryn – MCPB	1.8 - 0.1 - 0.1	3.6 a	0 e	3.6 a

[a]A spaced dash (–) means two or more herbicides were applied as a proprietary mixture. A plus (+) means the chemicals were applied separately at about the same time. IPE = isopropyl ester. EE - ethyl ester. [b]Av of four replications/site.

no NA was added, grain yield was lower in the plots treated with butachlor at 3 DAS than in those treated earlier or later. When the seeds were coated with NA, time of butachlor application did not affect yield (Table 12).

Effect of time of flooding on weed control and butachlor phytotoxicity. During the 1982 WS, a field experiment was conducted to evaluate the effect of butachlor application and time of flooding on weed control and on rice growth and yield.

Flooding time had no effect on yield. But plots flooded at planting time had reduced crop stand, plant height, tiller number, and high weed weight compared with plots flooded later (Table 13).

Butachlor application at 6 DAS reduced crop stand, plant height at 25 DE, tiller number, and yield. Weed weight and yield in the butachlor-treated plots were not different from those in the untreated plots (Table 14). The best results were from the hand-weeded plots.

Effect of antidote and depth of flooding on butachlor phytotoxicity. During the WS, the effect of depth of flooding and use of NA on butachlor phytotoxicity was studied in the greenhouse.

Without herbicide treatment, plant height was not affected by depth of flooding and NA use. However, plants protected with NA from phytotoxicity of butachlor applied at 6 DAS were significantly taller than the unprotected plants, regardless of the flooding depth. Plants were tallest when saturated and shortest when flooded to one-half of their height (Table 15).

Flooding depth had no effect on shoot dry weight. With butachlor application, NA-treated plants were significantly heavier than those without NA. However, without butachlor application, the NA-protected and the unprotected plants did not differ in shoot dry weight (Table 15).

Improving the selectivity of butachlor by use of safeners. A greenhouse experiment was conducted during the WS to find ways of protecting pregerminated rice from butachlor phytotoxicity using NA and activated charcoal.

Butachlor caused significant reduction in survival percentage, plant height, and shoot dry weight of the unprotected plants (Table 16). However, coating the seeds with NA before sowing significantly increased survival, plant height, and shoot weight more than did the other treatments. Coating the seeds with activated charcoal did not protect them from butachlor toxicity. Plant height and shoot dry weight in plots without herbicide treatment did not differ among the treatments.

Rainfed transplanted rice. *Preliminary screening.* All herbicide-treated plots yielded significantly higher than the untreated check and similarly to the hand-weeded check (Table 17). M-8140 and oxyfluorfen yielded significantly more than the thiobencarb - 2,4-D check.

Application of herbicides at low spray volume. Regardless of the spray volume, all the herbicide-treated plots showed reasonable weed control. Plots treated with oxadiazon at high volume and thiobencarb at low volume yielded significantly

Table 11. Effect of time of herbicide application on weed control and growth and yield of direct-seeded flooded IR36.[a] IRRI, 1982 WS.

Herbicide treatment[b]	Rate (kg ai/ha)	Weed wt[c] (g/m²)			Tiller[d] (no./m²)			Yield[d] (t/ha)		
		2- to 3- leaf stage	5- to 7- leaf stage	Tillering stage	2- to 3- leaf stage	5- to 7- leaf stage	Tillering stage	2- to 3- leaf stage	5- to 7- leaf stage	Tillering stage
Hand-weeded check	–	8 a	6 a	16 a	842 a	279 a	800 b	2.0 a	2.2 a	2.0 a
Propanil	3.0	131 b	37 b	21 a	938 a	804 a	937 ab	1.8 ab	1.7 a	1.7 a
Bentazon	2.0	38 b	37 b	29 a	837 a	871 a	683 b	1.5 ab	1.9 a	1.6 a
Bentazon	1.0	87 b	66 bc	39 a	775 a	804 a	700 b	1.5 ab	1.6 a	1.4 a
Propanil	1.5	78 b	50 b	41 a	732 a	805 a	1088 a	1.7 ab	1.6 a	1.2 a
Fluazifop - butyl	0.5	134 b	154 c	31 a	894 a	642 a	1150 a	1.0 b	0.2 b	0.8 a

[a]Av of three replications. [b]Hand-weeded check = weeded at 15, 30, and 45 DAS. [c]Sampled at 70 DAS. [d]Taken at 100 DAS.

Table 12. Effect of time of butachlor application on weed control, stand count, and yield of direct-seeded, flooded IR36 with and without NA protection.[a] IRRI, 1981 WS.

Time of application	Weed wt[b] (g/m²)	Stand count[c] (no./m²)			Yield (t/ha)		
		With NA	Without NA	Difference	With NA	Without NA	Difference
3 DBS	2 a	226 ab	169 b	56[ns]	3.4 a	4.3 a	–0.9[ns]
At seeding	5 a	202 ab	94 bc	108*	3.6 a	3.2 ab	0.4[ns]
3 DAS	7 a	192 b	46 c	146**	3.4 a	2.9 b	0.5[ns]
6 DAS	22 b	249 ab	181 b	68*	3.5 a	3.6 ab	0.1[ns]
10 DAS	39 b	355 a	291 a	64[ns]	3.4 a	3.5 ab	–0.1[ns]

[a]Av of four replications. [b]Av of two NA treatments. Sampled at 45 DAS. [c]At 14 DAS.

Table 13. Effect of time of flooding on grain yield and other characters of wet-seeded IR36.[a] IRRI, 1982 WS.

Character	Flooding time					
	Planting time	3 DAS	6 DAS	9 DAS	12 DAS	15 DAS
Stand count (no./m²)	159 b	193 ab	194 ab	225 ab	220 ab	243 a
Plant ht (cm) 25 DE	28 b	31 a	32 a	32 a	32 a	33 a
Plant ht (cm) 70 DE	76 b	77 b	79 ab	80 ab	81 ab	82 a
Tillers (no./m²)	390 b	527 a	500 a	554 a	521 a	567 a
Total weed wt (g/m²)	75 a	19 bc	33 bc	14 c	40 ab	24 bc
Yield (t/ha)	2.3 a	2.5 a	3.1 a	3.0 a	3.1 a	3.1 a

[a]Av of four replications and three weed control methods.

Table 14. Effect of weed control methods on yield and other characters of wet-seeded IR36.[a] IRRI, 1982 WS.

Weed control method	Stand count (no./m²)	Plant ht (cm)		Tillers (no./m²)	Total weed wt (g/m²)	Yield (t/ha)
		25 DAS	70 DAS			
Butachlor (1 kg ai/ha)	135 b	29 b	79 a	433 c	45 a	2.8 b
Two hand weedings	230 a	33 a	80 a	574 a	11 b	3.2 a
No weeding	252 a	32 a	79 a	522 b	46 a	2.6 b

[a]Av of four replications and six flooding times.

Table 15. Effect of depth of flooding and application of NA on plant height and shoot dry weight of wet-seeded IR36.[a] IRRI agronomy greenhouse, 1982.

Depth of flooding[b]	Plant ht (cm) 14 DAS			Shoot dry wt (g) 28 DAS		
	With NA	Without NA	Difference	With NA	Without NA	Difference
			Butachlor (1.0 kg ai/ha)			
Saturated	34 a	18 a	16**	2 a	1 a	1**
1/10 of plant ht	34 ab	16 a	17**	3 a	2 a	1**
1/5 of plant ht	32 ab	17 a	15**	3 a	2 a	1**
3/10 of plant ht	32 ab	13 ab	19**	2 a	1 a	1**
2/5 of plant ht	32 ab	11 b	21**	2 a	1 a	1**
1/2 of plant ht	28 b	10 b	19**	2 a	1 a	1**
			No herbicide			
Saturated	34 a	34 a	0ns	2 a	2 a	0ns
1/10 of plant ht	33 a	35 a	−2ns	2 a	2 a	0ns
1/5 of plant ht	32 a	35 a	−3ns	2 a	2 a	0ns
3/10 of plant ht	32 a	33 a	−1ns	2 a	2 a	0ns
2/5 of plant ht	33 a	35 a	−2ns	2 a	2 a	0ns
1/2 of plant ht	33 a	35 a	−2ns	2 a	2 a	0ns

[a]Av of six replications. [b]Based on the average plant ht 6 DAS and maintained throughout the experiment.

Table 16. Survival, plant height, and shoot dry weight of wet-seeded IR36 as affected by butachlor application and use of safener.[a] IRRI agronomy greenhouse, 1982.

Safener	Survival (%)			Plant ht (cm) at 35 DAS			Shoot dry wt (g)		
	Butachlor	No herbicide	Difference	Butachlor	No herbicide	Difference	Butachlor	No herbicide	Difference
Naphthalic anhydride	93 a	91 b	2ns	53 a	53 a	0ns	0.6 a	0.6 a	0.0ns
Activated charcoal	43 b	98 a	−55**	44 b	55 a	−11**	0.2 b	0.6 a	−0.4**
None	38 b	100 a	−62**	41 b	52 a	−11**	0.3 b	0.7 a	−0.4**

[a]Av of six replications.

higher than the untreated check (Table 18). Plots treated with butachlor and oxadiazon, regardless of the application method, had significantly fewer weeds than the untreated check.

Rainfed direct-seeded rice. *Preliminary screening*. Plots treated with the coded herbicides yielded significantly more than the untreated check (Table 19). Oxyfluorfen and M-8140 were initially moderately toxic to rice.

Dry-seeded rainfed bunded rice. *Preliminary screening*. Herbicide trials in dry-seeded bunded rice continued in the WS. *Melochia concatenata* was the dominant weed.

At 30 DE, most plots treated with propanil and

Table 17. Effect of herbicides on weed control, crop tolerance, and yield of rainfed transplanted IR42. IRRI, 1982 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		
M-8140 EC	2.0	17	2 a	41 a	0 a	1	4.4 a
Oxyfluorfen G	0.1	5	1 a	53 a	3 a	0	4.4 a
M-8140 EC	1.0	17	1 a	33 a	44 a	2	4.2 a
M-8140 EC	1.0	13	1 a	89 a	1 a	0	4.1 a
DPX 5384 G	0.05	5	0 a	58 a	186 a	1	3.9 ab
Hand-weeded check	Twice	15 + 30	0 a	63 a	187 a	0	3.8 ab
DPX 5384 G	0.05	5	0 a	35 a	4 a	0	3.6 ab
Thiobencarb – 2,4-D check	1.0 – 0.5	5	3 a	16 a	72 a	0	3.0 bc
Untreated check	–	–	1 a	50 a	4 a	0	2.3 c

[a]A spaced dash (–) means that two herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of three replications. [c]Rated at 2 wk after herbicide application on a scale of 0-10 (0 = no toxicity and 10 = complete kill).

Table 18. Effect of herbicide spray volume on weed control, crop tolerance, and yield of rainfed transplanted IR36.[a] IRRI, 1982 WS.

Treatment	Application[b]		Total weed		Visual toxicity rating[d]	Yield (t/ha)
	Method	Rate (kg ai/ha)	Time (DT)	Weight[c] (g/m²)		
Oxadiazon	KS	0.6	2	8 a	4	3.4 a
Thiobencarb	MH	1.5	2	33 ab	0	3.0 a
Hand-weeded check	–	Twice	15 & 30	12 ab	0	2.9 a
Oxadiazon	MH	0.6	2	8 a	3	2.7 ab
Butachlor	MH	1.0	2	3 a	0	2.5 ab
Butachlor	KS	1.0	2	4 a	0	2.5 ab
Thiobencarb	KS	1.5	2	26 ab	1	2.3 ab
Untreated check	–	–	–	113 b	0	1.7 b

[a]Av of three replications. [b]KS = knapsack sprayer. MH = micronherbi. [c]Sampled at 50 DT. [d]Rated at 10 DT on a scale of 0-10 (0 = no toxicity and 10 = complete kill).

Table 19. Effect of herbicides on weed control, crop tolerance, and yield of rainfed wet-seeded IR42. IRRI, 1982 WS.

Treatment[a]	Application		Weed weight[b] (g/m²)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Broadleaf weeds	Grasses	Sedges		
M-8140 EC	2.0	13	0 a	26 a	29 a	4	4.8 a
DPX 5384 G	0.5	5	1 a	23 a	15 a	0	4.7 a
M-8140 EC	2.0	17	0 a	5 a	0 a	1	4.5 a
Oxyfluorfen G	0.15	5	0 a	35 a	20 a	4	4.3 a
DPX 5384 G	0.2	5	0 a	10 a	1 a	1	4.0 a
M-8140 EC	1.0	17	0 a	8 a	0 a	1	3.4 a
Oxyfluorfen G	0.1	5	1 a	31 a	9 a	4	3.3 ab
Thiobencarb – 2,4-D check	1.0 – 0.5	5	0 a	33 a	21 a	2	3.2 ab
Untreated check	–	–	0 a	23 a	31 a	0	1.2 b

[a]A spaced dash (–) means that two herbicides were formulated on the same carrier and applied as a single treatment. [b]Av of three replications. [c]Rated at 2 wk after herbicide application on a 0-10 scale (0 = no toxicity and 10 = complete kill).

those with the herbicide combinations had significantly fewer weeds than the untreated plots (Table 20). Toward crop maturity, however, there was tremendous weed regrowth in the plots. At harvest, only the fluorodifen + propanil treatment provided weed control comparable with that of hand weeding. However, all the treated plots gave significantly higher yields than the untreated control, which yielded nothing. Butachlor and pendimethalin gave lower yields than the other herbicides because they did not control *M. concatenata*.

Advanced trials. Most herbicide treatments provided adequate weed control. Plots treated with thiobencarb, RH 8817, pendimethalin + propanil, and thiobencarb + propanil without a follow-up hand weeding yielded similarly to hand weeded plots and significantly higher than the untreated check (Table 21). Herbicide treatment with hand weeding increased grain yields only slightly over herbicide treatment alone. Propanil failed to control *M. concatenata* and *Chloris barbata*.

Herbicide application at low spray volume.

Table 20. Effect of promising herbicides on weed control and yield of dry-seeded bunded rice.[a] IRRI, 1982 WS.

Weed control method[b]	Application		Total weed wt (g/cm^2)		Yield (t/ha)
	Rate (kg ai/ha)	Time	30 DE	Harvest	
Propanil – thiobencarb	1.61 – 0.89	8 DE	8 b	178 bcd	2.6 a
Propanil – thiobencarb – fenoprop	1.96 – 1.09 – 0.45	8 DE	25 bc	139 abc	2.4 a
Three hand weedings	–	14, 28, 42 DE	2 a	95 a	2.4 a
Oxadiazon	0.5	PE	51 bcd	199 bcd	2.2 ab
Molinate + propanil	2.375 – 2.375	8 DE	28 b	292 bcd	2.0 ab
Propanil	2.0	8 DE	26 bc	386 bcd	2.0 ab
Fluorodifen + propanil	1.5 + 1.5	8 DE	31 bcd	143 ab	2.0 ab
Propanil + 2,4-D	1.5 fb 0.5	8 DE	21 bc	324 bcd	1.8 abc
Pendimethalin	1.5	PE	93 cde	256 bcd	1.1 bc
Butachlor	1.5	PE	177 e	583 d	0.5 cd
Untreated check	–	–	153 de	428 cd	0.0 e

[a] Av of three replications. [b] A spaced dash (–) means two herbicides were applied as a proprietary mixture. + = tank mixed.

Table 21. Effect of different herbicides on weed control and yield of dry-seeded bunded rice.[a] IRRI, 1982 WS.

Weed control method	Application		Total weed wt (g/m^2)	Yield (t/ha)	
	Rate (kg ai/ha)	Time		Unweeded	Weeded
Pendimethalin + propanil	1.5 + 1.5	8 DE	32 abc	2.6 ab	2.9 a
Thiobencarb	3.0	PE	4.6 abcd	2.2 ab	3.1 a
RH-8817	1.0	PE	13 ab	2.2 ab	3.0 a
Three hand weedings	–	14, 28, 42 DE	0 a	2.6 a	2.5 abc
Butachlor + propanil	1.5 + 1.5	8 DE	32 abc	1.7 abc	3.2 a
Thiobencarb + propanil	2.25 + 1.25	8 DE	23 ab	2.2 ab	2.6 abc
Butachlor	2.0	PE	71 bcde	1.8 abc	2.8 ab
Dicamba + butachlor + propanil	0.25 + 1.0 + 1.0	8 DE	48 abcd	1.2 bc	3.1 a
Dicamba + butachlor + propanil	0.25 + 1.505	8 DE	102 abcd	1.4 abc	2.8 ab
Dicamba + butachlor	0.25 + 1.5	8 DE	108 de	1.6 abc	2.6 abc
Oxadiazon + pendimethalin	0.25 + 1.5	PE	35 abc	1.3 bc	2.6 abc
Oxadiazon + pendimethalin	0.25 + 2.0	PE	23 abc	1.4 abc	2.3 abc
Oxadiazon	0.75	PE	199 de	0.8 c	2.3 abc
Pendimethalin fb 2,4-D	2.0 fb 0.5	PE fb 15 DE	216 de	1.1 bc	1.9 abc
Pendimethalin	2.0	PE	103 abcd	0.9 bc	1.7 bc
Propanil	3.0	8 DE	452 e	0.7 c	1.5 c
Untreated check	–	–	474 e	0.7 c	1.5 c

[a] Av of three replications.

Oxadiazon and thiobencarb applied with the micronherbi sprayer provided significantly better weed control than the untreated check (Table 22). Butachlor controlled weeds better when applied with the knapsack sprayer. However, only the oxadiazon-treated plots yielded significantly more than the untreated check.

Effect of land preparation and herbicide on weed control. Evaluation of land-preparation methods in dry-seeded bunded rice continued during the WS. On each land preparation, post-planting weed control treatments were superimposed.

The best weed control was with glyphosate in the untilled plots and the poorest in the stale seedbed. Inadequate rain for uniform weed germination before harrowing or herbicide application resulted in poor weed control with the stale seedbed method (Table 23). Consequently, the time required for weeding was high.

Increased weed infestation after the rice planting resulted in zero yields in the untreated plots of all land preparation methods. Application of butachlor + propanil significantly increased grain yield in the stale seedbed. Yields among the tillage treatments were generally similar in the hand-weeded plots (Table 23).

Dryland rice. *Advanced trials, IRRI and Batangas.* At IRRI, pendimethalin provided the best control of *R. exaltata*, the dominant weed. However, the highest yield was obtained with oxadiazon. It was comparable with yields from the other treatments except propanil and thiobencarb (Table 24).

In Batangas, all the herbicide treatments had significantly lower weed weights than the untreated

Table 22. Crop injury, total weed weight and yield of IR36 under dry-seeded bunded conditions as affected by volume of herbicide spray[a]. IRRI, 1982 WS.

Treatment	Application		Total weed wt[b] (g/m^2)	Visual toxicity rating[c]	Yield (t/ha)
	Method	Rate (kg ai/ha)			
Hand-weeded check	–	Twice	39 a	0	1.5 a
Oxadiazon	MH	0.6	74 ab	2	1.2 a
Oxadiazon	KS	0.6	113 bc	2	0.9 ab
Butachlor	MH	2.0	102 bc	1	0.5 bc
Butachlor	KS	2.0	74 ab	1	0.4 bc
Thiobencarb	KS	2.0	131 bc	0	0.3 bc
Thiobencarb	MH	2.0	76 ab	0	0.1 c
Untreated check	–	–	258 c	0	0.0 c

[a]Av of four replications. [b]Sampled at 50 DE. [c]Rated at 10 DE on a scale of 0-10 (0 = no toxicity, and 10 = complete kill).

Table 23. Effect of land preparation methods on weed control and yield of dry-seeded rainfed bunded rice[a]. IRRI, 1982 WS.

Land preparation method[b]	Weed count ($no./m^2$)	Weeding time	Yield (t/ha)		
			Untreated control	Butachlor + propanil (1.5 + 1.5) (kg ai/ha)	Hand-weeded check (14 fb 35 DE)
Stale seedbed fb 1 harrow	394 b	1116 b	0 a	2.6 a	3.8 a
Stale seedbed fb paraquat	376 b	844 ab	0 a	2.5 a	3.6 a
Zero tillage	148 a	859 a	0 a	0.9 b	3.3 a
Conventional tillage	216 ab	809 a	0 a	0.5 b	3.4 a
Minimum tillage	222 ab	802 a	0 a	0 b	2.1 b

[a]Av of three replications. [b]Paraquat was applied at 0.75 kg ai/ha. Glyphosate was used on the zero-tillage plots at 1.5 kg ai/ha. Conventional tillage = one plowing + three rotovations. Minimum tillage = one plowing + one rotovation.

Table 24. Effect of herbicides on weed control, crop tolerance, and yield of IR36 under dryland condition.[a] 1982 WS.

Treatment	Application[b]	IRRI[b]			Batangas		
	Rate (kg ai/ha)	Weed wt[c] (g/m^2)	Toxicity rating[d]	Yield (t/ha)	Weed wt[e] (g/m^2)	Toxicity rating[d]	Yield
Hand-weeded check	Twice	242 abc	0	1.2 a	108 a	0	1.5 a
Pendimethalin	2.0	123 ab	2	1.1 a	262 b	3	1.6 a
Dinitramine	1.5	132 ab	2	1.0 ab	166 ab	3	1.4 a
Butralin	2.0	220 abc	2	1.0 ab	248 b	3	1.2 a
Oxyfluorfen	0.5	286 abcd	4	0.9 abc	182 ab	4	1.1 ab
Oxadiazon	1.0	212 abc	3	1.2 a	262 b	4	0.6 bc
Butachlor	2.0	146 ab	2	1.0 ab	219 b	2	0.3 bc
Thiobencarb	3.0	314 bcd	2	0.5 c	273 b	3	0.6 bc
Propanil	2.0	393 cd	3	0.7 bc	237 b	3	0.3 c
Untreated check	—	707 d	0	0.0 d	508 c	0	0.1 c

[a]Av of four replications/site. [b]All plots, except the untreated check, were hand weeded at 35 DE because of heavy *Rottboellia exaltata* infestation. [c]Weeds were sampled at harvest. [d]All plots rated 10 DE except the propanil treatment, which was rated 6 DAT on a scale of 0-10 (0 = no toxicity and 10 = complete kill). [e]Weeds were sampled at 69 DE.

check. But only dinitramine and oxyfluorfen controlled weeds similarly to two hand weedings. Plots treated with pendimethalin, dinitramine, butralin, and oxyfluorfen yielded higher than the untreated control.

Oxadiazon and oxyfluorfen were moderately toxic at both sites.

Herbicide application at low spray volume. Regardless of the spray volume, butachlor and thiobencarb did not control *R. exaltata*. Oxadiazon provided slightly better weed control and gave significantly higher yields than either thiobencarb or butachlor. Application of oxadiazon with micronherbi further improved weed control by about 50% over knapsack spraying.

Preplanting control of weeds with chemicals. Three herbicide combinations were evaluated as substitutes for tillage and for the control of existing weeds. Postplanting weed control measures were overlaid on each tillage treatment.

Fast regrowth of *C. rotundus* was observed in all untilled plots, regardless of the herbicide. The relative dry weight of *C. rotundus* ranged from 72 to 86% of the weed flora (Table 25). Conventional tillage (one plowing + three rotovations) produced the lowest relative dry weight of *C. rotundus*. However, *I. triloba, C. mucunoides,* and *Paspalum* sp. became dominant after *C. rotundus* senesced at around 50 DE. As a result, the untreated, conventionally tilled plots yielded no grain. Regardless of the tillage treatment, yields of the hand-weeded plots were generally higher than those of the other weed control treatments (Table 26).

Selectivity of butachlor as influenced by seeding depth and seed coating. During the WS, the effect of seeding depth and coating of the rice seeds with NA and activated charcoal on butachlor toxicity was evaluated in a greenhouse trial. The mesocotyl length of IR36 was related to the seeding depth. Burying the seeds 2 cm deep resulted in shorter mesocotyl than planting them 4 cm deep. The protected and the unprotected seeds did not differ in mesocotyl length in any herbicide treatment. However, in the herbicide treatment, the mesocotyls of the NA-coated seeds were significantly longer than those without NA or those coated with activated charcoal. Activated charcoal as a safener was ineffective (Table 27).

Plant height at 13 DAS was not affected by seeding depth. However, NA-coated seeds produced taller plants than the unprotected seeds, except in the no-herbicide, 4-cm planting (Table 27).

PERENNIAL WEEDS AND THEIR CONTROL

Long-term effects of reduced tillage. The study on the effects of reduced tillage on weed shift and density in transplanted rice (TPR) continued on the 17th and 18th crops. IR34, IR40, and IR42 were planted in plots prepared by conventional tillage, minimum tillage, and zero tillage. Conventional tillage involved one plowing and two harrowings; minimum tillage involved one harrowing;

Table 25. Relative dry weights of some weed species 30 DE as affected by herbicides used as tillage substitutes. IRRI, 1982 WS.

Weed species[a]	Relative dry wt (%)			
	Conventional tillage (one plowing + three harrowings)	Zero tillage[b]		
		Glyphosate fb paraquat (1.5 fb 0.5)	Paraquat — ametryn fb paraquat (1.1 — 0.9 fb 0.5)	Paraquat — diquat fb paraquat (0.5 — 0.3 fb 0.5)
Cyperus rotundus	28	86	72	77
Ipomoea triloba	26	5	3	1
Calopogonium mucunoides	19	1	1	1
Paspalum sp.	14	0	0	0
Cynodon dactylon	0	4	8	15
Ageratum conyzoides	0	1	1	4
Digitaria setigera	4	2	1	0
Eleusine indica	3	0	1	1
Others	5 (15)	1 (9)	13 (13)	1 (15)
Total weed wt (g/m^2)	65	155	176	150

[a]The number of the other weed species in parentheses. [b]The herbicides were applied 10 DBS and 1 DBS. Values in parentheses are rates in kilograms of active ingredient per hectare. A spaced dash (—) means the herbicides were applied as a proprietary mixture.

Table 26. Yield as affected by tillage and weed control practices.[a] IRRI, 1982 WS.

Postplanting weed control	Application		Yield (t/ha)				
	Rate (kg ai/ha)	Time	With tillage treatment[b]				Mean
			CT	ZT_1	ZT_2	ZT_3	
Hand-weeded check	—	2 fb 5 WE	1.2 a	1.4 a	1.2 a	1.2 a	1.2 a
Butachlor fb 2,4-D	2.0 fb 0.5	PE fb 2 WE	1.1 a	1.2 a	1.0 a	0.9 a	1.1 a
Thiobencarb fb 2,4-D	3.0 fb 0.5	PE fb 2 WE	1.0 a	1.0 a	1.0 a	0.2 a	0.1 b
Untreated check	—	—	0 b	0.8 b	0.9 a	0.9 a	0.6 b
Mean			0.8 b	1.1 b	1.0 ab	1.0 ab	

[a]Av of three replications. [b]CT = conventional tillage. ZT (zero tillage)$_1$ = glyphosate fb paraquat. ZT_2 = paraquat-ametryn fb paraquat. ZT_3 = paraquat-diquat fb paraquat.

Table 27. Mesocotyl length and plant height of IR36 as affected by herbicide, depth of seeding, and use of safener.[a] Agronomy greenhouse, IRRI, 1982.

Safener	Mesocotyl length (mm) at seeding depth of			Plant ht (cm) at seeding depth of		
	2 cm	4 cm	Difference	2 cm	4 cm	Difference
No herbicide						
Naphthalic anhydride	5 a	15 b	−10**	24 a	23 a	1^{ns}
Activated charcoal	6 a	16 a	−10**	22 b	23 a	−1^{ns}
None	6 a	16 ab	−10**	22 b	24 a	−2^{ns}
Butachlor						
Naphthalic anhydride	6 a	13 a	−7**	13 a	12 a	1^{ns}
Activated charcoal	4 b	11 b	−7**	6 b	6 b	0^{ns}
None	3 b	11 b	−8**	6 b	6 b	0^{ns}

[a]Av of six replications.

zero tillage involved removing stubble of the previous crop and applying paraquat. The zero-tillage plots in the 17th crop were cultivated conventionally to check the buildup of *Paspalum paspalodes*.

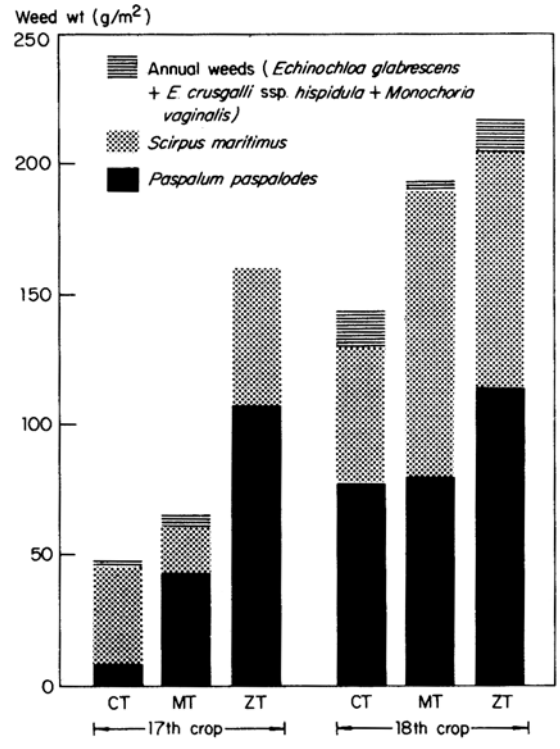
Annual weeds were *E. glabrescens, E. crus-galli* ssp. *hispidula,* and *M. vaginalis*; perennials were *P. paspalodes* and *Scirpus maritimus*.

In the 17th crop, *P. paspalodes* infestation was still high on the zero-tillage plots although they were cultivated (Fig. 2). Consequently, yields in the zero-tillage plots were significantly lower than those in the conventional tillage plots, regardless of variety (Table 28). Infestation of *S. maritimus* and the annual weeds did not vary with tillage intensity (Fig. 2).

In the 18th crop, total weed infestation also increased with decreasing tillage (Fig. 2). However, the differences were minor and did not cause significant variation in yield between tillage treatments in most varieties (Table 28).

Management and control of Scirpus maritimus. Field experiments begun in the 1974 DS were continued in 1982. During the DS, the herbicide-treated and rotary-weeded plots yielded similarly and statistically higher than the untreated check (Table 29). Because of the heavy population of *S. maritimus*, the untreated check yielded very low.

Where maize was intercropped with soybean, weeds did not greatly affect yields of either crop in the untreated check.



2. Weed dry weights at harvest as indices of weed control by conventional tillage (CT), minimum tillage (MT), and zero tillage (ZT). Av of three cultivars/tillage level per crop. IRRI, 1982.

Where maize was planted alone, the yield differences between treatments were not significant. Maize competed with weeds even in the untreated check.

Table 28. Effect of tillage treatments on weed control and yield of the 17th and 18th crops. IRRI, 1982 DS and WS.

Treatment	IR34				IR40				IR42			
	Weed wt[a] (g/m²)			Yield[b]	Weed wt[a] (g/m²)			Yield[b]	Weed wt[a] (g/m²)			Yield[b]
	Annual	Perennial	Total	(t/ha)	Annual	Perennial	Total	(t/ha)	Annual	Perennial	Total	(t/ha)
17th crop, 1982 DS												
Conventional tillage	1	40	41	2.3 a	4	27	31	1.5 a	1	70	71	2.9 a
Minimum tillage	1	58	59	2.3 a	9	58	67	1.3 ab	0	72	72	2.8 a
Zero tillage	0	212	212	1.6 b	0	145	145	0.8 b	0	124	124	2.0 b
18th crop, 1982 WS												
Conventional tillage	9	109	118	2.9 b	30	137	167	1.4 a	3	145	148	3.2 a
Minimum tillage	2	294	296	2.7 b	4	115	119	1.3 a	1	165	166	3.2 a
Zero tillage	21	222	243	3.4 a	10	152	162	1.0 a	3	240	243	2.7 a

[a]At rice harvest. Annuals were *Echinochloa glabrescens, Echinochloa crus-galli* ssp. *hispidula,* and *Monochoria vaginalis*; perennials were *Paspalum paspalodes* and *Scirpus maritimus.* [b]Av of four replications.

Table 29. Effect of weeding method and cropping pattern on crop yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1982 DS.

Cropping pattern and weeding treatment	Yield[a]/ha	Weeds (no./m²)				
		Grasses	Broadleaf weeds	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous TPR	Rice (t)					
Rotary weeding	5.2 a	142	2	24	58	0
Bentazon (2 kg ai/ha)	5.0 a	74	16	24	16	0
No weeding	0.6 b	98	0	2	244	0
Dryland crops – TPR	Maize + soybean (ears) (kg)					
Hand weeding	39 000 + 350 a	42	0	0	8	0
Butachlor (1.2 kg ai/ha) fb Bentazon (1.0 kg ai/ha)	32 000 + 310 a	312	0	0	0	0
No weeding	30 000 + 350 a	220	0	0	0	
Dryland crop – dry-seeded rainfed bunded rice						
Butachlor (1.2 kg ai/ha) fb Bentazon (1.0 kg ai/ha)	31 500 a	236	8	0	0	2
Hand weeding	33 000 a	64	18	0	0	0
No weeding	43 500 a	408	6	0	0	0

[a]Av of two replications.

Table 30. Effects of weeding method and cropping pattern on rice yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1982 WS.

Cropping pattern and weeding treatment	Yield[a] (t/ha)	Weeds (no./m²)				
		Grasses	Broadleaf weeds	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous TPR						
Rotary weeding	2.7 a	2	8	32	250	0
Bentazon (2 kg ai/ha)	2.4 a	24	40	30	78	0
No weeding	0.6 b	0	20	0	400	0
Dryland crops – TPR						
Rotary weeding	2.6 a	0	34	52	68	0
Bentazon (2 kg ai/ha)	2.2 a	0	164	146	72	0
No weeding	1.5 a	2	12	2	344	0
Dryland crop – dry-seeded, rainfed bunded rice						
Hand weeding	2.4 a	28	24	12	0	0
Butachlor (1.5 kg ai/ha)	1.9 ab	0	30	0	0	0
No weeding	0 b	0	101	0	0	0

[a]Av of two replications.

During the WS, in the continuous rice - continuous rice - TPR pattern, the herbicide-treated and rotary-weeded plots yielded similarly and statistically higher than the untreated check (Table 30). A heavy population of *S. maritimus* resulted in only 0.6 t/ha yield in the untreated check.

In the dryland crop - TPR pattern, the nonsignificant yield differences among treatments were probably due to fewer weeds in the untreated plot.

In the maize - dry-seeded rainfed bunded rice pattern, only the hand-weeded plots had statistically higher yields than the untreated check. Because of the buildup of the broadleaf *Macroptilium lathyroides*, the untreated control yielded nothing. Butachlor reduced grass and sedge populations, but not the broadleaf weeds. Conse-

quently, the plot with the butachlor treatment had a low yield statistically similar to that of the untreated check.

Control of perennial weeds with herbicides. During the 1982 WS, fluazifop - butyl, glyphosate, and paraquat, applied 8 d before and 8 d after a minimum soil cultivation in separate treatments, were compared with conventional tillage for the control of perennial weeds in TPR. Minimum tillage involved one plowing and one harrowing; conventional tillage one plowing and three harrowings. The perennial weeds were *P. paspalodes* and *S. maritimus*.

Perennial weed control was generally more effective and yields were higher where herbicide application preceded tillage (Table 31). For example, plots treated with fluazifop - butyl, glyphosate, and paraquat yielded significantly higher when the herbicides were applied before tillage than when they were applied after. The highest weed weight was in the plots where tillage was followed by paraquat but it was not significantly different from the weed weights in the other treatments.

Control of *S. maritimus* with herbicides. The control of *S. maritimus* with herbicides in direct-seeded flooded rice was studied at IRRI during the 1982 crop seasons.

In the DS, different rates of 2,4-D were applied alone and in sequential combination with bentazon and propanil at 15 and 25 DAS. Bentazon and propanil were also applied singly. The weed had 4-6 leaves at 15 DAS and 6-7 leaves at 25 DAS.

No grain was harvested in the untreated plot because of heavy *S. maritimus* infestation. All herbicide treatments, except bentazon, propanil, and 2,4-D at 0.75 kg/ha, applied at 15 DAS yielded significantly higher than the untreated check (Table 32). All treatments applied at 25 DAS, except 2,4-D at 0.5 kg/ha, had significantly less weed weight than the untreated control.

In the WS, single and tank-mixed applications of bentazon and 2,4-D were made at 15, 20, and 25 DAS, and tank mixtures of propanil and 2,4-D at 20 and 25 DAS. The weed had 5-6, 6-7, and 7-8 leaves at 15, 20, and 25 DAS. All the treated plots had significantly higher yields than the untreated control (Table 33). However, the weed weights of plots treated with 2,4-D at 0.75 kg ai/ha at 15 and 20 DAS, bentazon at 20 DAS, and bentazon + 2,4-D at 20 DAS, were not significantly different from weed weight in the untreated check. The lowest weed weights of 5, 6, and 7 g/m^2 were in plots treated with bentazon + 2,4-D, bentazon, and propanil + 2,4-D, respectively, all applied at 25 DAS.

Control of *Cyperus rotundus*. During the 1982 WS, preplant herbicides fluazifop - butyl, SC-0224, and glyphosate, applied before or after one rototillage, were evaluated and compared with conventional tillage for *C. rotundus* control in dryland rice. Conventional tillage was one plowing and three rotovations.

In general, glyphosate and SC-0224 were equally effective regardless of application time relative to tillage operation. However, glyphosate applied after, rather than before, tillage significantly

Table 31. Perennial weed control and yield of transplanted IR36 as affected by chemicals and reduced tillage.[a] IRRI, 1982 WS.

Treatment[b]	Weed wt[c] (g/m^2)		Total	Yield (t/ha)
	P. paspalodes	*S. maritimus*		
Fluazifop – butyl fb paraquat fb tillage	8 ab	24 a	32 a	4.0 a
Glyphosate fb tillage	18 ab	20 a	38 ab	3.8 a
Fluazifop – butyl fb tillage	13 ab	54 ab	67 ab	3.2 ab
Conventional tillage	10 ab	62 ab	72 ab	4.1 a
Tillage fb glyphosate	8 ab	89 ab	97 ab	2.5 bc
Paraquat fb tillage	9 ab	30 ab	39 ab	3.4 ab
Tillage fb paraquat	64 b	84 ab	148 b	1.5 cd
Tillage fb fluazifop-butyl	6 a	118 b	124 ab	0.8 d

[a]Av of three replications. [b]Butachlor was applied before weed emergence to control annual weeds. [c]Sampled at near senescence of *S. maritimus*.

Table 32. Effect of herbicides on the control of *Scirpus maritimus* and yield of direct-seeded flooded IR36[a]. IRRI, 1982 DS.

Treatment[b]	Application		*S. maritimus*[c]		Yield (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Count (no./m²)	Dry wt (g/m²)	
Bentazon	1.0	25	51 a	30 a	3.5 a
2,4-D	1.0	25	239 b	234 ab	2.4 ab
2,4-D	1.0	15	283 bc	266 abc	2.2 ab
2,4-D	0.75	25	246 bc	214 ab	1.9 abc
2,4-D	0.5	15	293 bc	371 bc	1.8 abc
2,4-D fb 2,4-D	0.5 fb 0.5	15 fb 25	279 bc	217 ab	1.7 abc
Propanil fb 2,4-D	2.0 fb 0.5	15 fb 25	257 bc	187 ab	1.7 abc
Bentazon	1.0	15	230 bc	143 ab	1.6 bcd
2,4-D	0.5	25	255 bc	348 bc	1.1 bcd
2,4-D	0.75	15	291 bc	260 abc	1.0 bcd
Propanil	3.0	15	478 bc	427 bc	0.4 cd
Untreated check	–	–	615 c	521 c	0 d

[a]Av of three replications. [b]Butachlor was applied before emergence to control annual weeds. [c]Sampled at near senescence.

Table 33. Effect of herbicides on the control of *Scirpus maritimus* and yield of direct-seeded flooded IR36[a]. IRRI, 1982, WS.

Treatment	Application		*S. maritimus*[b]		Yield (t/ha)
	Rate (kg ai/ha)	Time (DAS)	Count (no./m²)	Dry wt (g/m²)	
2,4-D	0.75	25	32 ab	20 ab	4.2 a
Propanil + 2,4-D	1.5 + 0.5	20	36 bc	16 ab	4.2 a
2,4-D	0.75	15	122 de	80 cd	4.1 a
Bentazon	1.0	15	74 cd	41 bc	3.9 a
Bentazon + 2,4-D	0.5 + 0.5	25	10 a	5 a	3.9 a
Bentazon	1.0	25	15 ab	6 a	3.8 a
Propanil + 2,4-D	1.5 + 0.5	25	14 ab	7 a	3.8 a
Bentazon	1.0	20	175 de	115 cd	3.7 a
Bentazon + 2,4-D	0.5 + 0.5	20	120 de	80 cd	3.6 a
Bentazon + 2,4-D	0.5 + 0.5	15	103 cd	68 c	3.5 a
2,4-D	0.75	20	145 de	95 cd	3.3 a
Untreated check	–	–	305 e	201 d	1.8 b

[a]Av of four replications. [b]Sampled at near senescence.

reduced *C. rotundus* density. Fluazifop - butyl was consistently ineffective against the weed.

The highest yield of 1.1 t/ha obtained with tillage followed by either SC-0224 or glyphosate was comparable with the yields of all the other treatments except tillage followed by fluazifop - butyl. The low yield with the latter treatment could be attributed to poor weed control and greater phytotoxicity, which resulted in crop stunting and reduced tillering.

Irrigation water management

Irrigation Water Management and Agricultural Economics Departments and Irrigation Water Management Committee

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AN EFFICIENT MODEL FOR LARGE PUMP SYSTEMS MANAGEMENT

Irrigation Water Management Department

Pump irrigation systems are costly to construct and operate. In many circumstances, however, no better alternative to pumping water for irrigation is available. With the cost of energy rising, pump irrigation can be economically attractive only if its operational efficiency is high.

In 1981, a study was begun in the Libmanan-Cabusao Pump Irrigation System (LCPIS) in Camarines Sur Province, Philippines, in collaboration with the National Irrigation Administration (NIA) and the Bicol River Basin Development Program (BRBDP). A major objective is to develop an efficient, practical, and implementable method for the water management in the LCPIS for two annual rice crops. The study results may be applicable to a number of other irrigation investments planned for the farmers of the Bicol River Basin.

LCPIS has four 91.4-cm propeller pumps that lift water from the Libmanan River. Water is diverted through a main canal and its laterals to a potentially irrigable 3,472-ha area. As in most other irrigation systems, LCPIS was designed to operate according to the so-called rotational method of water distribution. This method had various problems. For example, during the 1981 WS, the first season after construction, it was found that the different reaches of the laterals could not be supplied with adequate continuous flow because of excessive checking of the flow by head-end farmers, pumping schedule interruption due to electric outages, and use by some farmers of unauthorized cuts in the canal banks. As a result, the most distant farmers depended entirely on rainfall. Only about 1,668 ha, mostly located at the head reaches of the lateral canals, were irrigated and planted to rice during the 1981 WS.

To solve these problems, an alternative method of water allocation-distribution was designed and implemented starting the second season of operation (1982 DS). The revised method can be called "sectionwise rotation in laterals" and was aimed at:

- better equity in water distribution,
- greater efficiency in water utilization,
- acceptability by all farmers, and
- practicality in implementation.

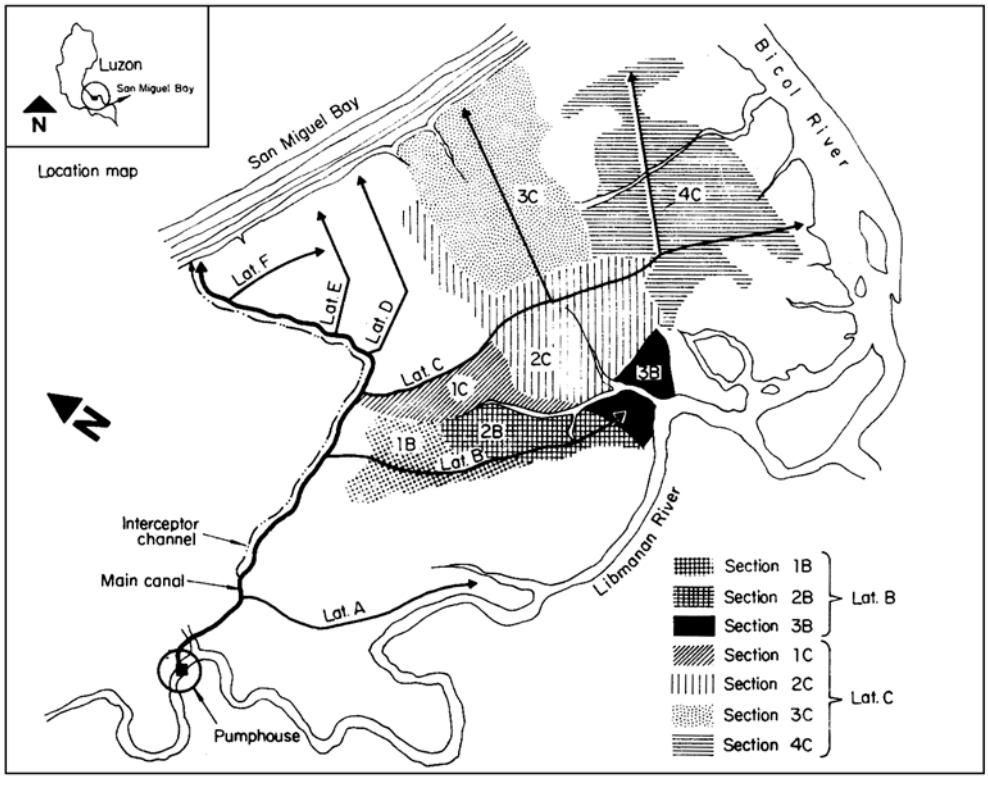
Distribution in laterals B and C, which together supply water to about 76% of the serviceable LCPIS area, would be made at weekly fixed periods for each delineated lateral section. Each lateral canal service area was divided into three or four sections depending on the location of appropriate control structures and the flow capacity of the lateral and its sublaterals. The physical layout is in Figure 1. The allocation and distribution schedules for the different sections are in Figure 2. Laterals A and D and the main canal tailend (MC tail), together servicing about 24% of the area, were irrigated with the conventional method.

System performance. *Area irrigated and water supply*. During the consecutive 1981 WS and 1982 DS and WS, 1,668, 1,634, and 2,032 ha were irrigated (Table 1). These areas correspond to 48%, 47%, and 58%, respectively, of the entire area. In lateral B, the area irrigated did not vary much from season to season. In lateral C, the area irrigated increased every season (Fig. 3); in lateral D and MC tail, it decreased during the 1982 DS and WS compared with the 1981 WS. The revised water allocation-distribution method was implemented only in laterals B and C starting in the 1982 DS.

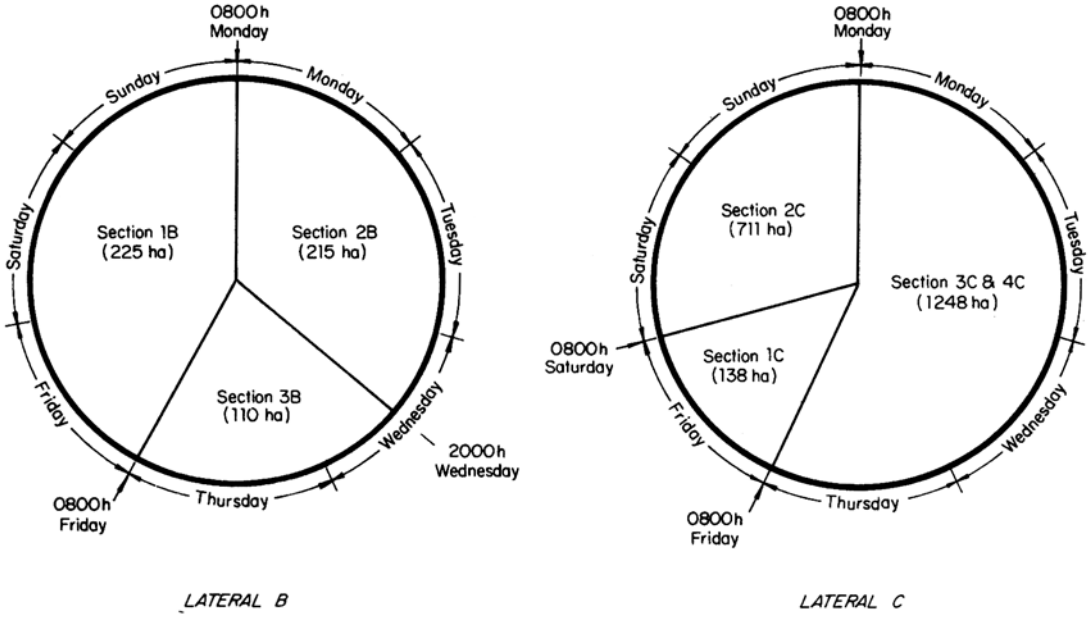
In the 1982 DS, the irrigation coverage in the system as a whole could be maintained at about the same level as in the 1981 WS despite a relative water supply (RWS) from pump and rainfall sources of only 1.1 in the 1982 DS compared with 1.35 in the 1981 WS (Fig. 4). In the 1982 WS, the irrigated area increased by 364 ha, or 22%, compared with the 1981 WS.

Ideally, the proportion of total flow received by each lateral should match the proportion of total area planted off of that lateral. In the 1981 and the 1982 WS, lateral B received less than its proportional share (Table 2). The percentage was very much lower during the 1982 WS because rainfall was frequent and abundant. Further, the number of operating pumps was reduced to two, one, or none and when only one pump ran, lateral B received no water because the bed level of the portable Parshall flume, which was installed below the headgate, was too high to allow water to pass through the flume. However, rainfall was abundant in the lateral B service area.

Lateral C received more than its proportional share of the flow during the 1981 WS but a lower



1. General layout of the LCPIS showing the different sections of laterals B and C. Philippines, 1982.



2. Schedule of irrigation water delivery by section of lateral canal. LCPIS, Philippines, 1982 DS.

Table 1. Irrigable and actually irrigated areas. LCPIS, Philippines, 1981 WS, 1982 DS and WS.

Lateral, section	Irrigable[a]	Benchmark 1981 WS	Post implementation	
			1982 DS	1982 WS
A	91.0 (2.6)	7.7	40.1	46.6
B	550.0 (15.8)	416.3	420.2	435.1
1B	225.0	189.4	172.7	173.0
2B	215.0	153.6	179.3	180.8
3B	110.0	73.3	68.2	81.3
C	2097.0 (60.4)	678.4	811.5	1049.5
1C	138.0	118.5	61.5	126.8
2C	711.0	381.5	378.6	494.5
3C	643.0	101.3	156.6	170.2
4C	605.0	77.3	214.8	258.0
D&MC Tail	686.0 (19.8)	536.4	321.1	468.3
MCSP-3[b]	48.0 (1.4)	29.1	41.2	32.8
Total	3472.0 (100)	1667.9	1634.1	2032.3

[a]The figures in parentheses are the percentages of command area under the lateral. [b]A compact farm supplied directly from the main canal between laterals B and C.

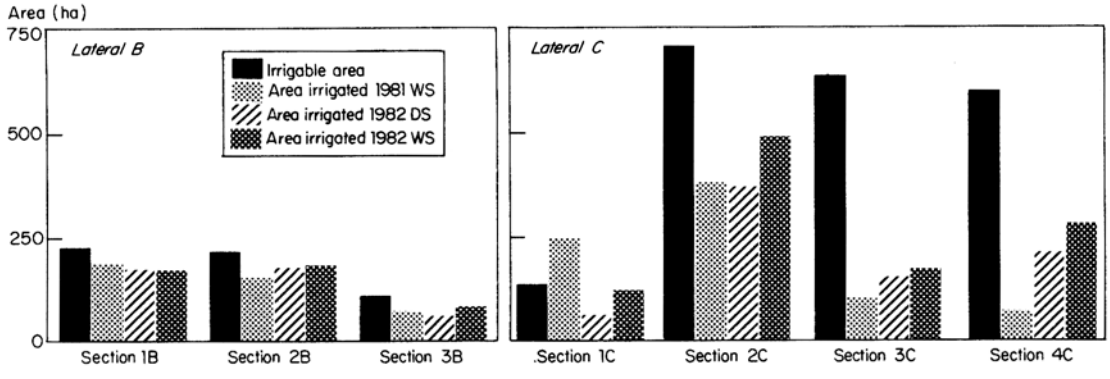
flow during the 1982 DS. Lateral D and the MC tail had a lower flow during the first WS and a higher flow in the succeeding seasons.

In the last two seasons, lateral D and the MC tail received higher flow rates per hectare than either lateral B or C. Water was used less efficiently in lateral D and MC tail compared with laterals B and C.

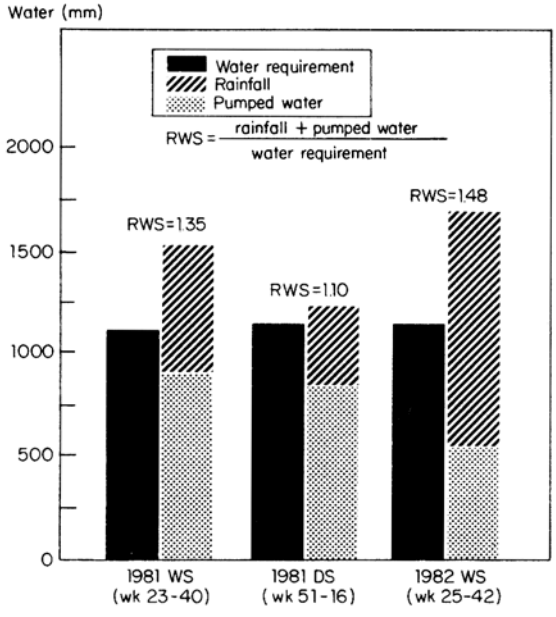
The largest amount of water (925 mm) was pumped during the 1981 WS; the lowest (527 mm) during the 1982 WS (Fig. 4). The amount of water pumped depended greatly on rainfall. However, pumping was also interrupted because of power failure, mechanical breakdown, and limited canal capacities. Figure 5 shows the contribution of these factors to usage. In 1982 WS, almost all of the unused available time was due to rainfall, showing that sound decisions were made to take full advantage of rainfall.

Water distribution equity. Different sections of the area being irrigated by laterals B and C are being compared to assess the possible improvement in water distribution equity due to the revised method.

There were no substantial differences among the seasons in the area planted in the three sections of



3. Irrigable areas and actually irrigated areas of the different sections in laterals B and C. LCPIS, Philippines, 1981 WS and 1982 DS and WS.



4. Water requirement, water use, and RWS. LCPIS, Philippines, 1981 WS and 1982 DS and WS.

lateral B (Table 1, Fig. 3). The middle section had an increase of 26 ha during the 1982 DS; during the succeeding seasons, the area planted remained steady.

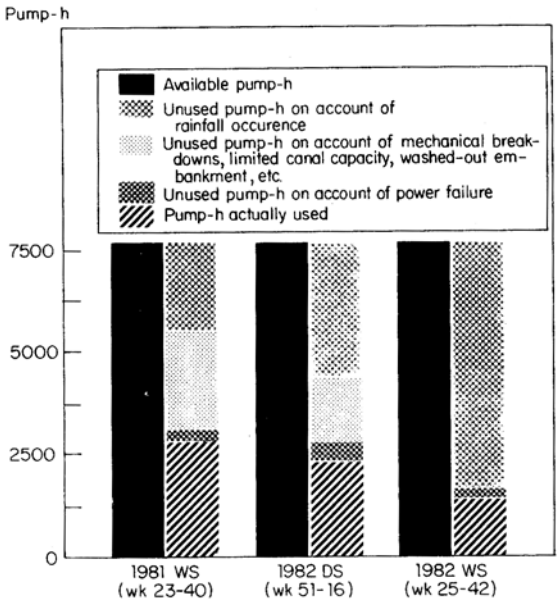
In lateral C, a major improvement in water distribution took place during the 1982 DS, the first season for the revised method. The area irrigated increased 191 ha in sections 3C and 4C (the last two sections). In the first section, area irrigated decreased by 57 ha during the 1982 DS. Most of these high-elevation farms got water only by unauthorized checking of the canal during the previous season. The revised method did not provide much opportunity for unscheduled checking, which was to benefit many farms in the last two sections. During the 1982 WS, the area irrigated increased in all sections of lateral C as more rainfall occurred.

To further evaluate the distribution equity within a lateral, the Distribution Equity Index (DEI) was introduced. DEI is defined as the degree of success

Table 2. Area planted and distribution of irrigation water flows by laterals and weekly rainfall amounts. LCPIS, Philippines, 1981 WS, 1982 DS and WS.

Parameter	Lateral	Benchmark 1981 WS	1982 DS	1982 WS
% of total area planted[a]	B	25.5	27.1	22.3
	C	41.6	57.2	53.7
	D&MC-tail	32.9	20.7	24.0
	All	100.0	100.0	100.0
Av flow rate (liters/s)	B	463.4	599.6	115.61
	C	1168.5	1056.5	525.4
	D&MC-tail	633.5	586.1	322.3
	All	2265.4	2242.4	963.3
% of total flow	B	20.4	26.8	12.0
	C	51.6	47.1	54.5
	D&MC-tail	22.8	26.1	33.5
	All	94.8	100.0	100.0
Av flow rate per unit area (liters/s per ha)	B	1.11	1.43	0.26
	C	1.72	1.30	0.50
	D&MC-tail	1.18	1.83	0.69
	All	1.39	1.44	0.47
Av weekly rainfall (mm)	B			
	C	33.3	25.9	64.3
	D&MC-tail			
	All			
Period considered (week no.)	B			
	C			
	D&MC-tail	23-40	51-16	25-42
	All			

[a] Includes area planted in laterals B, C, and D&MC tail only.



5. Number of available and actually used pump-hours. LCPIS, Philippines, 1981 WS and 1982 DS and WS.

achieved in irrigating the different sections of a canal with respect to the areas targeted for irrigation in those sections and measured by the equation:

$$DEI = 1.0 - \sum_{i=1}^{n} /X_i - Y_i/ \div 100$$

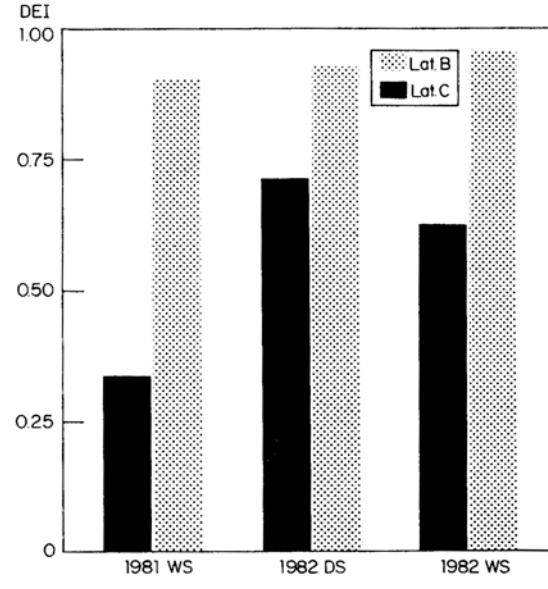
where: X_i is the percentage of total area targeted for irrigation in the ith section of the canal, Y_i is the percent of total irrigated area in the ith section, and n is the number of sections. The absolute values of $(X_i - Y_i)$ were used for summation in the equation because a deviation to the positive or negative would mean a divergence from the ideal.

There was a significant increase in DEI in lateral C during the first season (1982 DS) of implementation of the revised model. Its value remained more or less the same during the succeeding season (Fig. 6). In lateral B, the DEI was already high at the benchmark time and it remained slightly higher during the succeeding seasons when the revised model was used.

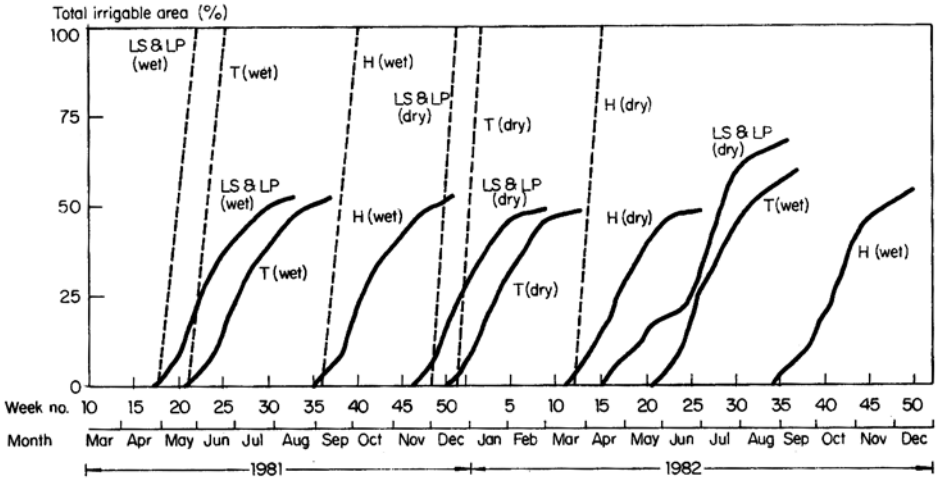
Cropping schedule. The farmers' cropping schedule is particularly important for a pump irrigation system. For example, when transplanting is extended over a long period during a season, pumping costs go up to meet the water needs of the late-transplanted areas. This also upsets the system's operational plan by hampering the repair and maintenance schedule for the canals, other structures, and equipment.

For all seasons, it took about 19 wk to complete rice transplanting. This compares very unfavorably with the 3-4 wk originally planned during the system's first operation in the 1981 WS (Fig. 7). A survey was conducted for the 1982 WS to determine the specific reasons why some farmers transplanted very late and others early. One hundred and two farmers were categorized as early, middle, and late on the basis of their transplanting dates. Eighty-five percent of the early transplanters said they wanted to avoid typhoon and flood damage, which usually hit the late-transplanted areas. To achieve early transplanting, most farmers gave land-preparation priority to plots with sufficient water. Late transplanters cited lack of water and capital as the major reasons for failing to transplant early. In the flood-prone areas, too much water in the beginning of the season was a major cause of delayed transplanting.

Rice production and water productivity. Average yield was highest (3.63 t/ha) in the 1982 DS. The lowest yield (2.74 t/ha) in the 1982 WS (Table 3) can be attributed to two typhoons in July and



6. Water DEI values for laterals B and C. LCPIS, Philippines, 1981 WS and 1982 DS and WS.



7. Farming activities calendar, actual (—) and planned (---). LCPIS, Philippines, 1981 WS and 1982 DS and WS. LS = land soaking; LP = land preparation; T = transplanting; H = harvesting.

Table 3. Seasonal yields and water productivities. LCPIS, Philippines, 1981 WS, and 1982 DS and WS.

	Benchmark 1981 WS	Post implementation	
		1982 DS	1982 WS
Av yield (t/ha)	3.26	3.22	2.74[a]
Area planted (ha)	1667.90	1634.10	2032.30
Total production (t)	5437.00	5915.00	5568.00
Water productivity (kg/ha per mm pumped water)	3.47	4.47	5.59
Water productivity (kg/ha per mm pumped water + rainfall)	2.09	2.84	1.64

[a]The low yield in the 1982 WS was due mainly to two typhoons in July and September.

September; the second one badly damaged many fields ready for harvest.

The water productivity, defined as the grain yield per unit area for each unit of water used and based on pumped water plus rainfall, was higher in the 1982 DS than in the 1981 and 1982 WS (Table 3) because the average yield in the DS was higher. When only pumped water productivity is considered, the 1982 WS has the highest value because, although the yield was lower, much less pumping was done because of high rainfall (Fig. 4).

Related training. In the 1982 DS, two training programs for farmers and water tenders were conducted:

- On-farm water management and leadership training of farmers and farmer leaders. The objective was to improve understanding of water management principles and techniques and to identify the causes of conflicts in water sharing and problems of the system's operation. The program was conducted in three sessions, each for 3 d in February and March. More than 140 officers of the farmers' service cooperative, farmer (compact farm) leaders, and selected farmer members participated.
- Seminar-workshop on water management for the water tenders, watermasters, and potential farmer leaders. The objective of this 3-d activity was to familiarize the 27 participants with water management principles and techniques, water flow measurement, monitoring of farming activities, billing and irrigation-fee collection procedures and strategies, and leadership.

ECONOMIC ANALYSIS OF FARMERS IN THE LIBMANAN-CABUSAO PUMP IRRIGATION SYSTEM

Agricultural Economics and Irrigation Water Management Departments

The LCPIS is an example of a large pump system with an irrigable area of about 3,470 ha. However,

the high investment, operation, and maintenance costs may make the system economically infeasible. This point is critical to financiers and beneficiaries. So, an economic analysis was included as a major component of the joint IRRI-NIA study. The main objective is to evaluate the economic efficiency of LCPIS from both the farmers' and the system's sides.

To generate the necessary cost-and-return information, a farm management survey has been conducted each cropping season since crop year 1979-80, a year before system operation began. About 120 farmers selected from the potential service area of the system are being interviewed on production, labor inputs, fertilizers, chemicals, and other costs of farm production.

Two crop years' data have been collected and analyzed. Data related to crop year 1979-80 represent the before situation, and data for crop year 1981-82 represent the after situation. The difference between the two situations will be the basis for estimating system benefits.

Farmers' socioeconomic characteristics. The socioeconomic characteristics of the sample farmers before and after the system establishment displayed changes in area planted and yield per hectare (Table 4). Area planted increased from 22% to 78% in the DS and from 64 to 72% in the WS. Yield increased from 1.9 t/ha in WS, when a majority of the farms are rainfed, to 2.5 t/ha in WS with irrigation. For the DS, yield increased from 1.8 to 2.9 t/ha.

Costs and returns per hectare. To quantify the farmer benefits from the system, the gross margin from rice production for the before and after situations was estimated (Table 5). To eliminate inflation biases, all costs and returns were expressed in 1981-82 constant prices. The prevailing prices for rough rice in 1981-82, $0.13/kg for WS and $0.14 for DS, were used in both situations. Similarly, costs of major inputs such as fertilizer and chemicals were expressed in the 1981-82 prices.

The total value of ouput per hectare was computed by multiplying the unit price of rough rice by the yield per hectare. Variable costs consist of the cost of fertilizers, herbicides, insecticides, hired labor, imputed family labor, seeds, and other costs of production.

Table 4. Socioeconomic characteristics of farmers in LCPIS, Camarines Sur, Philippines, crop years 1979-80 and 1981-82.

	WS		DS	
	Before LCPIS	After LCPIS	Before LCPIS	After LCPIS
Sample (no.)	114	111	114	131
Av farm size (ha)	2.0	1.5	2.0	1.5
Av area planted to rice (ha)	1.5	1.3	1.4	1.3
Area planted (%)	64	72	22	78
Mean rice yield (t/ha)	1.9	2.5	1.8	2.9
Tenure status (%)				
Owner-operators	16	18	16	16
Leaseholder or CLT	57	48	57	50
Share tenant	24	31	24	32
Mixed (others)	3	3	3	2
Mean age of farmers (yr)	49	47	48	48
Mean family size (persons)	6	6	6	6

The total gross margin per hectare per year before the LCPIS was begun was $220.50. After the introduction of irrigation, it rose to $367.20/ha, reflecting an increase of $146.70/ha. The increase is higher in the DS than in the WS because irrigation water availability is more critical in the DS. A detailed analysis of the data also showed no significant change in input use; it could be assumed that this increment in gross margin is attributable to the increase in yield per hectare and the increase in cropping intensity to the introduction of irrigation water and the provision of flood control and drainage facilities.

COMPARISON OF THREE MODELS OF IRRIGATION MANAGEMENT INTENSITY

Irrigation Water Management Department

A collaborative study of the NIA and IRRI is comparing three intensities of irrigation system management in the Upper Pampanga River Integrated Irrigation System (UPRIIS) of Central Luzon, Philippines.

The three models of irrigation management intensity are applied in three major components of the UPRIIS (Fig. 8). The intensive model is applied in the Lower Talavera River Irrigation System (LTRIS) with water measurement and control occurring at the turnout level to areas ranging from 20 to 50 ha. The intermediate model is used in the Pampanga River Irrigation System (PRIS) with

Table 5. Comparative gross margin per hectare in LCPIS, Camarines Sur, Philippines, crop years 1979-80 and 1981-82.

	Before LCPIS	After LCPIS	Difference
WS			
Total value of output ($/ha)	284.7	374.0	89.3
Total variable cost ($/ha)	178.4	229.6	51.2
Gross margin ($/ha)	106.3	144.4	38.1
DS			
Total value of output ($/ha)	282.0	474.7	192.7
Total variable cost ($/ha)	167.8	251.9	84.1
Gross margin ($/ha)	114.2	222.8	108.6
Total gross margin per crop year ($/ha)	220.50	367.20	146.7

measurement and control done at the section level for areas averaging 500-600 ha. The extensive model is implemented in District I and comprises four subsystems. Two of the subsystems, the San Agustin Extension and the Talavera River Irrigation System-upper portion, are run-of-the-river types served only by available river flows. The other two, the Talavera River Irrigation System and the Santo Domingo area-lower portion, are reservoir supported. In the extensive model, the measurement and control of water are focused at the head gates of laterals that serve from 300 to 2,500 ha each.

The major focus of the three treatments is on equity in access to, and receipt of, water by farmers. All treatments attempt to deliver the amount of water the farmers need. This amount is calculated as the sum of estimated evapotranspiration (ET) plus seepage and percolation (S&P) and is referred to as the target discharge requirement (TDR) for that area. The available water supply (AWS) is the sum of rainfall (R) and irrigation (I). Available water supply as a multiple of the target discharge is the relative water supply (RWS) expressed as:

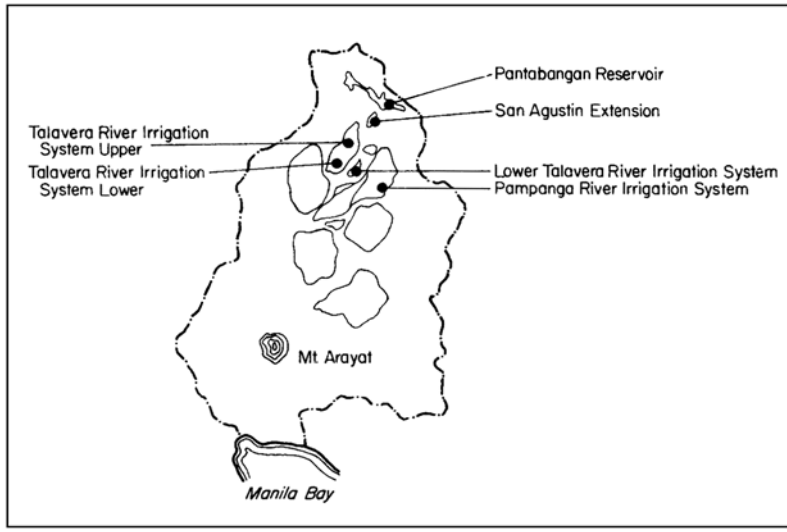
$$\text{RWS} = \text{AWS}/\text{TDR}$$

The relative equity of water supply for head (h), middle (m), and tail (t) sections is simply the ratio of the relative water supplies RWS_h:RWS_m:RWS_t. The water utilization efficiency (WUE) is the ratio of water use or water requirement to the water supply as:

$$\text{WUE} = \text{TDR}/\text{AWS} \times 100\%$$

Efficiency and production are the additional focus of the system management.

Intensive model of management. *Equity and efficiency.* The intensive model of irrigation system management has been implemented since the 1977 WS. In the sixth year of implementation, the DS equity of RWS experienced by the head, middle, and tail portions of the system were in the ratio 1.85:1.22:1.02 (Table 6). The head had essentially



8. UPRIIS layout showing the areas under the three models of irrigation system management, Philippines, 1982.

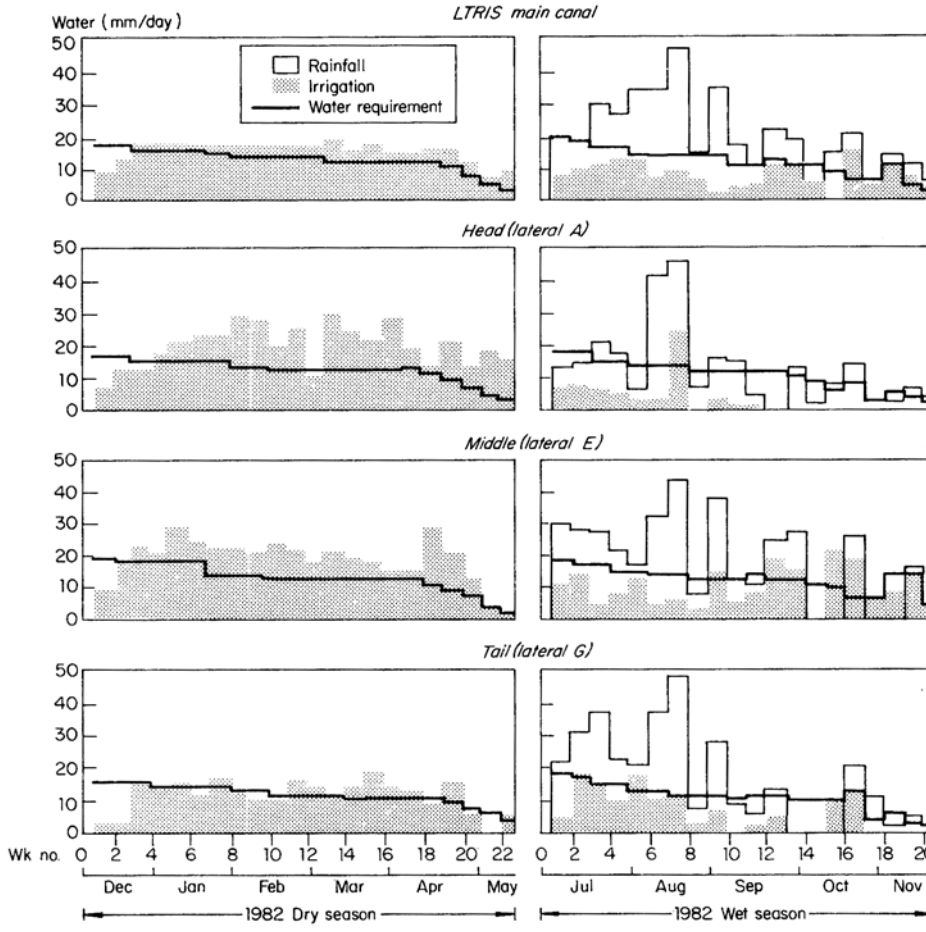
Table 6. Weekly mean of WUE and RWS for main canal, laterals A (head), E (middle), and G (tail). LTRIS, District II-UPRIIS-NIA, Talavera, Nueva Ecija, Philippines, 1982 DS and WS.

Irrigation week	Main canal		Lateral A (head)		Lateral E (middle)		Lateral G (tail)	
	WUE (%)	RWS	WUE (%)	RWS	WUE (%)	RWS	WUE (%)	RWS
				DS				
1	100	0.48	100	0.39	100	0.37	100	0.08
2	100	0.66	100	0.81	100	0.52	100	0.06
3	88	1.14	88	1.14	100	0.95	100	0.85
4	66	1.52	75	1.34	85	1.17	100	0.91
5	81	1.23	62	1.62	62	1.62	100	0.81
6	88	1.14	61	1.65	100	0.96	81	1.24
7	86	1.16	44	2.25	89	1.12	100	0.99
8	80	1.25	44	2.30	77	1.29	100	0.81
9	76	1.32	61	1.64	80	1.25	100	0.86
10	74	1.36	44	2.27	76	1.31	75	1.34
11	72	1.39	100	0.86	74	1.36	71	1.41
12	70	1.42	36	2.75	73	1.37	100	1.00
13	100	0.67	47	2.14	85	1.18	76	1.31
14	69	1.44	54	1.85	68	1.46	55	1.83
15	71	1.41	41	2.45	73	1.37	75	1.34
16	81	1.23	65	1.55	67	1.49	90	1.11
17	100	0.78	94	1.06	100	0.89	100	0.67
18	72	1.39	39	2.56	97	1.03	60	1.67
19	59	1.68	54	1.86	49	2.03	100	0.73
20	75	1.34	22	4.58	61	1.65	70	1.43
Mean	80.4	1.20	61.55	1.85	80.8	1.22	87.65	1.02
				WS				
1	83	1.20	100	0.74	59	1.69	74	1.35
2	68	1.46	100	0.93	60	1.66	48	2.07
3	55	1.83	72	1.39	59	1.69	38	2.63
4	55	1.81	72	1.38	67	1.49	58	1.72
5	35	2.85	100	0.60	76	1.31	59	1.70
6	48	2.09	34	2.91	38	2.61	32	3.15
7	29	3.40	29	3.42	28	3.61	23	4.35
8	96	1.04	100	0.64	100	0.69	100	0.75
9	73	1.37	73	1.36	31	3.27	37	2.72
10	98	1.02	78	1.28	94	1.06	–	–
11	100	0.87	100	0.41	100	0.96	100	0.50
12	55	1.8	77	1.29	44	2.28	76	1.31
13	56	1.79	29	3.45	–	–	–	–
14	100	0.71	–	–	–	–	–	–
15	54	1.86	59	1.70	46	2.15	81	1.23
16	29	3.40	25	3.98	27	3.69	27	3.69
17	66	1.50	100	0.35	100	0.93	35	2.89
18	80	1.24	100	0.55	100	0.54	100	0.24
19	19	5.16	17	5.96	19	5.37	39	2.57
Mean	63.10	1.92	70.28	1.79	61.64	2.05	57.94	2.05

83% more water than the tail. The tail had just enough for the season as a whole with RWS just 2% above the requirements. The tail portion lacked water (RWS < 1.00) in 10 of 20 wk during the DS. This contributed substantially to yield loss caused by moisture stress.

Figure 9 indicates the target discharge requirement for the year in the entire system and the three monitored sections at the head, middle, and tail of the system. The DS has virtually no rainfall to interfere with irrigation schedules. WUE for the 1982 DS was 80%, the highest observed in the period of implementation. The previous high WUE values were 73% in 1979 and 75% in 1981 compared with the preproject value of 51% observed by the NIA operations staff.

In the WS, the middle and tail sections had a high RWS at 2.05. The high RWS frequency



9. Average daily water requirement, actual irrigation flow, and rainfall (mm/day) for main canal, lateral A (head), lateral E (middle) and lateral G (tail) by weekly intervals. LTRIS, District II-UPRIIS, NIA, 1982 DS and WS.

(>2.0) indicates that substantial portions of water could be saved with careful rainfall monitoring and rapid irrigation suspension. This was observed especially in weeks 1 through 9 and 12 through 13 when significant irrigation releases were made while rainfall was high and generally greater in total depth than the irrigation depth (Fig. 9). Weeks 9 and 10 are examples of properly applied suspension with excessive rainfall and minimal irrigation. Irrigation releases in weeks 12 and 13 were wasted because rainfall was essentially equal to the TDR. With the Pantabangan reservoir levels steadily declining with increased power demands for the Luzon Grid, WS irrigation deliveries from storage must be reduced and local flows in the Talavera River tapped to the maximum extent possible to save water.

In the 1982 WS, the intensive management WUEs averaged 63%, comparable to 65% in 1981 and 70% in 1979.

Status of farming activities. The speed of rice farming activities is determined by the NIA's efficiency of water delivery and the farmers' rate of response in terms of farming activities. In the DS, 50% of the area was soaked in 3 wk and 100% in 7 wk (Table 7). The tail section serving laterals G, H, and I of LTRIS was the most rapid, as observed in previous years. Fifty percent of the land preparation was achieved within 5 wk and 100% within 10 wk. Fifty percent of the transplanting was achieved in 7.8 wk and 100% in 14 wk, indicating a high degree of asynchrony in the season (Fig. 10).

Table 7. The duration of the different farming activities for the system, LTRIS, District II-UPRIIS-NIA, Talavera, Nueva Ecija, Philippines, 1982 DS and WS.

Farming activity	Duration (wk)			
	System	Lateral A (head)	Lateral E (middle)	Lateral G, H, I (tail)
		DS		
Land soaking				
50% area soaked	3	2	5	2.2
100% area soaked	7	7	7	6
Plowing and harrowing				
50% area plowed and harrowed	5	5	5.5	5.5
100% area plowed and harrowed	10	9	8	9
Transplanting				
50% area transplanted	7.8	8	9	8
100% area transplanted	14	14	14	13
		WS		
Land soaking[a]				
50% area soaked				
100% area soaked				
Plowing and harrowing				
50% area plowed and harrowed	2	1.5	2	2
100% area plowed and harrowed	8	8	8	7
Transplanting				
50% area transplanted	5	4.5	5	6
100% area transplanted	11	11	11	9

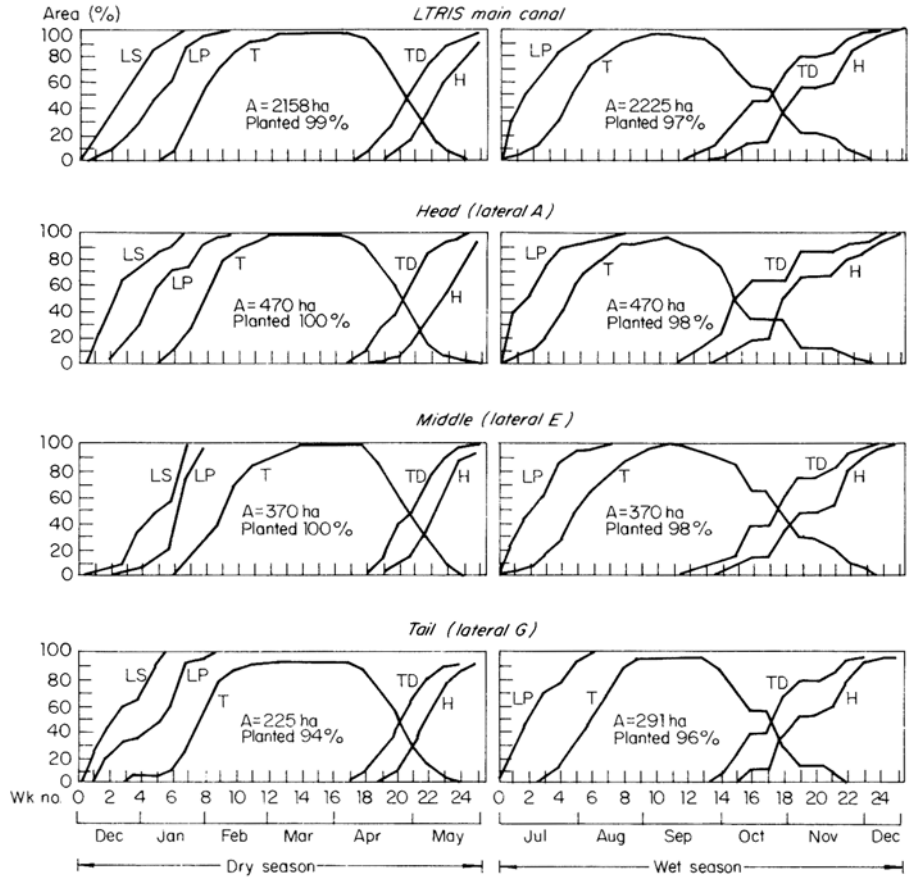
[a] 100% of the area was soaked by using rainfall before the start of the water delivery.

In the system as a whole, transplanting occurred over 11 wk, despite a rigid plan of cropping activity developed by the provincial agricultural coordinating council. This incongruency indicates that farmers' wishes, schedules, and practices are not reflected in NIA's program of work approved by the high-level coordinating council.

In the 1982 WS, fortuitous rains accompanying early-season typhoons in Central Luzon allowed essentially all land soaking to be accomplished without irrigation releases. Fifty percent and 100% of the land preparation were completed in 2 and 8 wk, respectively. Fifty percent and 100% of the transplanting were completed within 5 and 11 wk (Table 7). The tail section was completely planted earliest, by 9 wk after the first water release at the end of August (Fig. 10). Planting of all other portions was delayed until mid-September. This delayed-planting behavior of farmers indicates the need to reexamine the arbitrary determination of irrigation release dates in the current management practice. Substantial amounts of irrigation water could be saved in the reservoir for DS use if the WS releases were closely managed and first water releases were delayed to fit the farmers' cropping calendar.

Rice yields. LTRIS yields averaged 4.0 t/ha in the DS and 3.5 t/ha in the WS. The middle and tail lateral areas had significantly greater yields than the headend areas in the DS and WS. Tail lateral G area historically has had the highest DS yields. In the DS, significant water shortage occurred because of the inequitable water distribution. Peak DS yield for the tail area was achieved in 1980 (5.1 t/ha) and the WS peak in 1977 (4.7 t/ha). This is clearly a case of the trade-off between WUE and yield, such that 80% efficiency can not be considered a viable target because of negative effects on yield.

Intermediate model of management. The intermediate model has reduced intervention of research personnel assigned to communication, measure-



10. Percentage of area land soaked (LS), land prepared (LP), transplanted (T), terminally drained (TD), and harvested (H) for LTRIS main canal, laterals A (head), E (middle), and G, H, and I (tail), by weekly intervals. LTRIS, District II-UPRIIS, NIA, Philippines 1982 DS and WS.

ment, control, monitoring, and evaluation. Measurement and control are done at the section boundary, each section averaging 200 to 600 ha and representing the area serviced by an assistant water management technician (AWMT). The PRIS system has been monitored since the 1979 WS through the 1982 DS to provide 3 yr of benchmark information (Annual report for 1981)

Equity and efficiency. Water distribution equity for the 1982 DS is shown by the RWS ratios (Table 8). The PRIS system, as a whole, had a RWS equal to 1.56, meaning that the system had 56% excess above the crop ET plus land S&P water requirements. The tail portion (lateral F) had the least water along the lines of the traditional maldistribution. The RWS at the tail was less than 1.0 in 11 of 23 wk in the DS compared with 0 wk at the middle and 10 wk at the head (Fig. 11). This water shortage was sufficient to reduce rice yields.

The WUE was 64% for the PRIS system, 70% for lateral C-1, 60% for lateral C, and 87% for lateral F.

In the WS, the system, as a whole, experienced a RWS of 1.82. Water was concentrated in lateral C at the middle portion of the system where the RWS was 2.08; water was in lowest supply in lateral C-1, where the RWS was 1.35. In the WS, the RWS exceeded 2.0 in 5 wk, indicating substantial opportunities for water savings in the Pantabangan reservoir with the implementation of water conservation techniques.

Status of farming activities. The duration of land soaking during the DS in the PRIS system was

Table 8. Weekly mean WUE and RWS for PRIS, District II, UPRIIS, Nueva Ecija, Philippines, 1982 DS.

Irrigation week	PRIS system		Lateral C-1 (head)		Lateral C (middle)		Lateral F (tail)	
	WUE (%)	RWS	WUE (%)	RWS	WUE (%)	RWS	WUE (%)	RWS
1	56	1.8	100	0.7	71	1.4	50	2.0
2	56	1.8	100	0.7	67	1.5	56	1.8
3	63	1.6	100	0.7	63	1.6	53	1.9
4	63	1.6	100	0.7	63	1.6	100	0.7
5	63	1.6	100	0.7	63	1.6	100	0.8
6	71	1.4	100	0.7	71	1.4	100	0.8
7	83	1.2	100	0.9	67	1.5	100	0.6
8	67	1.5	100	0.9	63	1.6	100	0.9
9	71	1.4	100	0.9	63	1.6	100	0.9
10	56	1.8	100	1.0	63	1.6	100	0.8
11	56	1.8	100	0.9	63	1.6	100	0.9
12	59	1.7	71	1.4	50	2.0	100	0.8
13	59	1.7	67	1.5	53	1.9	100	0.9
14	59	1.7	77	1.3	56	1.8	100	0.9
15	63	1.5	67	1.5	59	1.7	100	1.0
16	63	1.5	67	1.5	63	1.6	91	1.1
17	71	1.4	67	1.5	63	1.6	100	1.0
18	83	1.2	63	1.6	63	1.6	83	1.2
19	71	1.4	63	1.6	59	1.7	83	1.2
20	59	1.7	53	1.9	56	1.8	83	1.2
21	56	1.8	50	2.0	63	1.6	83	1.2
22	50	2.0	48	2.1	50	2.0	77	1.3
23	45	2.2	45	2.2	50	2.0	26	3.8
Mean	64	1.56	70	1.43	60	1.67	87	1.15

8 wk; it was shortest in lateral C (6 wk). Land preparation was completed after 10 wk and transplanting after 17 wk. Transplanting was completed earliest, in only 13 wk, at tail lateral F.

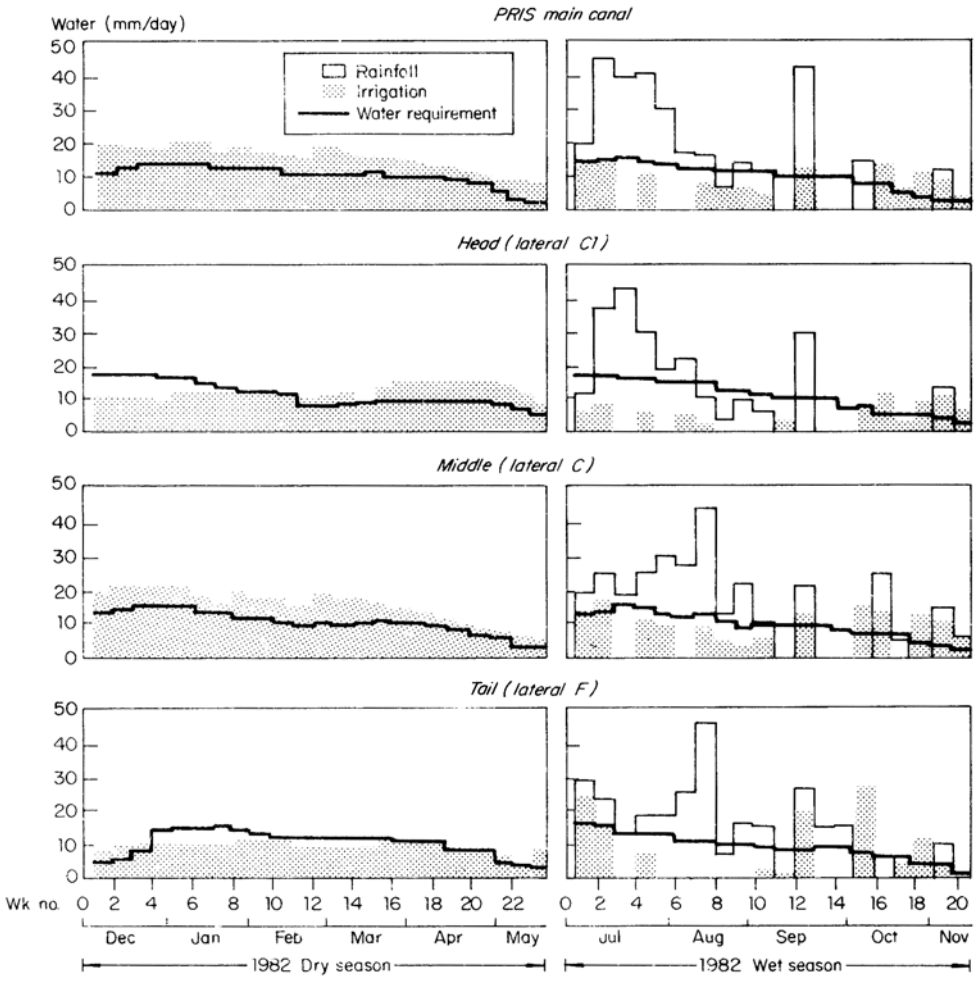
In the WS, land soaking was not necessary in lateral F at the tail, but required 5.5 wk for the system. Land preparation was completed after 13.5 wk and transplanting only after 14 wk. Again, in the tail lateral F land preparation was completed earliest, in 10 wk; transplanting was completed in 11 wk. Because the area of the PRIS system is more than five times larger than that of LTRIS, the asynchrony has become pronounced and duration of specific farming activities has lengthened.

The plotted farming DS activities (Fig. 12) were delayed because target discharges were greater than actual releases (Fig. 11) particularly in lateral C-1 in the first 8 wk of the season and in lateral F in weeks 4 through 8. These instances correspond to the very flat transplanting curve for lateral C-1 and the horizontal portions of the land soaking, land preparation, and transplanting curves in Figure 12. This late delivery of water represents the system responsibility for delayed farming activity.

Crop yields. In the 1982 DS, yields in the PRIS system averaged 4.1 t/ha. They were highest at the head lateral C-1 (4.6 t/ha) and gradually declined at middle lateral C (4.0 t/ha) and tail lateral F (3.7 t/ha). The RWS inequity from head to tail is considered responsible for the yield decline as the distance from the source increased. In the WS, the average crop-cut yield was 3.9 t/ha. Yields in laterals C-1 and F averaged 3.8 t/ha; lateral C had the highest yield (4.2 t/ha). Seven weeks of water shortage probably caused the lower WS yields in lateral C-1's area (Fig. 11).

Extensive model of management. *Equity and efficiency.* The extensive model was implemented in the 1982 WS after one season of benchmark information collection.

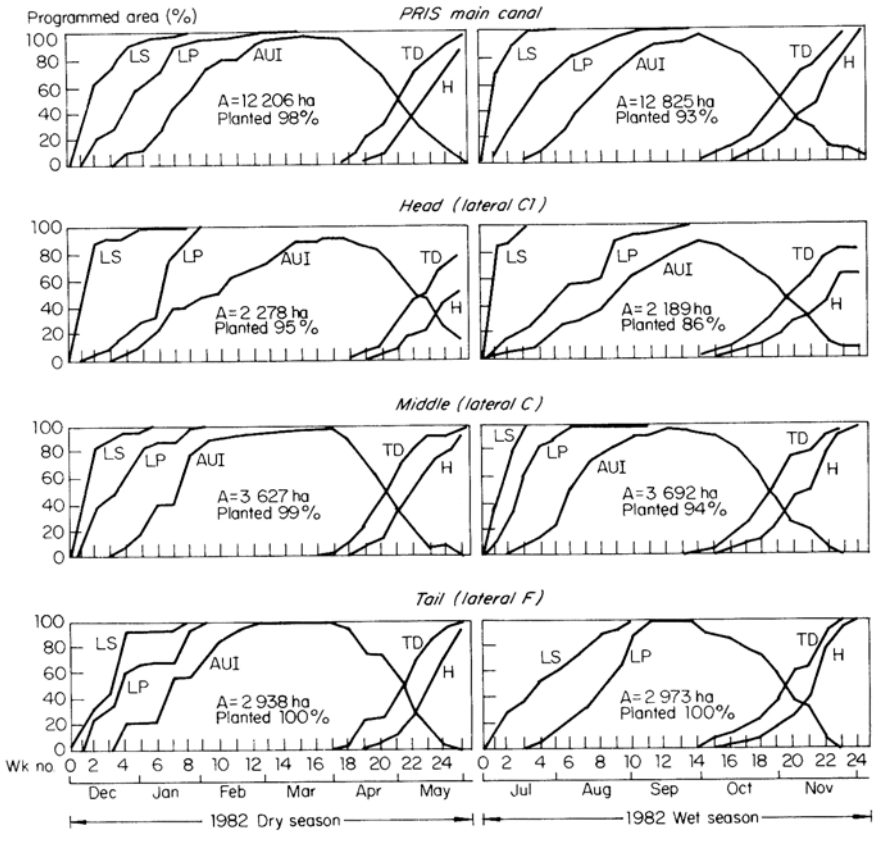
In general, the water supplies to the different parts of the four subsystems in District I satisfied target demands during the 1982 DS and WS (Table 9). RWS ranged from 1.04 in the Santo Domingo area to 3.87 in TRIS upper area during the DS, and 1.18 in the San Agustin Extension and 1.77 in the Santo Domingo area during the WS. These figures indicate that the DS water supplies



11. Water supply (rainfall + irrigation) and requirement (ET + SP) at PRIS main canal and laterals C-1 (head), C (middle), and F (tail), by weekly intervals, District II, NIA, Philippines, 1982 DS and WS.

were 4% in excess of target field demands at the Santo Domingo area and 287% in excess at the TRIS upper area. During the following WS, water supplies were 18% in excess at San Agustin Extension and 77% at Santo Domingo. A case in point is the higher water adequacy to meet the target demands of the two run-of-the-river-type subsystems (San Agustin Extension and TRIS Upper) in the DS than in the WS. This can be largely explained by the conservative estimates of the program areas included in the DS irrigation. With the same available flows and at the DS target WUE of 65%, 170 and 1,281 ha should have been adequately irrigated at San Agustin Extension and at TRIS Upper area. However, only 120 ha at San Agustin and 500 ha at TRIS Upper were actually irrigated (Table 10). The higher water adequacy in District I during the WS can be attributed to rainfall, which averaged about 50% of the total seasonal water supplies. The findings support the farmers' experience of no significant water shortage to reduce their yields.

Although the water supplies were more than adequate to meet the target demands of the subsystems, their allocation and distribution can be considered inequitable (Table 10, Fig. 13-15). For the reservoir type in the DS, 11% of the flows at TRIS Lower went into headender farms, 26% into midenders, and 63% into tailenders. This corresponded with 13, 32, and 55% of the total programmed area. Thirty-two percent of the total flows went into the first half of the service area of



12. Percentages of area land soaked (LS), land prepared (LP), transplanted (AUI), terminally drained (TD), and harvested (H) for PRIS laterals C-1 (head), C (middle), and F (tail). PRIS, District II, NIA, Philippines, 1982 DS and WS.

Santo Domingo Area, accounting for 48% of the total program area. The remaining 68% were concentrated at the second half of the service area. The same patterns of water allocation or distribution inequity were observed in the WS (Table 10, Fig. 13-15). Whether allocations were based on service areas or upon water requirements, the distribution of supplies was generally inequitable. This is particularly true in Santo Domingo Area where the DS and WS flows were practically dumped into the second half of the service area. To correct these inequities, monitoring and control of flow at the head, middle, and tail of each subsystem will start in the 1983 DS.

Seasonal WUE was computed for each subsystem and different locations within a certain subsystem (Table 9). During the DS, WUE was highest at TRIS Lower area (95.2%) and lowest at TRIS Upper area (25.4%); during the WS, it was highest at San Agustin Extension (71.5%) and lowest at Santo Domingo Area (37.7%). Because rainfall contributed 50% of the total seasonal water supplies, it was effectively used. WUE also varies among strategic locations within a particular subsystem. It was 100% at the head and middle portions and 78.6% at the tail-end portions of the TRIS Lower area during the DS and 70.0, 47.9, and 56.6, respectively, during the WS. The lowest WS WUE (26.8%) was computed for the second half of Santo Domingo Area.

Status of farming activities. Farming progress in sampled areas of District I showed remarkable uniformity except at the run-of-the-river TRIS Upper area, where crops other than rice confound the pattern of M curves (Fig. 16-18). The trend is for downstream areas to have delayed schedules, as indicated by the reduced slope of the curves, particularly the area under irrigation.

Table 9. Water adequacy situations, District I, NIA-UPRIIS, Nueva Ecija, Central Luzon, 1982 DS and WS.

Subsystem	DS		WS	
	Weeks	Actual relative water supply[a]	Weeks	Actual relative water supply[a]
San Agustin Extension	14	2.49 *ba*	20	1.18 *ab*
TRIS Upper	22	3.87 *aa*	19	1.64 *ab*
TRIS Lower	25	1.37 *cb*	20	1.59 *ab*
Upstream	15	3.57 ac	21	1.42 ab
Middle	22	0.93 cc	19	1.84 ab
Downstream	24	1.22 bc	21	1.76 ab
Santo Domingo Area	21	1.04 *da*	17	1.77 *ab*
First half	19	0.72 bd	21	1.60 bc
Second half	22	1.73 ac	22	3.90 ab

[a]The statistical significance (p = 0.05) of difference in means among subsystems and locations within a particular subsystem in a particular season is denoted by the first letter of the pairs (roman for within and italic for among subsystems) compared vertically; the statistical significance (p = 0.05) of difference in means of any particular subsystem or location within a subsystem between seasons is denoted by the second letter of the pair compared horizontally.

Production. Only 75 farms (located on a 1.4-× 1.4-km grid) were sampled for estimating production in the DS because a majority of the sample farmers in the two run-of-the-river subsystems had no dry crop. Samples increased to 113 in the WS. The overall average production was 5.1 t/ha in the DS and 4.4 t/ha in the WS in District I (Table 11). For both seasons, the mean production did not differ significantly by location within any of the subsystems, even among subsystems. Except in one case (upstream section, TRIS Lower), yields did not differ substantially between seasons. The tentative conclusion is that water is not a production constraint in District I because irrigation supplies were plentiful in reservoir-type subsystems and conservative diversion-type subsystems in the DS.

METHODOLOGIES OF WATER MANAGEMENT RESEARCH

Irrigation Water Management Department

Work on development of standard methodologies for irrigation water management research continued. Field research methods of the Irrigation System Management Research Committee were collected and published in English and Tagalog for field-level personnel. At IRRI, water management technicians (WMTs) and assistant water management technicians (AWMTs) were trained to use these data-collection methods. The WMTs and AWMTs then trained the ditchtender field personnel.

Data gathering and processing refinements were made in: field prediction of rice crop evapotranspiration, determination of spatial variability of rainfall, variability of DS seepage and percolation, and stress-day indexing with artesian ground water supply.

Evapotranspiration prediction. Extended debate has occurred on predicting rice crop ET. The instrumentation and calculation procedures must be simple and easily applied. A simple agrometeorological installation, including a class A evaporation pan and a standard nonrecording rain gauge, is commonly used in modern irrigation systems as a predictor of evaporative demand. However, the device is frequently installed in a grassed, dryland site away from the wetland microenvironment that has an evaporative demand 10 to 25% lower than the dryland. Another common problem is installation maintenance.

The commonly used prediction of rice crop ET from Class A pan evaporation (E_{pan}) in the Philippines in wetland conditions is based on the four equations of Kampen from work conducted at UPLB in 1970. These four equations as obtained under controlled research plot conditions are:

1968 WS		
Vegetative stage	$ET = 0.84\ E_{pan} + 0.35$	($R^2 = .88$)
Reproductive stage	$ET = 0.91\ E_{pan} + 0.17$	($R^2 = .81$)
1969 DS		
Vegetative stage	$ET = 0.87\ E_{pan} + 0.52$	($R^2 = .77$)
Reproductive stage	$ET = 0.94\ E_{pan} + 0.46$	($R^2 = .83$)

Table 10. Water distribution equity indicators, District I, NIA-UPRIIS, Nueva Ecija, central Luzon, Philippines, 1982 DS and WS.[a]

Subsystem	1982 DS			1982 WS			
	Program area (ha)	Diverted flows (Q) ($m^3 \times 10^6$)	Target discharge (ET + S&P) ($m^3 \times 10^6$)	Program area (ha)	Diverted flows (Q) ($m^3 \times 10^6$)	Total diverted flows (RN + Q) ($m^3 \times 10^6$)	Target discharge (ET + S&P) ($m^3 \times 10^6$)
Run-of-the-river type	620	40.1	11.1	4448	78.0	133.1	64.8
San Agustin Extension	120 (19)	4.9 (12)	2.2 (20)	720 (16)	7.4 (9)	15.3 (11)	11.0 (17)
TRIS Upper	500 (81)	35.2 (88)	8.9 (80)	3729 (84)	70.6 (91)	117.8 (89)	53.8 (83)
Reservoir type							
TRIS Lower	7822	101.8	91.6	9398	127.2	246.6	129.5
Upstream	999 (13)	10.9 (11)	11.6 (13)	999 (11)	9.2 (7)	20.4 (8)	14.3 (11)
Middle	2536 (32)	26.6 (26)	29.5 (37)	2539 (27)	59.3 (47)	87.7 (36)	36.8 (28)
Downstream	4287 (55)	64.3 (63)	50.5 (55)	5860 (62)	58.7 (46)	38.5 (56)	78.4 (61)
Santo Domingo Area	8914[b]	147.8	134.5	9144[b]	267.5	343.8	129.5
First half	4283 (48)	46.8 (32)	65.7 (49)	4466 (49)	59.2 (22)	102.4 (30)	64.8 (50)
Second half	4630 (52)	100.9 (68)	68.8 (51)	4678 (51)	208.3 (78)	241.4 (70)	64.7 (50)

[a]Computation for each subsystem was based on the same time references. Figures inside parentheses represent percentage of total. [b]Excluding program area of lateral B-extra.

Although the equations are simple and readily applied to available Class A E_{pan} data, a serious concern exists for the wetland environmental difference from the dryland installation and the difference of this data as applied in the Kampen equations.

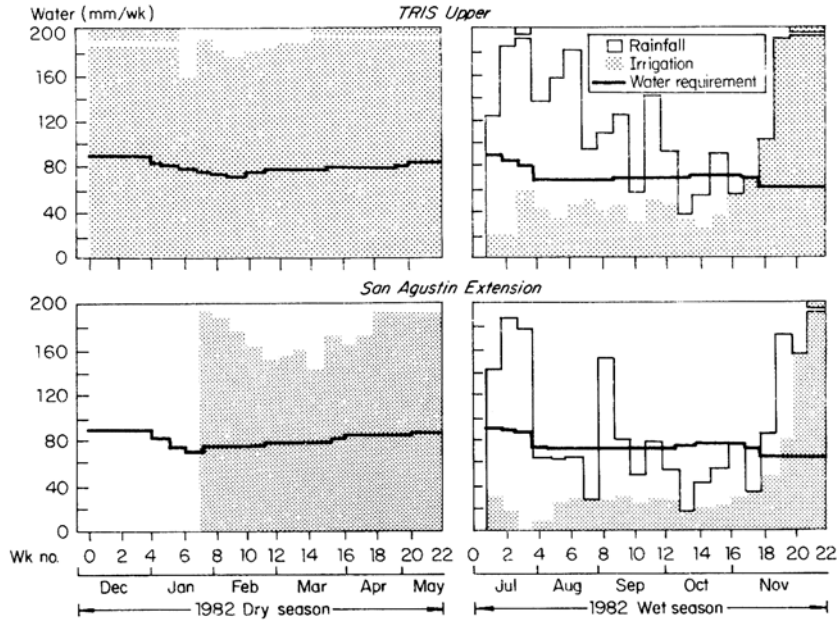
Three class A pans were elevated within rice fields in broad irrigated areas of Central Luzon with the upper edge approximating the maximum height of the crop canopy. A calibration was conducted for an entire DS and the elevated, raw class A E_{pan} were compared with the ET using the E_{pan} applied in the respective equations.

Mean daily ET values by the Kampen equations are virtually identical to mean daily E_{pan} observations (Table 12). Statistically, the values are not significantly different. Comparison of daily differences provides a maximum difference of 0.7 mm, an amount that is totally beyond the concern of a system manager. The conclusion was that for DS conditions in broad irrigated rice-growing areas, unmodified Class A E_{pan} data are essentially equivalent to values based on the currently used Kampen transformations.

Spatial variability of rainfall. For irrigation planning and management, rainfall must be considered in scheduling reservoir releases, particularly when water savings in a WS can be retained and used in the DS. The spatial variability of rainfall is reflected directly by the intensity of data collection and monitoring. Calibration studies were conducted between low-cost plastic rain gauges (PRG) ($4 each) and standard nonrecording rain gauges (STD) ($50 each). The calibration, based on 283 pairs of nonzero rainfall events, was

$$\text{STD} = 0.92\ \text{PRG} + 0.40 \qquad (R^2 = .99)$$

The high accountability for variation suggests that the substitution of low-cost rain gauges may be a good investment. The question of spatial variability was addressed at a site in the irrigated area of District IV of UPRIIS. Sample correlation statistics between a reference rain gauge and 10 other plastic rain gauges in the area were computed for separation distances ranging from 550 to 3,300 m. The coefficient of determination for the respective regressions was plotted against the respective distances of separation between the gauges (Fig. 19).



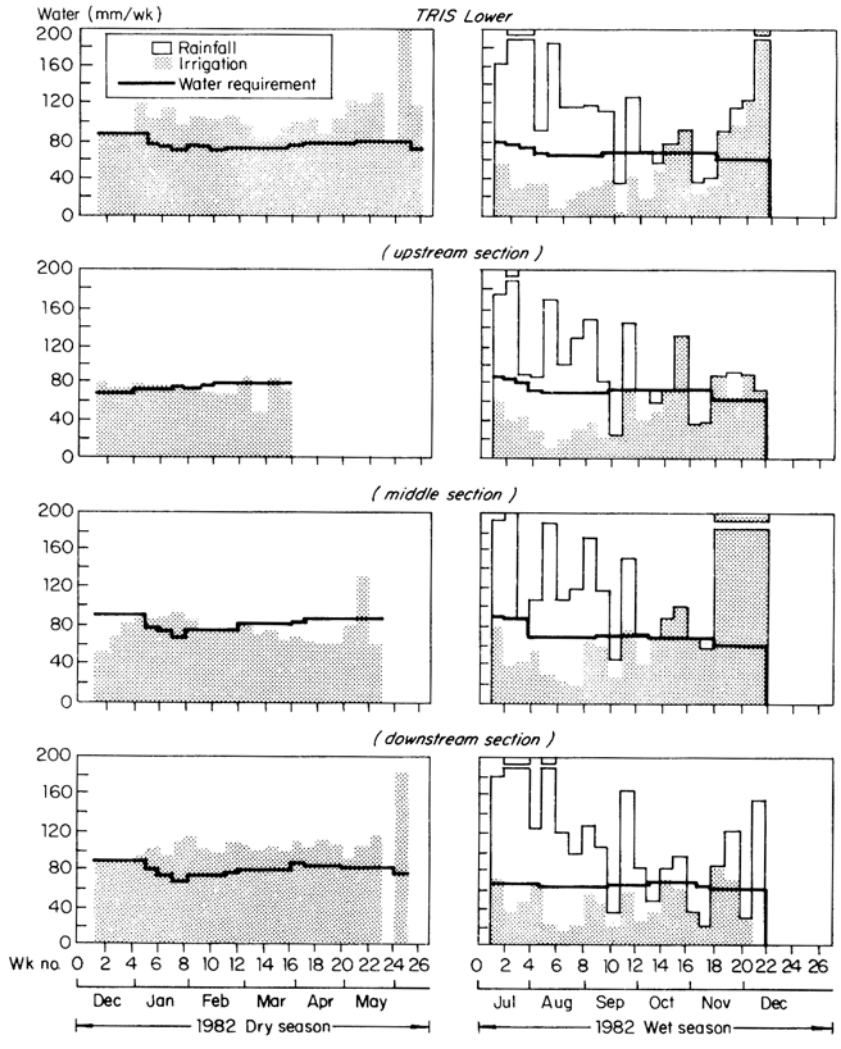
13. Water supply (rainfall + irrigation) and requirements (ET + SP) by weekly intervals at TRIS Upper and San Agustin Extension, District I, NIA, Philippines, 1982 DS and WS.

This linear relationship between R^2 and distance has a coefficient of variation of 0.80. Interpretation of this relationship indicates that for each 0.5 km of separation, a corresponding loss of approximately 10% in coefficient of determination is the trade-off.

This rainfall variability with distance corresponds to complaints by farmers that irrigation suspension schedules do not always treat them fairly. Their area can be dry and without rain while another area represented by the rain gauge has had rain and temporarily needs no water. Considering that current irrigation management is based on rainfall measurement at the division level with one hydromet station for each 2,500 ha, a rainfall data-gathering must be reexamined. Assuming a regular square geometric spacing, the distances between the division-level rain gauges in UPRIIS average approximately 5 km. With this spacing, the farthest set of fields would be 2.5 km from the nearest hydromet station if it were halfway between two stations. For this spacing, the rain gauge at the center of a division would have a coefficient of determination of only 0.6 (Fig. 19), which would only explain 50% of variability for the most remote field in the site. This analysis confirms the inappropriateness of suspension schedules for some farmers in the irrigation system. The hydromet station network at the division level only exists and operates on paper. Observation of field operations in UPRIIS would indicate that perhaps only half of the stations are serviced and have data gathered and utilized regularly to guide the actions of the Water Control and Coordinating Center.

Dry-season variability of seepage and percolation. The irrigation of wetland rice must counterbalance ET and S&P. While ET is uniform and reasonably predictable across wide areas, S&P is highly variable and often determined by site-specific characteristics. Detailed DS records of S&P were observed in the lowest topographic position of UPRIIS, District IV, at the tail of lateral C of the Peñaranda River Irrigation System (PeñRIS). This site was studied in detail in the mid-1970s, when it was still a run-of-the-river type system. In 1976, it was integrated with the more reliable water supply of the Pantabangan reservoir. With this change and more reliable water supply, the average DS stress days dropped from 31/crop to 7/crop, with a corresponding rise in the water table.

S&P observations in 1980 indicated a preponderance of negative values not previously encountered (Table 13). Negative S&P implies an



14. Water supply (irrigation + rainfall) and requirements (ET + S&P) at different sections of TRIS Lower, District I, NIA, Philippines, 1982 DS and WS.

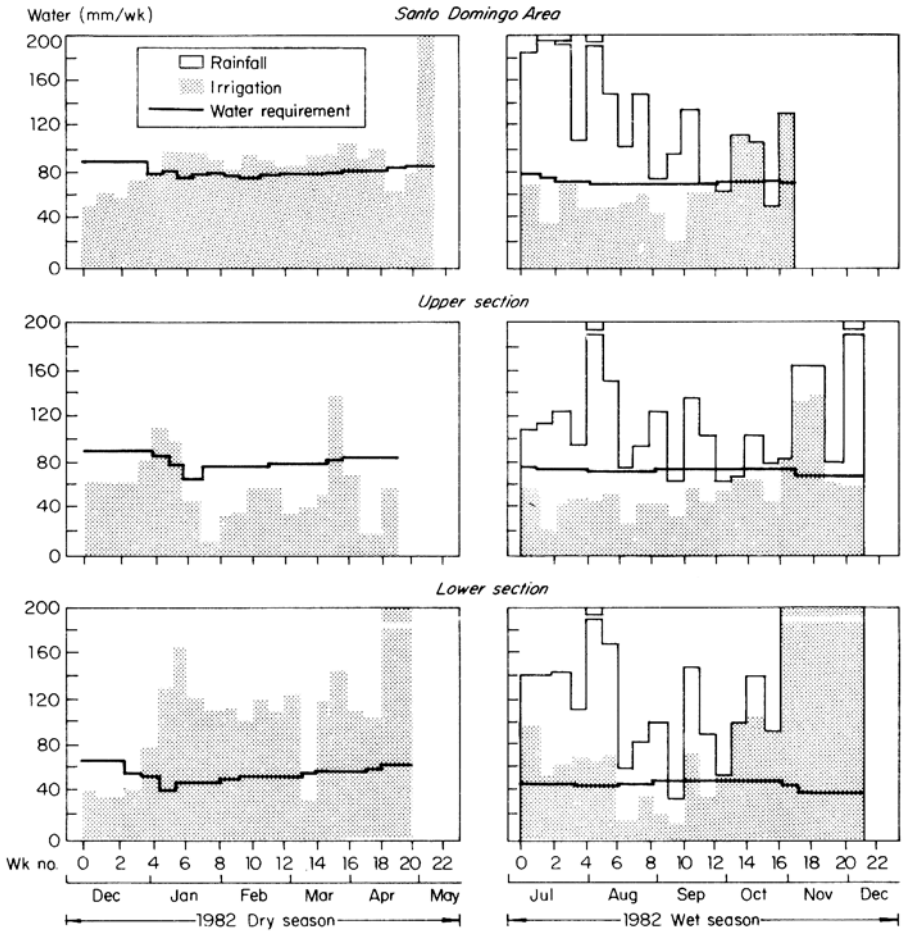
upward flow of water from subsoil influenced by artesian pressures.

The values are tabulated at the 95% confidence interval. In all cases, the interval was not sufficiently wide to change the sign from negative to positive. This shows the importance of evaluating irrigation requirements site by site within an irrigation system. There are also environmental consequences of introducing irrigation in the humid tropics. Irrigation can be a hazard if the standard rate of 1.5 liters/s per hectare amounting to 13 mm/d continues to be applied when only half of that rate would supply 6.5 mm/d, which still exceeds the evaporative demand of 5.0 mm/d.

TERTIARY IRRIGATION MANAGEMENT

Irrigation Water Management Department

In 1982 a major comparative study was completed on tertiary-level irrigation practices under three water-supply types in San Miguel, Bulacan, and Gapan, Nueva Ecija, Philippines. The three systems included a communal pump system, a communal gravity system, and a national reservoir-backed irrigation system, all located within a 10-km radius of San Miguel. A sample of 101 farmers were periodically interviewed and sample fields from each type were monitored for input use, water status, and occurrence of moisture stress (Table 14).



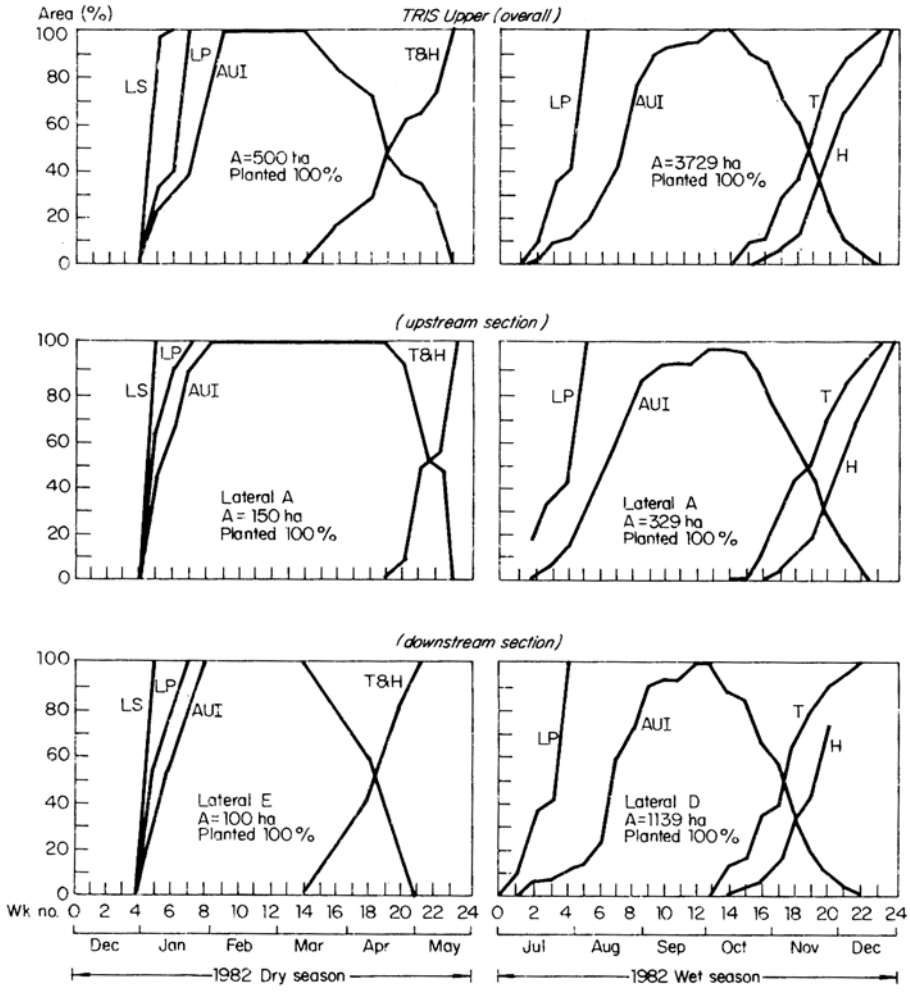
15. Water supply (irrigation + rainfall) and requirements (ET + S&P) at upper and lower halves of Santo Domingo Area main canal, District I, NIA, Philippines, 1982 DS and WS.

Input use. In general, N fertilizer use in the DS was double that in the WS (Table 14). Pump system farmers at the higher elevations with lighter textured soil used considerably more P and K fertilizer than farmers in the other two systems. In general, these farmers did not borrow as frequently or as much for agricultural input purchases as the farmers of the other two systems. Most of the pump farmers' loans were from family sources. Farmers in the two gravity systems tended to use government program credit sources at rates of $400 to $490/ha (Table 14). It appears that pump breakdown has caused the farmers in the communal pump system to be more cautious.

Water supply. The pump system was located on the large Angat River so water supply was never a problem. The pumping cost limited the amount of water used. The farmers could choose the timing of their cropping calendar.

The communal gravity system had the most precarious water supply because water came directly from the smaller San Miguel River that normally has a low base flow in the DS. Farm operation timing was very important if there was to be a second or DS crop, as shown in the early planting and harvest of the WS crop and the very short turnaround time between crops (Fig. 20) and in the use of direct seeding by 86% of the farmers for the DS (Table 14).

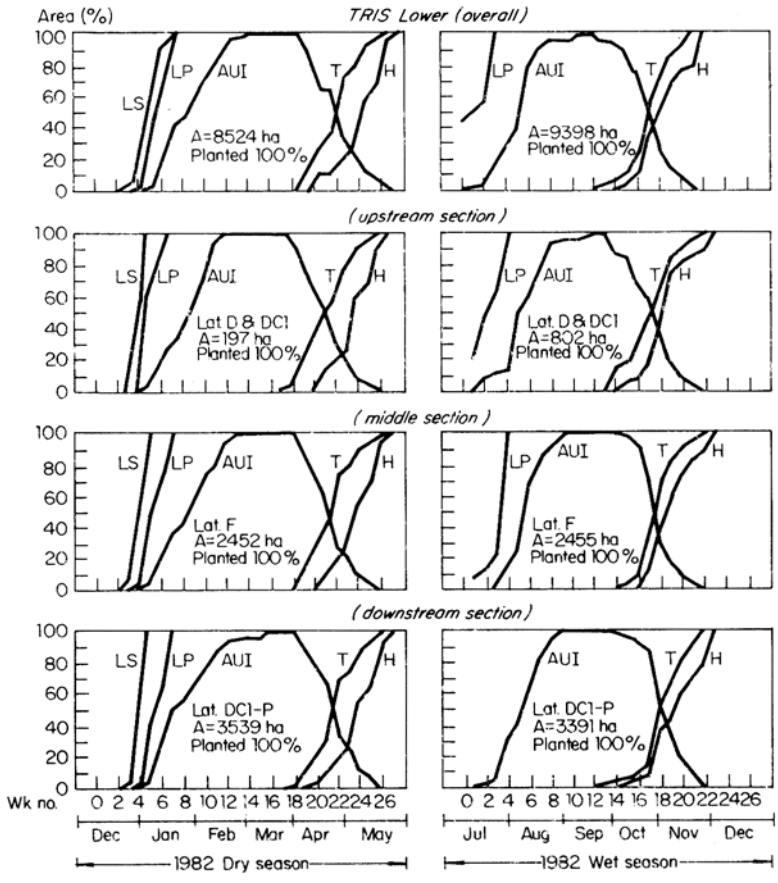
The farmers in the reservoir-backed system planted their crop the latest; some even had schedules similar to those of the nearby rainfed



16. Land soaking (LS), land preparation (LP), area under irrigation (AUI), terminally drained (T) and harvested (H) at different sections of TRIS upper, District I, NIA, Philippines, 1982 DS and WS.

farms, particularly turnout units C9b-6 and C9b-9 (Fig. 20). The delays in the national system reflect the operating procedure that generally services the upstream areas first. The six turnout units of the study were near the tail of the UPRIIS system and more than 70 km from the reservoir.

The highest average daily irrigation rate was in the communal gravity system (6.66 mm/d), the next highest was in the reservoir system (6.13 mm/d). The communal gravity system had a greater rainfall utilization opportunity (2.03 mm/d) than the pump (0.34 mm/d) and reservoir (0.29 mm/d) systems, giving it a 44% greater available supply than the pump and 26% more than the reservoir system. ET demand was relatively uniform, as expected. Also there were fewer fluctuations in S&P rates — 2.46 mm/d at the pump site and 2.89 mm/d at the gravity site. The national reservoir site was located at a topographic low and at the tail-end of the irrigated Central Luzon basin, so it had a consistently negative S&P rate, indicating artesian pressures and a lower demand for water from the irrigation system. The weighted mean RWS was 0.64 for the pump site, 1.22 for the communal gravity site, and 1.79 for the reservoir site. The low value at the pump site reflects the farmers' reluctance to pump at their own expense. If the S&P at the reservoir site had been positive



17. Land soaking (LS), land preparation (LP), area under irrigation (AUI), terminally drained (T), and harvested at different sections of TRIS Lower, District I, NIA, Philippines, 1982 DS and WS.

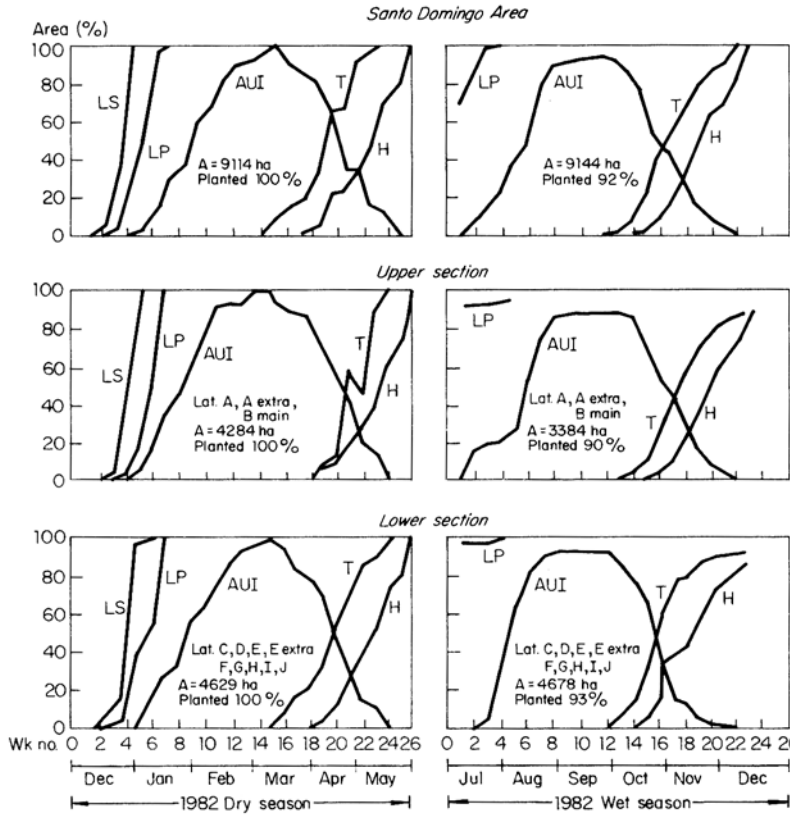
and of the same magnitude as that at the other two sites, tail-end site would have had a RWS of only 0.83. The artesian flow down the system saves this tail-end site from encountering severe moisture stress.

Farming response to water supply. About 80% of the pump farmers reported dependency on irrigation for land preparation. Only 13% reported waiting for rains before beginning land preparation. About 52% of the farmers in the communal gravity system reported total dependence on irrigation; 47% reported waiting for rain. In the tail-end portion of the reservoir gravity system, 25% of respondents reported total dependence on irrigation; 45% reported waiting for rain to begin land preparation. Hence, there was a general decreasing dependence on irrigation as the water supply arrived later.

Two-thirds of the pump farmers, 52% of the communal gravity farmers, and 44% of the tail-end reservoir farmers reported the initial water arrived on time. Only 3% of the 98 respondents reported that the water arrived early; 41% reported that it came late; 7% said they had no knowledge of the schedule.

Land-preparation period for pump farmers paying for all water used was only 12 d compared with 23 d for communal gravity system farmers and 27 d for the reservoir system farmers. The average seedling age was 33, 26, and 24 d for the pump, communal gravity, and reservoir system respondents respectively. The communal gravity farmers used varieties requiring a shorter irrigation period (87 d) than those used by the pump farmers (97 d). This corresponds to a planned strategy to avoid moisture stress for the less-assured run-of-the-river water supply.

Farming operation timing also plays an impor-



18. Land soaking (LS), land preparation (LP), area under irrigation (AUI), terminally drained (T), and harvested (H) at different sections of Santo Domingo, District I, NIA, Philippines, 1982 DS and WS.

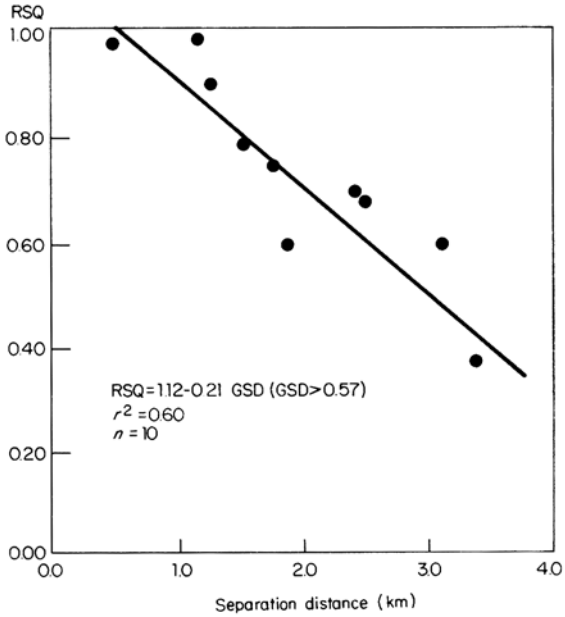
Table 11. Mean crop-cut yield samples, District I, NIA-UPRIIS, Nueva Ecija, Central Luzon, 1982 DS and WS.[a]

Subsystem	DS[a]		WS	
	Samples (no.)	Yield[b] (t/ha)	Samples (no.)	Yield[b] (t/ha)
San Agustin Extension	–	–	4	5.0 *A*
TRIS Upper	–	–	15	4.2 *A*
First half	–	–	5	3.8 *a*
Second half	–	–	10	4.4 *a*
TRIS Lower	36	5.3 *AB*	42	4.4 *AB*
Upstream	7	5.6 *aa*	11	4.2 *ab*
Middle	10	4.8 *ab*	9	4.0 *ab*
Downstream	19	5.5 *aa*	22	4.7 *ab*
Santo Domingo Area	39	4.9 *AB*	52	4.5 *AB*
Upstream	23	5.1 *ab*	33	4.6 *ab*
Middle	7	4.2 *ab*	14	4.0 *ab*
Downstream	9	4.7 *ab*	5	5.0 *ab*

[a] A dash (–) means that no rice crop was planted. [b] The statistical significance ($p = 0.05$) of difference in means among subsystems and locations within a particular subsystem in a particular season is denoted by the first letter of the pair (lower case for locations within subsystems and capital for among subsystems) compared vertically while the statistical significance ($p = 0.05$) of difference in means of any particular subsystem or location within a subsystem between seasons is denoted by the second letter of the pair compared horizontally.

Table 12. Comparison of Class A (elevated) E_{pan} with Kampen equation ET predictions. Central Luzon, Philippines, 1979-80 DS.

Site	No.	Mean	Standard deviation	Minimum	Maximum	T-statistic	Pr>/t/
Talaksan	78						
E_{pan}		4.81	1.43	0.8	9.4		
Kampen ET		4.81	1.26	1.2	8.7		
Difference		-0.003	0.225	-0.7	0.4	-0.14	0.89
Salapungan	80						
E_{pan}		4.55	1.34	0.4	8.4		
Kampen ET		4.57	1.18	0.9	8.4		
Difference		0.019	0.209	-0.5	0.5	0.83	0.41
Gapan	87						
E_{pan}		4.96	1.26	0.0	8.6		
Kampen ET		4.94	1.17	0.5	8.0		
Difference		-0.011	0.176	-0.6	0.5	-0.58	0.56



19. Rain gauge separation distance (GSD) vs coefficient of determination (RSQ). UPRIIS, 1982.

tant role in providing opportunities for rainfall to be effectively used in cropping. Because of its early schedule, the communal gravity system had 211 mm through 30 rainy days in the DS (av 7 mm/d or 2.1 mm/d of land preparation and normal cropping up to terminal drainage). The communal pump system had 131 mm of rain in 19 d (also av 7 mm/d and 1.4 mm/d from land preparation through terminal drainage). During normal cropping, the amount was only 0.4 mm/d for the pump system and 0.3 mm/d for the reservoir system.

Table 13. Average S&P rates. Central Luzon, Philippines, 1979-80 DS.

Site	No.	S&P and 95% confidence interval	Minimum	Maximum
Talaksan	17	2.9 ± 1.4	-1.5	8.4
Salapungan				
Pasong Hari	11	-0.8 ± 0.8	-3.0	1.4
Mabato	8	5.7 ± 0.6	4.1	7.3
PeñRIS				
C9b-6[a]	8	-2.0 ± 1.1	-3.0	-1.5
C9b-9	13	-3.7 ± 0.5	-5.1	-2.8
C9c-1	14	2.4 ± 0.5	0.9	4.0
C9d-3	10	-1.6 ± 0.4	-2.5	-0.7
C9d-5	12	-1.3 ± 0.1	-1.7	-0.9
C9d-7	9	-2.6 ± 0.4	- .38	-1.7

[a]Rotational area designation by the NIA.

About 85% of the pump farmers reported total dependence on irrigation delivery for initial land preparation; 7% reported delayed land preparation because of no water. About 76% of the communal gravity farmers reported dependence on irrigation delivery for the start of land preparation; 24% reported delays. About 92% of the reservoir farmers reported dependence on irrigation; 35% reported delays.

DS land preparation took 12 d for the pump and communal gravity systems and 19 d for the national reservoir system. About 86% of the communal system farmers, who had the least reliable water supply, direct seeded. They had the shortest cropping duration of 100 d, saving 21 d from the average duration of the transplanted crop. Only 42% of the reservoir farmers direct

Table 14. Characteristics of the tertiary units at San Miguel, and San Rafael, Bulacan and Gapan, Nueva Ecija, Philippines, 1979 WS and DS.

Type of system	Turnout units (no.)	Sample farmers (no.)	% DS direct seeding (%)	N fertilizer usage (kg/ha)		P use (kg/ha)		K use (kg/ha)		Borrow agr. credit (%)	Av loan ($)
				DS	WS	DS	WS	DS	WS		
Communal pump	1	14	0	75	37	41	26	26	18	36	156[a]
Communal gravity	2	22	86	99	50	5	5	1	2	68	490[b]
National reservoir	6	65	42	102	60	29	21	7	6	83	400[c]
Overall		101	48%	100	55						

[a]100% from private sources. [b]Mixed sources. [c]64% from institutional sources.

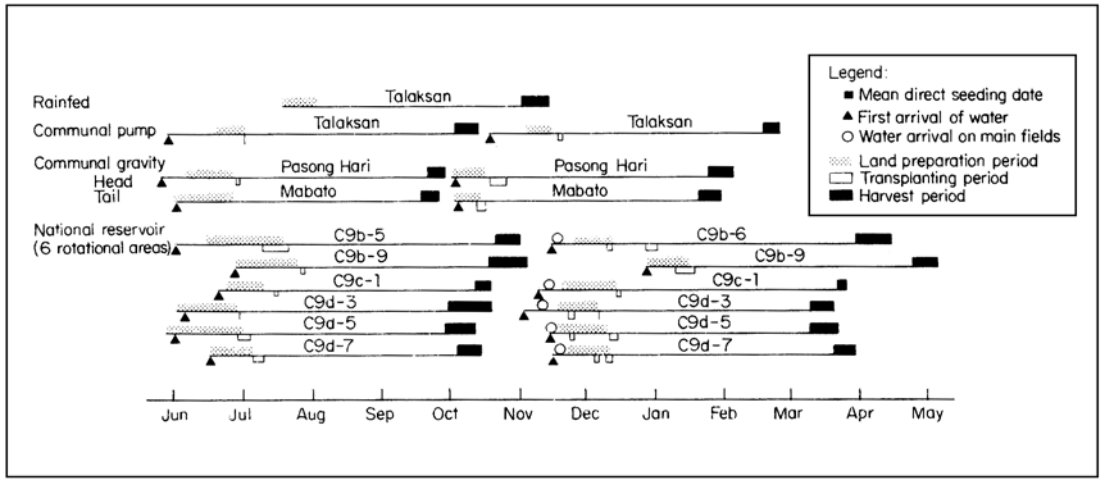
seeded. Their cropping duration was 107 d. The turnaround time (duration from WS threshing to beginning of DS land preparation) was 30 d in the reservoir system, 21 d in the pump system, and 7 d in the communal gravity system. Direct seeding and the short turnaround time in the run-of-the-river communal gravity system indicate that the farmers recognize seasonal water fluctuation as a major constraint.

COMMUNAL IRRIGATION MANAGEMENT

Irrigation Water Management Department

Communal gravity irrigation is important to the Philippines in many ways. More than 5,600 systems throughout the country irrigated more than 580,000 ha (nearly 45% of the total irrigated area in the country compared with the 38% irrigated by national systems). Local farmers initiate the communal gravity irrigation systems without government stimulus. Irrigator groups construct, operate, and repair the systems. Later when more permanent structures are needed and certain types of maintenance are conducted, an irrigator association seeks the assistance of government agencies. Since 1974, government assistance to communals have required the irrigator associations to amortize the material costs in equal annual payments at no interest for up to 50 yr. This has caused great concern for making the assistance effective.

Of the more than 5,600 systems listed in provincial irrigation records, approximately 1,250 received some government assistance between 1965 and 1978. In 1980, a study was initiated with the



20. Timing of 1979 WS and 1980 DS farming activities in rainfed, communal pump, communal gravity, and reservoir-irrigated rice farming areas. UPRIIS, 1982.

NIA to determine the status and condition of the government-assisted communals.

Specifically, the study was to

- determine the irrigated area as related to the original design,
- determine the condition of the structures for both water diversion and conveyance,
- determine the state of system management used by the irrigator associations for operation and maintenance of the system, and
- provide feedback and improvements to the conceptualization, design, construction, and operation through NIA assistance procedures.

The interest is clearly to provide assistance to irrigator associations that will be responsive to farmer needs, enhance the viability of the associations, and encourage the repayment of the construction loan.

The major diagnostic analysis was concluded in 1982 in collaboration with NIA's Communal Irrigation Committee. A sample of 100 systems representing 8% of the total that had received NIA technical assistance from 1965 to 1978 was chosen. Particular reference was made to the development period, the system size, and the local climate based on the Corona Climatic Classification of the Philippines. The development periods were classified as the early period (1965-1969, immediately after NIA's creation when only 6% of the communals were assisted), the middle period (1970-1974 when the assisted communals gradually increased to 25%), and the latest period (1975-1978 when assisted communals were 69% of the total).

Four size categories were chosen centered around the mean communal system size at 100 ha: less than 50 ha (26% of the total of 1,253 assisted communals), 50-99 ha (21% of the total), 100 to 299 ha (34% of the total), and greater than 300 ha (18% of the total). The system size determines the structure complexity and the farmer management necessary to run the system.

The climatic types from most favorable to least favorable to rice production are Corona's type IV (rainfall more or less evenly distributed throughout the year), type II (no pronounced DS, but with a pronounced rainfall from November to January), type III (DS from November to April and wet the rest of the year), and type I (pronounced DS from November to April). This series represents the order in which increasing stress is placed on the irrigation system to provide water as less rain is available for year round cropping.

Area, production, and inputs. The survey results indicate that, of the designed service area for rice irrigation, only 74% is served in the WS and 48% in the DS. The data are summarized in Table 15.

Organizational characteristics. Data on the organizational characteristics of NIA-assisted communal irrigation systems are summarized in Table 16.

Operation and maintenance. Data on the operation and maintenance of NIA-assisted systems are summarized in Table 17.

Rating of structures, existence of channels, and farmer satisfaction. An objective rating system was developed for each structural component of the systems with 100 points as the maximum score. The data are summarized in Table 18. The NIA plans to respond to the initial findings by developing improved methods of predicting design service areas. Assistance in operation and maintenance will include system management planning, financial management, and farm water management training.

WATER MANAGEMENT PROFILE IN BANGLADESH COLLABORATIVE PROJECT

Irrigation Water Management Department

An applied research project for increasing irrigation effectiveness and crop production started in 1981 in collaboration with the Bangladesh Water Development Board and the Bangladesh Rice Research Institute. The research is conducted in two major irrigation systems — the North Bangladesh Tubewell Irrigation System, which has a cluster of 378 electrically driven deep tubewells, each with a discharge capacity between 60 and 120 liters/s, and the Ganges-Kobadak Irrigation System (Phase 1), in which water is lifted from the Ganges River to irrigate, using gravity canal, more than 40,000 ha.

Water management profile of North Bangladesh Tubewell Irrigation System. In 1982 DS, a sample of 10 tubewells representing the cluster was studied to establish the water resource available to the tubewells, the level of present and potential use, and to determine the major problems facing the farmers in increasing their crop production.

Table 15. Yield, service area, and input use in NIA-assisted communal irrigation systems, Philippines, 1980-1982 WS and DS.

	Mean	Corona climatic classification				System size categories (ha)				Period of NIA assistance		
		IV (uniformly distributed rainfall)	II (no DS pronounced rain in cool season)	III (less pronounced maximum rainfall, short DS)	I (pronounced WS and DS, long DS	<50	50-99	100-299	⩾300	1965-69	1970-74	1975-78
WS yield (t/ha)	3.2	3.8	3.4	2.9	2.8	2.7	3.1	2.9	3.6	3.2	3.5	3.0
DS yield (t/ha)	3.1	3.3	3.4	2.8	2.9	–	–	–	–	–	–	–
Cropping intensity	1.7	1.8	1.7	1.6	1.6	1.7	1.7	1.6	1.8	1.6	1.6	1.7
Decrease actual WS area (%)	36	27	40	39	40	14	49	48	27	32	37	37
Decrease actual DS area (%)	52	41	54	50	56	30	63	65	43	57	61	47
WS MV use (%)	86	96	97	77	78	79	88	84	88	92	74	90
DS MV use (%)	92	94	90	83	97	94	78	93	96	99	82	94
Masagana loan $/ha	153	108	156	113	105	100	108	120	120	100	125	119

Table 16. Organizational characteristics of NIA-assisted communal irrigation systems, Philippines, 1980-1982 WS and DS.

Organizational characteristic	Mean	Corona climatic classification				System size categories				Period of NIA assistance		
		IV	II	III	I	<50 ha	50-99 ha	100-299 ha	⩾300 ha	1965-69	1970-74	1975-78
Systems with an irrigation association (%)	91	96	83	95	88	83	96	90	95	93	85	93
Systems in which all irrigators are association members (%)	64	61	56	70	68	52	81	68	50	73	48	69
Irrigators association with membership fee (%)	66	64	61	65	71	57	69	65	75	60	52	74
Associations that compensate their leaders (%)	9	18	0	5	9	9	4	10	15	7	11	9
Associations that charge irrigation service fee (%)	38	57	39	35	24	35	27	48	40	40	30	41
Associations charging >50 kg/ha service fee (%)	31	46	39	30	15	30	23	48	15	40	11	38
Associations charging <50 kg/ha service fee (%)	7	11	0	5	9	5	4	0	25	0	19	3

Table 17. Operation and maintenance of NIA-assisted communal irrigation systems, Philippines, 1980-1982 WS and DS.

Operation and maintenance characteristic	Mean	Corona climatic classification				System size category				Period of NIA assistance		
		IV	II	III	I	<50 ha	50-99 ha	100-299 ha	≥300 ha	1965-69	1970-74	1975-78
Systems with distinct water distribution personnel (%)	48	71	22	40	47	43	42	55	50	47	44	50
Associations that compensate water distribution personnel (%)	19	29	6	10	24	13	12	16	40	7	26	19
Systems practicing field to field flow (%)	60	64	72	55	53	83	54	48	60	27	67	66
Systems with restrictions on taking water without authorization (%)	32	39	11	20	44	22	31	35	40	40	30	31
Systems with distinct maintenance personnel (%)	17	25	22	10	12	17	12	16	25	13	15	19
Associations that compensate farmers to do maintenance (%)	10	18	11	5	6	0	4	23	10	7	15	9
Associations whose members do repair and maintenance (%)	94	89	83	100	100	100	96	90	90	100	96	91
Farmers who assist in maintenance (%)	94	96	96	99	89	100	99	96	89	99	95	92

Table 18. Rating of structures, existence of secondary and tertiary channel network, and farmer satisfaction in NIA-assisted communal irrigation systems, 1980-1982 WS and DS.

	Mean	Corona climatic classification				System size category				Period of NIA assistance		
		IV	II	III	I	<50 ha	50-99 ha	100-299 ha	≥300 ha	1965-69	1970-74	1975-78
Overall rating of diversion structure[a] (n = 51 systems)	72	83	77	64	62	66	65	81	70	62	77	73
Overall rating of headgate structure[a] (n = 76 systems)	84	83	90	78	86	75	79	93	84	74	80	88
Overall rating of main canal[a] (n = 99 systems)	69	63	64	67	80	80	66	66	67	77	70	77
Systems with at least	25	29	11	15	35	17	23	16	50	20	30	24

Continued on next page

Table 18 continued

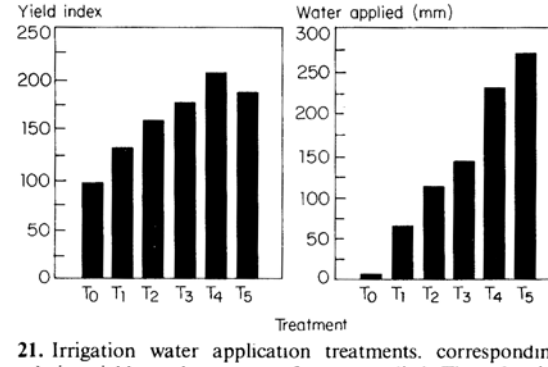
	Mean	Corona climatic classification				System size category				Period of NIA assistance		
		IV	II	III	I	<50 ha	50-99 ha	100-299 ha	⩾300 ha	1965-69	1970-74	1975-78
two laterals (%) (n = 100 systems)	59	61	56	65	56	39	50	74	70	73	48	60
Systems that have farm ditches (%) (n = 100 systems)	14	21	0	25	9	0	27	6	25	20	0	19
Systems with farm ditches having control structures (%) (n = 100 systems)	50	58	44	50	46	58	54	48	48	54	55	47
Farmers satisfied with operation and maintenance of the system (%) (n = 921 farmers)												

[a]Rating system with 100 points as the maximum score.

Dry season crop water requirement. In the rice-based cropping system, wheat is the most popular DS crop following the aman season rice because it is suited very well to the sandy loam soil and cool DS temperature. Because rainfall is very low, yields are low if the wheat is not irrigated. The optimum irrigation schedule and water requirement for irrigated wheat were established in a study conducted in randomized complete block design with six irrigation treatments, each with three replications, in 4- × 5-m field plots. The first irrigation was applied 20 DAS and subsequent ones at 15-d intervals. Each irrigation was applied only to saturate the soil. The wheat seed (variety Sonalika) was sown on 25 December 1981 and harvested on 13 April 1982. Only 8 mm of rain fell during the crop season.

Four irrigations requiring about 240 mm of water produced the highest yield (2.76 t/ha) (Fig. 21). Three irrigations produced a significantly lower ($p = .05$) yield than four irrigations. Yields of five irrigations averaged 0.3 t/ha less than those of four irrigations because of too much water. All treatments received the same fertilizer dose of 80-60-40 kg (N,P,K)/ha.

Modeling the productivity of wheat. Data on input use, water status, yield, and other agronomic practices were collected in the 1982 DS from 158 irrigated wheat farmers in the service area of four tubewells and 58 rainfed farmers within the command area of five tubewells. Crop-cut samples were used to obtain yield data for irrigated farms; farmers reported yields for the rainfed farms. Farmer interviews were used to collect all other data at the end of the season.



21. Irrigation water application treatments. corresponding relative yields, and amounts of water applied. The subscript denotes the number of irrigations. North Bangladesh Tubewell Irrigation System, Bangladesh, 1982.

In the irrigated areas, the wheat yields averaged 1.64 t/ha. Farmers applied an average fertilizer dose of 50-45-31 kg (N,P,K)/ha and 1.5 t organic manure (OM)/ha. In rainfed farms, the average yield was only 0.76 t/ha and the fertilizers used were 27-37-22 kg (N,P,K)/ha and 1.9 t OM/ha.

Production function relationships were developed for both irrigated and rainfed conditions using the multiple linear regression method. For the irrigated condition, the following variables were used in the regression: N, P, K, OM, I (no. of irrigation), DS (delay in sowing in days counting from 15 Nov), PC (% clay), N^2, NxP, NxK, NxOM, PxK, PxOM, and KxOM. For the rainfed condition, the variables included were: N, P, K, OM, N^2, NxP, NxK, NxOM, PxK, PxOM, KxOM, and PC. Following are the production functions of the significant variables with respect to the yield (Y) in tons per hectare:

For irrigated farms:

$$Y = -0.7795 + 0.0144\,N^{**} + 0.0200\,P^{**} - 0.00026\,NP^{**} - 0.0080\,DS^{**} + 0.3111\,I^{**} + 0.05136\,PC^{**}$$

($R^2 = 0.699$ $n = 158$ $F = 57.21^{**}$)

For rainfed farms:

$$Y = 0.3363 + 0.00737\,N^{*} + 0.01007\,K^{**} + 0.0649\,OM^{**} + 0.0000851\,NP^{*}$$

($R^2 = 0.814$ $n = 58$ $F = 45.58^{**}$)

In the foregoing equations, units for all inputs are in kilogram per hectare, except OM, which is in ton per hectare.

The irrigated crop production function shows that the number of irrigations (I) is an important positive contributor to the yield. I varied from one to three and each irrigation, on the average, contributed 311 kg wheat/ha. For every kilogram of N used, about 14 kg of wheat was produced on the irrigated farms. On the rainfed farms, the contribution of N to yield was half of its contribution on the irrigated farms. For irrigated farms, each day of delay in sowing after the cutoff date of 15 November reduced the yield by 8.0 kg/ha.

Tubewell discharge capacity and conveyance losses. The discharge capacities measured in the 1982 DS ranged between 34 and 104 liters/s for the 10 tubewells with an average of 72.5 liters/s (Table 19). There was, on the average, a 12% loss of discharge capacity in the tubewells compared with the recorded discharge capacity when they were constructed 15-17 yr ago. The greatest discharge loss (21%) occurred in tubewell no. 141, which also had a sand-pumping problem in the 1982 DS; tubewell no. 49 had the smallest loss (1.2%).

The water loss due to S&P from the wetted areas in the conveyance network was measured by the ponding method in the brick-lined main canals and selected earthen field channels in each of the 10 tubewells. Because the soil is light-textured, sandy loam for most areas, a relatively high conveyance loss would be expected in the main canals if the linings are ineffective, especially because the canal beds are at a higher elevation than the surrounding fields.

Table 19. Area actually irrigated and potentially irrigable area for 10 sample tubewells. North Bangladesh Tubewell System, Bangladesh, 1981 and 1982 DS.

Tubewell no.	Measured discharge capacity (liter/s)	Area irrigated (ha)		Potential irrigable area (ha) with daily pumping for			
		1981 DS	1982 DS	4 h	8 h	12 h	16 h
47	104.4	31.6	19.3	28	56	84	112
49	44.4	11.3	4.9	12	24	36	48
51	59.7	2.8	1.0	19	38	57	76
90	76.4	12.1	3.9	23	46	69	92
91	34.5	17.4	4.0	9	18	27	36
116	85.7	25.9	12.3	25	50	75	100
117	62.8	10.5	5.2	16	32	48	64
130	87.7	21.9	7.6	25	50	75	100
141	93.9	4.0	3.4	18	36	54	72
347	75.5	12.7	12.2	21	42	63	84
Av	72.5	15.0	7.4	19.6	39.2	58.8	78.4

The lined main canals had an average conveyance loss of 68 liters/h per m^2 of wetted area. Tubewell no. 141 had the highest rate of loss, 135 liters/h per m^2, which is a 3.5 times greater rate than the minimum found in tubewell no. 51. The wide range of loss rates reflects the high variation in the main canal lining conditions.

The general lining condition in most of the tubewells was unsatisfactory during the season. However, some canal repairs were done during the season and others were scheduled for next season. On the average, about 13% of the pumped water was lost in conveyance from a tubewell if it operated the usual 4 h/d during the 1982 DS. Tubewell no. 141 lost 23%; tubewell no. 51, only 5%.

The earthen channels had an average conveyance loss rate of about 180 liters/h per m^2 of wetted area — 2.5 times higher than the lined canals. The range of loss rates was narrower in these channels than in the main canals. Tubewell no. 130, which has more clay than any other soil among the tubewell sites, had the minimum conveyance loss rate in its field channels.

Why tubewell capacity utilization was low. On the average, only 7.4 ha was irrigated per tubewell during the 1982 DS. In the previous DS, more than double that area, but still very low for the given discharge capacities of the tubewells, was irrigated per unit (Table 19). A survey was conducted with 150 farmers from five tubewells (nos. 51, 90, 117, 141, and 347) to determine their awareness or ignorance of the value of irrigation water and their attitude toward the use of tubewell water. The survey data showed that most farmers understood and appreciated the value of irrigation water. About 93% of the farmers considered not only DS irrigation, but also supplemental irrigation in the aus and aman rice seasons necessary to achieve high yields. Of the 61 farmers who used tubewell water during 1982 DS, 52 reported inadequate supply to their farms. If the water supply uncertainty could be removed, farmer interest in using tubewell water in the DS could increase greatly. About 98% of the farmers indicated that they would plan to use tubewell water in the next DS if the water supply could be assured. The results indicated that any disinterest among farmers is due to their lack of faith in the tubewells' ability to meet their DS water requirement.

Field data collected during the 1982 DS indicate that the low operating hours and water loss seriously impede the irrigation of a greater area with the tubewells.

Low operating hours. On the average, each of the 10 sample tubewells operated only 125 h during the 1982 DS. Lack of electrical power was responsible for 43% of the total tubewell idle time. About 66% of the 61 sample farmers who irrigated their crop during the 1982 DS blamed their water shortages on the absence of the tubewell operator, too much water use by head-end farmers, low discharge capacity of the tubewells, and electrical power supply interruptions.

Water loss. Water loss in the field is high because of the damaged main canals and earthen field channels in the sandy loam soil, the scattered demand for water, the unsystematic delivery schedule, and the nonclosure of canal outlets not scheduled to receive water.

The survey asked farmers what they perceived to be the most critical factors contributing to the small area cropped within the tubewell command area. An overwhelming 94% indicated water shortage as the most serious problem. Other reasons cited were the high cost of fertilizer (90%), nonavailability of MV seeds (39%), and high cost of insecticide (16%).

How much area can be irrigated in the dry season? The average area irrigated during the 1982 DS was only 7.4 ha/tubewell, or about 0.1 ha/liter per second of a well's discharge capacity. On the average, only about 11% of a tubewell's command area was actually served during the DS.

The potentially irrigable area for wheat cultivation was estimated based on the optimum field water requirement of 240 mm of water in four irrigations. If a blockwise irrigation water schedule was followed, in which the service area was divided into three equal blocks, each block would receive water for 5 consecutive days for one irrigation so that each farm received four irrigations at 15-d intervals during the season. The percentage of water loss was assumed to be twice the conveyance loss measured in each tubewell in the main canal during 4 h of pumping.

The average estimated irrigable area for wheat cultivation varied between 20 and 78 ha/tubewell

depending on the length of pump operation (4-16 h/d). The average irrigable area per unit of discharge capacity was about 1.1 ha/liter per second for 16 h of pump operation per day.

Socioeconomic profile of the farmers. The 150 farmers in the sample fell into one of two equal groups — large landholders (≥1 ha in cultivation) and small landholders (<1.0 ha). The median land holding size of the sample was about 1.0 ha. Selected socioeconomic background of the farmers is in Table 20.

Efforts to increase irrigation coverage. Areas served by irrigation during 1981 and 1982 aman seasons (AMS) in a group of 12 selected tubewells were compared. In the 1981 AMS, the system management staff made no special effort to increase the service area of these tubewells. In the 1982 AMS, the concerned staff emphasized improving irrigation coverage of each tubewell. Activities highlighting this effort were:

- completion of measuring devices at the pump discharge point,
- greater supervision of pump operation and water allocation,
- better farmer contact to gain their confidence and motivate them to be better organized for the irrigation activities, and
- attention to the repair needs of canal breaches and construction of necessary field channels.

The total area served from the 12 tubewells in the

Table 20. Socioeconomic profile of farmers. North Bangladesh Tubewell System, Bangladesh, 1982 DS.

Item	Small landholders (n = 75)	Large landholders (n = 75)	Total (*n* = 150)
Av farm size (ha)	0.85	2.66	1.75
Av area irrigated (ha)			
1981 DS	0.27	0.45	0.36
1982 DS	0.22	0.40	0.31
Education level			
No formal education	23	19	42
Primary	39	40	79
Secondary	10	10	20
Higher than secondary	3	6	9
Family size			
1-4 members	20	6	26
5-8 members	41	33	74
more than 8	14	36	50
Tenure status			
Owner	37	34	71
Sharecropper	6	2	8
Owner-leaseholder	5	6	11
Owner-sharecropper	24	33	57
Others	3	0	3
Food production status			
Subsistence level	71	54	125
Surplus level	1	19	20
No answer	3	2	5
Off-farm income source (for family)			
None	53	55	108
Service	4	7	11
Small business	11	4	15
Day labor	2	0	2
Others	5	9	14
Was credit used?			
1981 aus season (yes/no)	34/41	38/37	72/78
1981 aman season	37/38	41/34	78/72
1982 DS	34/41	39/36	73/77

Table 21. Increases in area irrigated in the use of MVs in the 1982 AMS compared with 1981 AMS. Twelve Pilot tubewells, North Bangladesh Tubewell System, Bangladesh.

Tubewell no.	Area irrigated (ha)		Use of MV (%)		Increase achieved in 1982 AMS over 1981 AMS (%)	
	1981 AMS	1982 AMS	1981 AMS	1982 AMS	Irrigated area	MV adoption
63	14.1	31.8	0	56	126	–
77	20.2	30.6	15	38	72	153
89	6.0	32.7	46	59	440	28
93	28.2	34.3	5	74	21	138
117	2.8	28.6	0	62	914	–
118	15.3	38.7	0	58	153	–
119	7.7	26.2	20	50	242	150
120	–	36.3	3	14	–	366
125	23.4	50.4	14	43	116	207
126	16.5	41.4	12	44	149	266
138	23.4	48.4	23	71	107	208
142	16.9	35.9	41	87	112	112
All tubewells	174.6	435.1	15	55	149	–

1982 AMS increased by about 150% over that served in the 1981 AMS (Table 21). The area increase ranged from 21% in tubewell no. 93 to 914% in tubewell no. 117. The achievement indicates the improvement potential in the capacity utilization of all the tubewells in the North Bangladesh Tubewell Irrigation System.

Efforts to increase modern variety use. In 1982, a major effort to increase the use of MVs during the AMS was undertaken by the extension staff. The objective was pursued from the middle of the preceding AMS. Mainly, the following activities were undertaken:

- Target farms that were fallow and those planted to aus rice with potential to grow MVs, considering their aus crop stage, were identified.
- Extension work was intensified to inform target farmers of the different MVs suitable for transplanting early, middle, or late for the AMS.
- Farmer contact was intensified to encourage early planning for MV use in the AMS.
- Field supervision and inspection were intensified as were attempts to solve technical problems, such as a lack of field channels.

Table 21 compares the areas grown to MVs in the 12 tubewells in the 1981 and 1982 AMS. The results achieved in the 1982 AMS indicate the high potential for increasing crop production in the system area by greater adoption of MVs.

Soil and crop management

Soil characterization

Soil Chemistry Department

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NUTRIENT STATUS OF RICE ON SALINE AND SODIC SOILS

Soil salinity and sodicity are strong limiting factors in agricultural production. More than 60 million ha of saline and sodic soils lie uncultivated in South and Southeast Asia although they are climatically and physiographically suited to rice.

A study was conducted on the effects of salinity and sodicity on absorption of nutrients by IR9764-45 in a nearly neutral soil amended to give a wide range of salinity (3-11 dS/m) and sodicity (6-40% exchangeable Na). Sodicity increased the concentration of N and Na in the plant, but depressed that of most of the other elements. Salinity increased the concentration of most elements in the plant, but decreased that of P and Si. Salinity depressed grain and straw yield more than sodicity.

Zn application increased the content of Zn, N, and Mn but decreased that of P, Cu, and Fe. Cu application decreased the concentration of Fe and Zn, but increased that of Cu and Mn (Table 1).

ADSORPTION OF ZINC AND COPPER BY PEAT SOILS

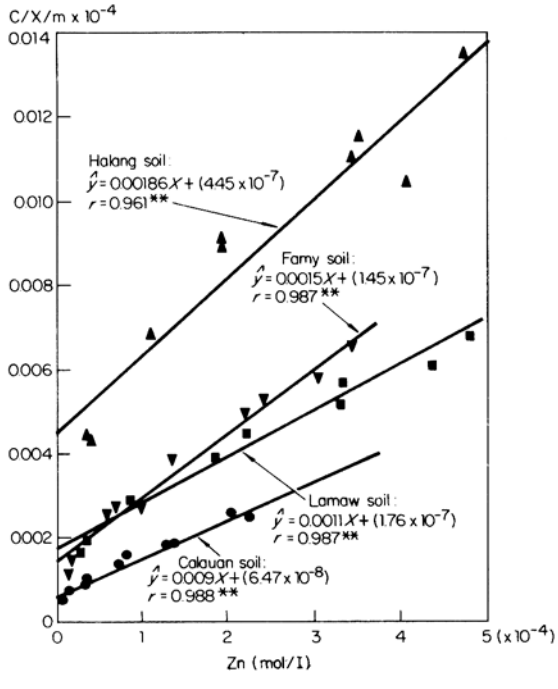
Adsorption reactions of Zn and Cu play a dominant role in their retention in peat soils. The data obtained for Zn and Cu in four peat soils conformed to the Langmuir equation in linear form (Fig. 1), showing that surface adsorption is an important process regulating the concentration of Zn and Cu in peat soil solution.

The organic matter content of the peat soils correlated significantly with the adsorption maximum of Zn (Fig. 2), but not with that of Cu. The adsorption of Cu may take place only on specific fractions of organic matter. The amount of Cu (97-100%) adsorbed by each soil was considerably higher than that of Zn (70-96%).

Table 1. Effect of Zn and Cu application on the content of elements in rice shoots 65 DAS. IRRI, 1982.

Treatment				Mineral content					
EC[a] (dS/m)	ESP[b]	Zn (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	N (%)	P (%)
5	16	12	6	44.8	12.2	83	587	1.74	0.252
5	16	36	6	57.3	9.8	76	661	1.83	0.242
5	16	12	18	40.7	17.7	73	669	1.68	0.250

[a]Electrical conductivity. [b]Exchangeable sodium percentage.

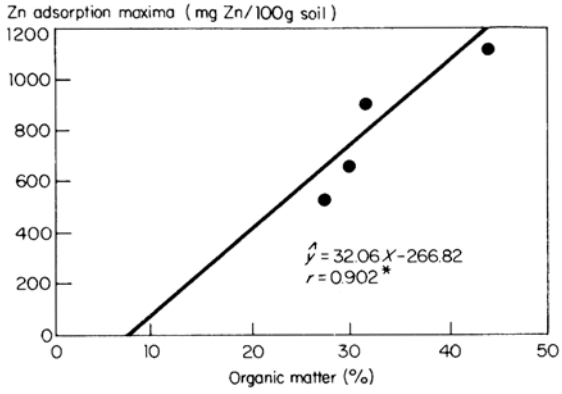


1. Langmuir isotherms for Zn adsorption of four peat soils. IRRI, 1982.

DECOMPOSITION OF ORGANIC MATTER IN RICE FIELDS

Although organic manures are assuming increasing importance in rice production, there is little information on the decomposition of organic matter in flooded soils in the tropics. It is generally believed that flooding slows down the decomposition.

In field experiments on the IRRI farm, ^{14}C-labeled rice straw was incorporated at different



2. Correlation between organic matter content and adsorption maxima for Zn. IRRI, 1982.

depths of the top 20 cm of a soil permanently submerged for 1 yr. Two rice crops were grown on half of the plots; the rest of the plots were kept fallow.

After 1 yr, the soil was sampled and the remaining specific activities of the resulting CO_2 were determined by wet combustion in a high-vacuum line and measured by scintillation counting.

Table 2 shows the changes in the specific activities related to different layers of straw incorporation. The remaining ^{14}C-carbon from the incorporated straw in the soil ranged from 7 to 20% after 1 yr with a marked difference between the puddled layer (0-10 cm) and the deeper layers (10-20 cm). No difference was found between fallow and cropped plots.

Table 2. Changes in specific activity of soil C after incorporation of ^{14}C-labeled rice straw. IRRI, 1982.

Depth of incorporation (cm)	Specific activity (μC/mmol)		Remaining ^{14}C (%)
	0 mo[a]	12 mo[a]	
0-5	0.88	0.08	9
5-10	0.70	0.05	7
10-15	0.50	0.09	18
15-20	0.49	0.10	20

[a]After incorporation.

HUMUS CHARACTERIZATION OF WETLAND SOILS

Humus composition of soils of the IRRI farm under different cultural management practices was compared with that of two other soils (Table 3). Humus was extracted with 0.1 *M* NaOH and 0.1 *M* $Na_4P_2O_7$. The results showed:

- the composition of humus differed according to soil properties and management,
- the amount of extracted humus decreased with increasing acidity,
- removing straw decreased the amount of extracted humus, and
- acid soils had relatively more fulvic acids and less humic acids.

Spectrophotometric characteristics showed that humic acid from the uncultivated Maahas clay had a higher degree of humification.

AVAILABILITY OF MICRONUTRIENTS IN AEROBIC SOILS

To determine available Fe, Mn, Cu, and Zn in aerobic soils planted to rice, three extraction

Table 3. Amounts[a] of humus components from extracted wetland soils. IRRI, 1982.

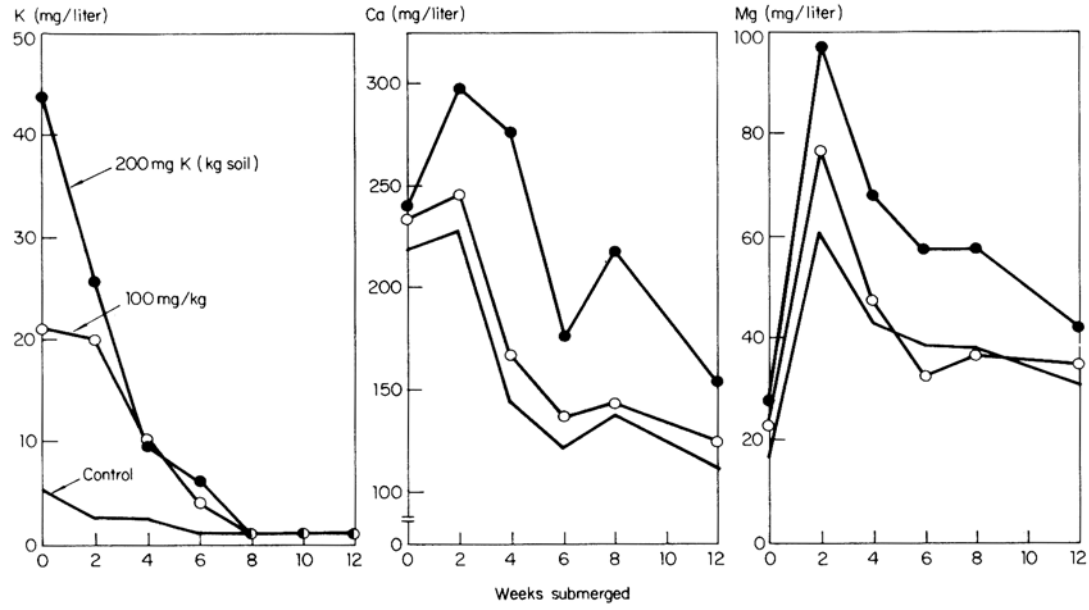
Soil	pH	Organic C (%)	0.1 *M* NaOH extractable		0.1 *M* $Na_4P_2O_7$ extractable		Total extracted humus
			Fulvic acid	Humic acid	Fulvic acid	Humic acid	
Luisiana clay	5.4	1.6	10.7	2.3	1.7	0.5	15.2
Pila clay loam	7.2	2.5	11.8	8.7	1.4	10.1	31.9
Maahas clay	6.0	1.4					
Uncultivated			7.9	5.1	1.7	7.8	22.5
Straw incorporated			6.1	6.8	1.9	5.6	20.3
Straw removed			4.6	3.8	1.5	4.9	14.7

[a]Expressed as the amount of 0.1 *M* $KMnO_4$ (ml/g of air-dried soil) consumed.

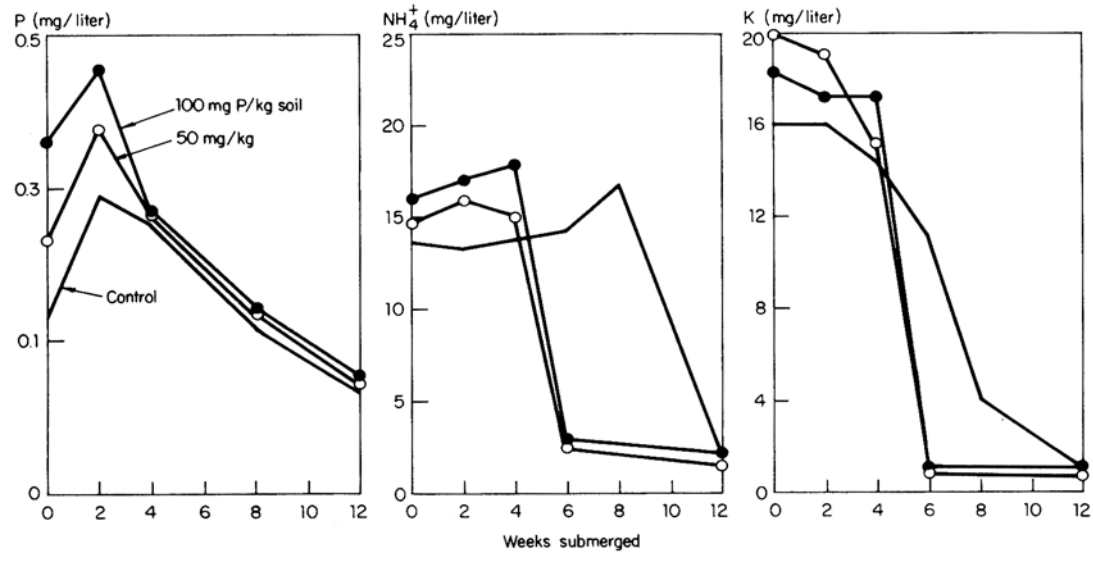
methods with DTPA, NH_4OAc, and 0.05 *M* HCl, which are simple, reliable, rapid, and inexpensive, were tested using 30 selected soils of the Philippines ranging in pH from 4.0 to 8.3.

The nutrient content of rice grown on these soils under aerobic conditions for 8 wk in the 1982 WS and DS was measured and correlated with the soil test values.

Not one of the methods was suitable for Fe. For the other nutrients 0.05 *M* HCl extraction worked best. Correlations between Cu, Zn, and Mn content of rice and soil test values were highly significant.



3. Effect of K fertilization on the kinetics of the soil solution of a K-deficient soil. IRRI, 1982.



4. Effect of P fertilization on the kinetics of the soil solution of a P-deficient soil. IRRI, 1982.

CHEMICAL KINETICS OF A K-DEFICIENT SOIL AND A P-DEFICIENT SOIL

In the greenhouse, the kinetics of the soil solutions of a K-deficient soil and a P-deficient soil was studied. The addition of K to the K-deficient soil increased not only its concentration in the soil solution, but also the availability of Ca and Mg (Fig. 3). P fertilization of a P-deficient soil increased the availability of P, NH_4^+, and K in the soil solution (Fig. 4).

P at 50 mg/kg and K at 100 mg/kg fertilization significantly increased the yields of IR26 and IR42. However, no difference was observed in grain yields of the two rices at the higher levels of applied P and K.

Table 4. Effect of four straw treatments on rice yield and the nutrient status of Maahas clay after the 20th crop. IRRI, 1982.

Straw treatment	Grain yield (t/ha)	Organic C (%)	Total N (%)
Removed	4.0 b	1.74 b	0.179 c
Burned	4.1 ab	1.75 b	0.180 c
Incorporated	4.5 a	1.94 a	0.195 b
Composted and added	4.3 ab	2.03 a	0.213 a

STRAW MANAGEMENT

Drum studies and field experiments were continued. The results of these long-term experiments in IRRI farm confirmed earlier findings that straw incorporation each season without fertilizer improves the nutrient status of the soil. The grain yield differences were not significant in 1982 (Table 4).

Soil and crop management

Management of soil and fertilizer nitrogen

Agronomy, Soil Chemistry, and Soil Microbiology Departments, University of California, Davis Cooperative Experiments, and IRRI-International

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VARIETAL DIFFERENCES IN ABILITY TO EXPLOIT SOIL NITROGEN USING ^{15}N-DEPLETED AMMONIUM SULFATE

Agronomy Department and University of California, Davis, Cooperative Experiments

During the 1982 DS and WS, experiments were conducted in three locations at IRRI to evaluate 105 rices for the ability to exploit soil N in wetland conditions. The experiments were carried out in a split-plot design with three replications. The main plots had two N levels (0 and 30 kg N/ha); the subplots had rice varieties and lines grouped by maturity. Group 1 was composed of early-maturing rices (100 d); group 2, medium-maturing rices (105-115 d); and group 3, late-maturing rices (120-135 d). In one experiment, ^{15}N-depleted ammonium sulfate (AS) was used on 33 varieties and lines, ordinary AS was applied on 72 rices distributed in two experiments.

Grain yield. Yield differences among varieties and lines were significant. Generally, late-maturing rices yielded higher than medium- or early-maturing ones.

^{15}N-depleted ammonium sulfate. In an experiment using ^{15}N-depleted AS, an application of 30 kg N/ha produced 6 t/ha or more during the DS with early-maturing IR22097-41-4-3, IR9752-71-3-2, and IR9729-67-3; medium-maturing IR9761-19-1; and late-maturing IR15314-30-3-1-3. During the WS, late-maturing IR15314-30-3-1-3 and IR19672-140-2-3-2-2 yielded more than 5 t/ha.

Without N fertilizer during the DS, early-maturing IR15429-268-1-2-1; medium-maturing IR25588-32-2, IR21015-136-1-2-3-1, and IR21912-56-3-1-2-2; and late-maturing IR15323-78-1-3-1 yielded more than 5 t/ha. In the WS, only late-maturing IR15314-30-3-1-3 yielded more than 5 t/ha.

In the DS, the lowest yielders without N application were early-maturing IR8608-189-2-2-1-3 and IR22097-41-4-3 (3.6 t/ha); medium-maturing IR13429-287-3, and late-maturing IR15314-30-3-1-3 (3.2 t/ha). In the WS, early-maturing IR19799-9-1-2-2-2 yielded lowest (2.9 and 2.7 t/ha) with and without fertilization. Late-maturing IR3525-43-2-3-1-3-2 yielded 4.3 with N fertilizer and 3.3 t/ha without. Yields were generally higher among the late-maturing than among the medium- and early-maturing varieties and lines.

Ordinary ammonium sulfate. In the DS experiments using ordinary AS, late-maturing IR25586-108-1-2 yielded highest (6.7 t/ha) at 30 kg N/ha, followed by medium-maturing IR13429-150-3-2-1-2 (6.3 t/ha). Early-maturing IR19743-8-1-2-2-2 and IR19728-6-3-2-2-3 yielded 5.5 t/ha and 5.0 t/ha.

Differing abilities to utilize soil nitrogen. Without N application during the DS, late-maturing IR19672-155-2-1-1-3 yielded 6.9 t/ha; medium-maturing IR13429-150-3-1-2, 5.7 t/ha; and early-maturing IR19743-25-2-2-3-1, 4.4 t/ha.

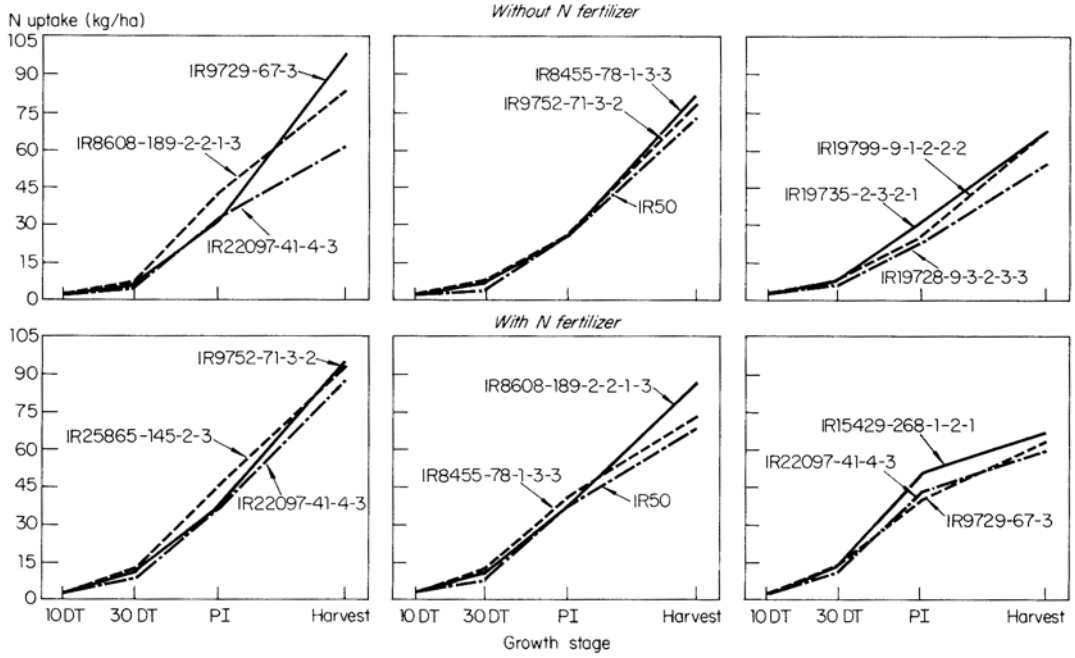
In the WS, late-maturing IR25586-108-1-2 and IR19672-155-2-1-1-3 yielded more than 5 t/ha with and without N fertilizer application. Medium-maturing IR13429-150-3-2-1-2 produced more than 4 t/ha.

Nitrogen content of rice. Regardless of maturity, more N was found in the leaves than in the culm during the vegetative stage. However, the N content at harvest was highest in the grains and next highest in the straw. The roots had the least N.

Nitrogen uptake. The ability of rice to exploit N in soil was examined through its absorption pattern. N uptake at various growth stages indicated that the magnitude of variability among the maturity groups differed depending on the growth stage of the rice plant (Fig. 1, 2, 3). In the early-maturing rices, the rate of N absorption was initially slow, but it increased between 10 DT and harvest (Fig. 1). However, N uptake of long-duration rices (120-135 d) was generally faster during early growth stages, and slowed down at 30 DT to panicle initiation (PI). From PI, the absorption of N further increased until harvest (Fig. 3).

Among the three maturity groups without N fertilizer, early-maturing IR9729-67-3 had the highest total N uptake (136 kg N/ha) and IR19728-9-3-2-3-3 the lowest (84 kg N/ha). Medium-maturing IR21912-56-3-1-2-2 had the highest (150 kg N/ha) and IR18349-135-2-3-2-1 the lowest (110 kg N/ha); late-maturing IR42 had the highest (213 kg N/ha) and IR22082-41-2 the lowest (107 kg N/ha).

Although early-maturing IR22097-41-4-3 and IR9752-71-3-2, and medium-maturing IR25861-45-2-3 and IR13429-287-3 had high N uptakes at 30 kg N/ha, they yielded lower than when no N fertilizer was applied.



1. Varietal differences in the utilization of soil N in transplanted rice of early maturity (100 d) with N fertilizer (30 kg N/ha) and without N fertilizer. IRRI, 1982 DS.

SOURCES AND METHODS OF NITROGEN APPLICATION IN WETLAND RICE

Agronomy Department

The efficiency of slow-release forestry-grade sulfur-coated urea (SCU), AS, and prilled urea (PU) with or without dicyandiamide (DCD), a nitrification inhibitor, was tested using IR36 with various application methods. DCD contains 66.6% plant-utilizable N after degradation. This N content was, however, not computed as an N source in the DS, but was considered in the WS.

Dry season. Results showed that PU and AS plus 10% or 15% DCD broadcast and incorporated (B&I) during the final harrowing gave comparable yields to those split-applied with PU or AS without DCD (Table 1). Surface broadcast PU with and without DCD gave comparable yields, which, however, were significantly lower than B&I SCU, PU with 10% or 15% DCD, and AS with 15% DCD.

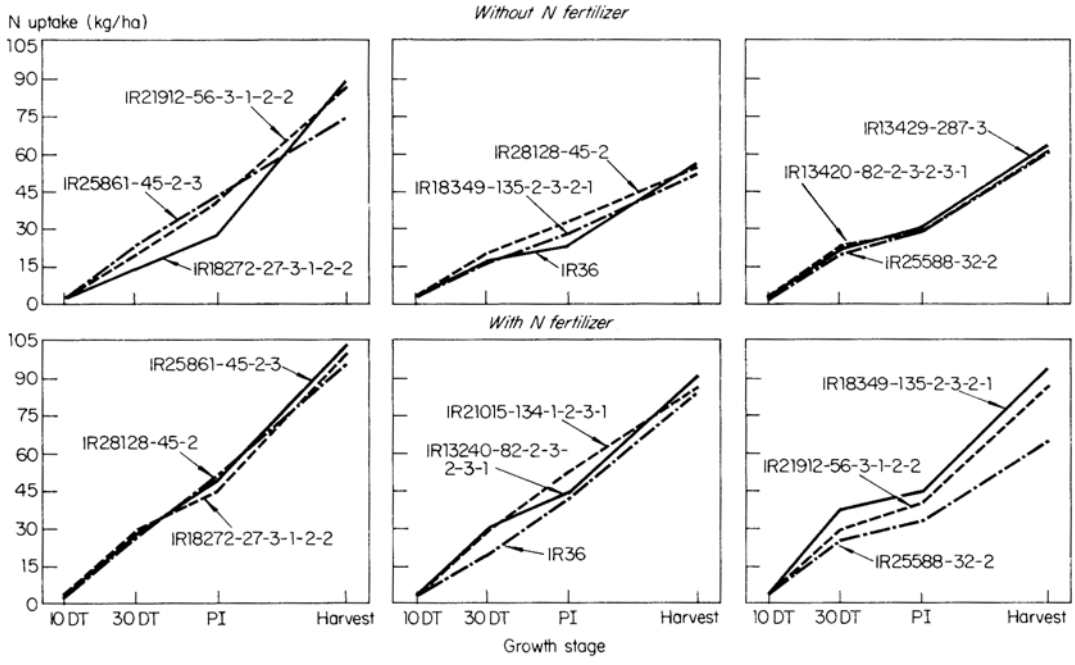
PU surface broadcast after transplanting at 90 kg N/ha increased the yield 1.4 t/ha over the unfertilized control. The yield was further increased by 0.8 t/ha with the researchers' split application of PU over surface broadcast at the same N rate. These results confirmed previous findings that incorporation of the first dose of N fertilizer into the soil considerably increases rice yields, compared with a surface broadcasting of the full dose immediately after transplanting.

Wet season. Yield differences were not significant when rice was irrigated, probably because of the high native soil exchangeable NH_4^+-N (12-25 ppm) during the first 20 DT (Table 2). In rainfed conditions, the SCU application at 45 kg N/ha and the 75-kg N/ha researchers' split application of PU or AS gave comparable yields. However, the researchers' method and the farmers' practice produced comparable yields. Similarly, full-dose incorporation of broadcast PU or AS amended with DCD showed no advantage over the researchers' split application of unamended PU or AS.

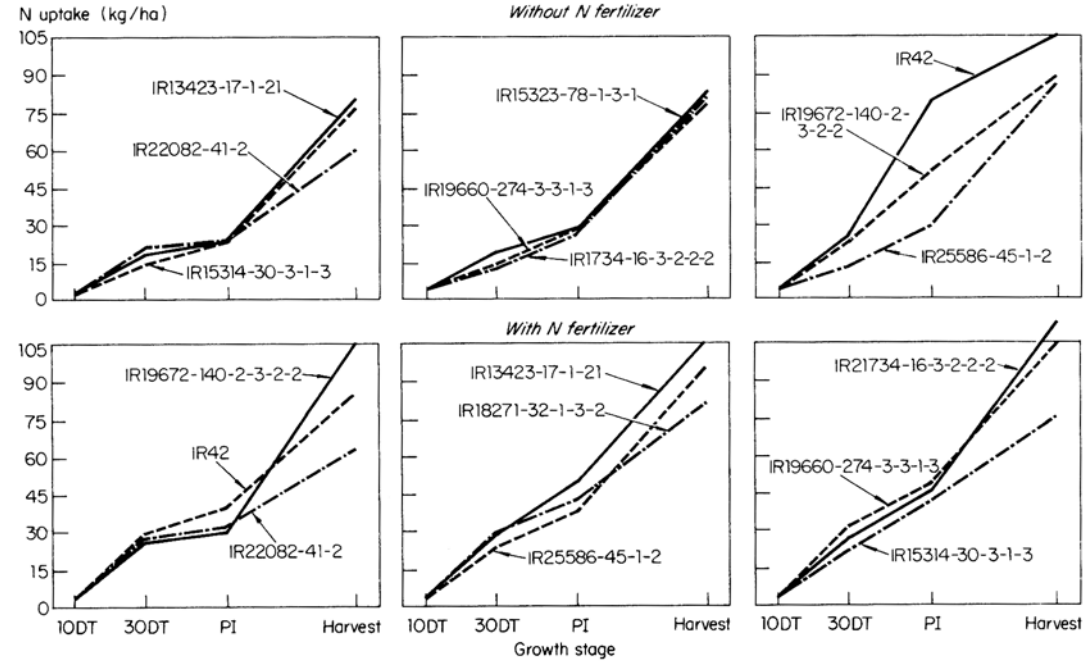
EVALUATION OF PLACEMENT MACHINES TO INCREASE N EFFICIENCY IN IRRIGATED RICE

Agronomy Department

Different placement machines and methods of N application using PU and urea supergranules (USG) were evaluated during the 1982 WS at IRRI and the Philippine Bureau of Plant Industry's Maligaya Rice Research and Training Center



2. Varietal differences in the utilization of soil N in transplanted rice of medium maturity (105-115 d) with N fertilizer (30 kg N/ha) and without N fertilizer. IRRI, 1982 DS.



3. Varietal differences in the utilization of soil N in transplanted rice of late maturity (120-135 d) with N fertilizer (30 kg N/ha) and without N fertilizer. IRRI, 1982 DS.

(MRRTC) in Muñoz, Nueva Ecija. Two experiments were carried out at IRRI and one at MRRTC.

In the first experiment at the IRRI farm, IR36 yields did not significantly differ among the sources of urea and application methods (Table 3). A

Table 1. IR36 yield response to various N sources and application methods. IRRI, 1982 DS.

N source	Rate (kg N/ha)	Application method	Yield[a] (t/ha)
No N fertilizer	0	–	4.2 d
PU	90	Basal, surface broadcast	5.6 c
PU	90	Researchers' split	6.4 ab
PU + 10% DCD	90	Basal, B&I	6.7 a
PU + 15% DCD	90	Basal, surface broadcast	5.7 bc
PU + 15% DCD	90	Basal, B&I	6.9 a
AS	90	Researchers' split	6.3 abc
AS + 10% DCD	90	Basal, B&I	6.4 ab
AS + 15% DCD	90	Basal, B&I	6.9 a
Forestry-grade SCU	90	Basal, B&I	6.7 a
PU	150	Researchers' split	6.9 a
AS	150	Researchers' split	6.6 a

[a]Av of four replications.

Table 2. IR36 (irrigated and rainfed) yield response to various N sources and application methods. IRRI, 1982 WS.

Source	Rate (kg N/ha)	Application method	Yield[a] (t/ha)	
			Irrigated	Rainfed
No N fertilizer	0	–	3.6 b	2.1 f
PU	45	Surface broadcast	3.6 b	2.6 ef
PU	45	Farmers' split	3.7 ab	2.8 de
PU	45	Researchers' split	3.9 ab	3.2 cd
PU + 10% DCD	45	Surface broadcast	3.6 b	2.8 de
PU + 10% DCD	45	B&I	3.9 ab	3.2 cd
AS	45	Researchers' split	4.1 a	3.4 bc
AS + 10% DCD	45	Surface broadcast	3.8 ab	2.8 de
AS + 10% DCD	45	B&I	3.8 ab	3.1 cde
Forestry-grade SCU	45	B&I	3.9 ab	3.8 ab
PU	75	Researchers' split	3.8 ab	4.1 a
AS	75	Researchers' split	4.1 a	4.2 a

[a]Av of four replications.

Table 3. IR36 yield response to various urea sources and application rates and methods. IRRI, 1982 WS.

Urea source	Actual rate applied (kg N/ha)	Application method	Yield[a] (t/ha)
No N fertilizer	0	–	3.2 c
PU	58	Researchers' split	4.0 ab
USG	58	Point placement by hand	4.4 a
PU	37	Point placement by spring auger	4.4 a
PU	57	Band placement by spring auger	4.4 a
USG	58	Point placement by deep plunger	4.4 a
USG	58	Point placement by furrower	4.4 a
USG	59	Point placement by electrically operated furrower	4.1 ab
PU	39	Point placement by liquid injector after transplanting	4.0 ab
PU	55	Point placement by liquid injector with transplanter	3.7 b

[a]Av of four replications. A typhoon hit the mature crop and shattered some grains.

Table 4. IR36 yield response to various urea sources and application rates and methods. 1982 WS.

Urea source	Rate (kg N/ha)	Application method	Yield[a] (t/ha)		Mean
			IRRI	MRRTC	
No N fertilizer	0	–	4.1 b	3.2 d	3.7
USG	29	Point placement by deep plunger	4.3 b	4.3 bc	4.3
PU	29	Point placement by liquid injector	4.8 ab	4.8 ab	4.8
USG	58	Point placement by deep plunger	5.0 ab	5.2 a	5.1
PU	58	Point placement by liquid injector	5.5 a	5.1 a	5.3
PU	58	Farmers' split	4.4 ab	4.0 c	4.2
PU	58	Researchers' split	5.0 ab	4.3 bc	4.7
PU	87	Farmers' split	4.7 ab	4.4 bc	4.6
PU	87	Researchers' split	4.9 ab	4.8 ab	4.9

[a]Av of four replications.

strong typhoon severely affected the crop at maturity resulting in poor yield differences. All fertilized plots, however, significantly outyielded the unfertilized plots.

In the second experiment at IRRI, the highest yield (5.5 t/ha) resulted from a point placement of 58 kg N/ha PU solution using a transplanter with liquid injector (Table 4). In MRRTC, IR36 yielded 5.2 t/ha with the same N rate by point placing USG with a deep plunger 4 DT. At both sites with the same N rate, yields from point-placed N fertilizers, using both machines, were higher than either farmers' or researchers' split application at 87 kg N/ha. Regardless of location, the farmers' and researchers' split applications of urea at 87 kg N/ha were only comparable with application with a transplanter with liquid injector at 29 kg N/ha.

AMMONIA VOLATILIZATION

Soil Chemistry and Agronomy Departments, IRRI-International Fertilizer Development Center (IFDC) Cooperative Experiments

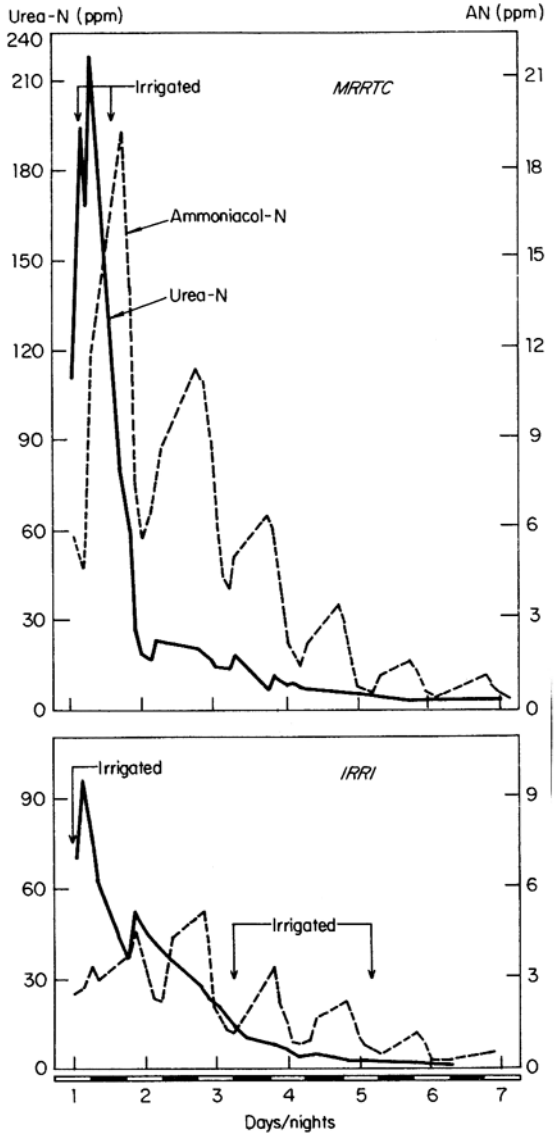
NH_3 volatilization was studied at IRRI and MRRTC using the mass balance micrometeorological technique. Urea was either B&I immediately before transplanting or topdressed into the floodwater 14 or 21 DT and 5-7 DBPI.

Floodwater urea and ammoniacal N. The concentrations of urea and ammoniacal N (AN) in the floodwater after the incorporation of urea into the Maligaya silty clay loam (MRRTC) and Maahas clay (IRRI) are shown in Figures 4, 5, 6. In the MRRTC study, floodwater urea-N peaked at 215 ppm, 8 h after urea incorporation (Fig. 4). Peak urea concentration (100 ppm) was lower in the IRRI study where a lower urea application rate was also used (Fig. 4). Floodwater urea concentration declined rapidly with time with low concentrations resulting 2-3 d after fertilizer incorporation.

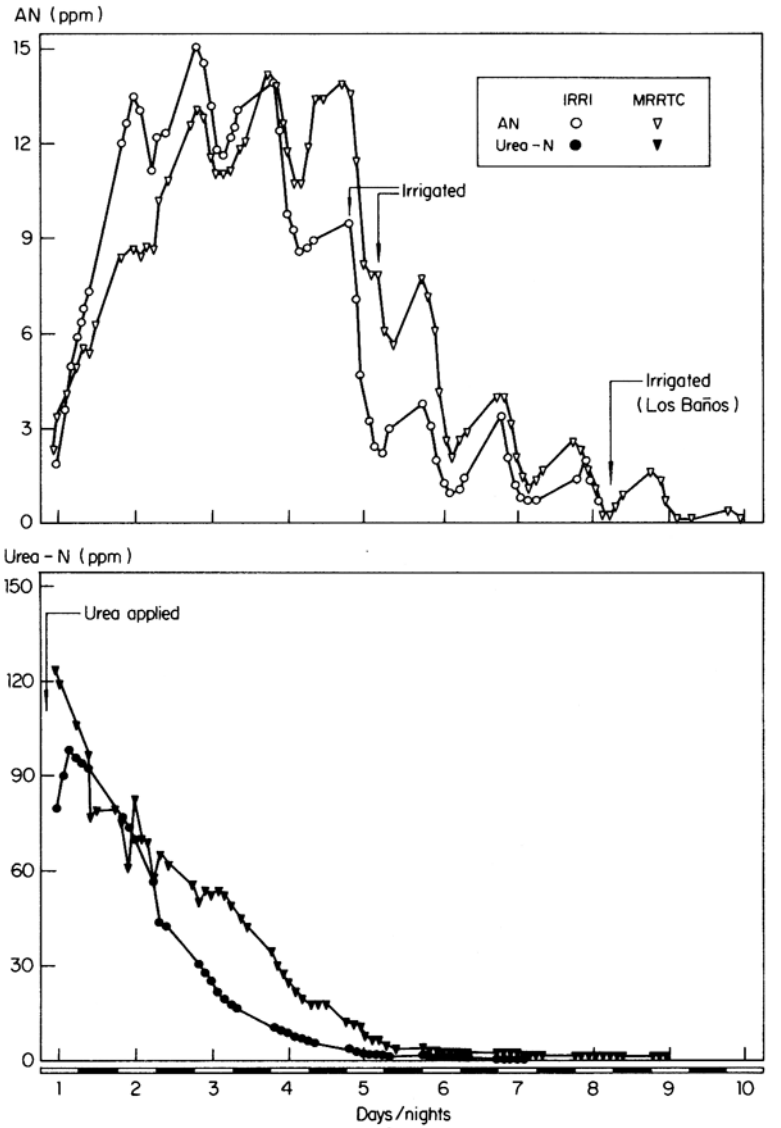
AN concentrations in the floodwater increased rapidly in both B&I studies, reaching a peak of 20 ppm at MRRTC on day 2, but only 5 ppm at IRRI on day 3 (Fig. 4). In both studies, floodwater AN concentrations decreased sharply thereafter, reflecting gaseous N loss, immobilization of AN by aquatic flora, absorption of AN on the soil exchange sites, and increased floodwater depth.

Topdressing urea into the floodwater after transplanting also resulted in high urea concentrations and elevated AN levels, even in deeper floodwater (Fig. 5). At MRRTC, the urea concentration in the floodwater peaked at 120 ppm, 2 h after topdressing; at IRRI, where a lower urea application was used, urea concentration peaked at 100 ppm. In both studies, rapid urea hydrolysis resulted in the depletion of most of the floodwater urea within 4 d of application. AN level increased concomitantly with urea hydrolysis, reaching values of 14-15 ppm AN after 2-3 d in both studies (Fig. 5). In contrast to the B&I studies, floodwater AN levels in the topdress studies remained high over 3 d (Fig. 5).

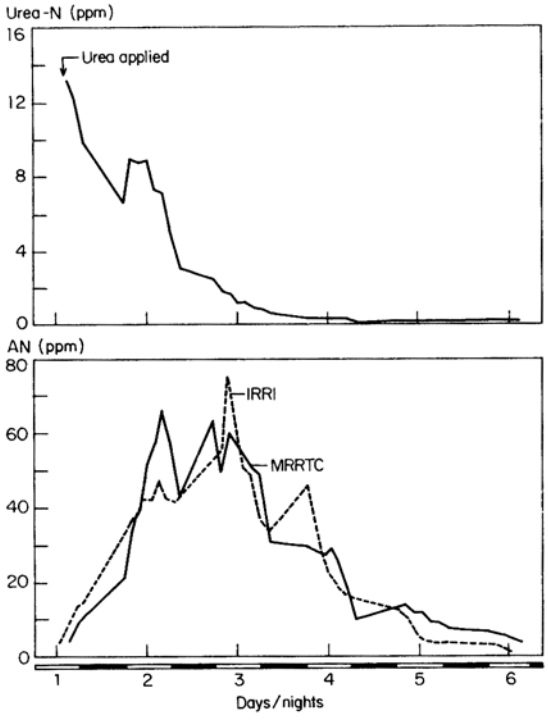
Delaying topdressing of urea until immediately before PI at MRRTC and IRRI did not appreciably reduce the peak AN concentration in the floodwater, even though only half the urea was topdressed (Fig. 6). However, the AN concentration in the floodwater declined more rapidly with time than observed in the 14- and 21-DT topdress-



4. Urea and AN concentrations in floodwater after basal broadcast and incorporation of urea. MRRTC and IRRI, 1982.



5. Urea and AN concentrations in floodwater after topdressing urea at 14 DT (MRRTC) and 21 DT (IRRI). MRRTC and IRRI, 1982.



6. Urea and AN concentrations in floodwater after application of urea 5-7 d before panicle initiation. MRRTC and IRRI, 1982.

ing studies (Fig. 6) — a feature that likely reflects the lower urea input and the increased competitiveness of the rice plant for N fertilizer topdressed at this growth stage. However, the initially high AN concentrations in the floodwater indicates a potential for NH_3 volatilization, should pH and wind speed also be favorable.

Floodwater AN concentration followed a marked diurnal pattern. This feature was especially pronounced in the B&I studies where overall AN levels in the floodwater were low (Fig. 4). In all studies, the floodwater AN level peaked daily at 0600-0700 h and was lowest early in the afternoon.

Floodwater pH. Floodwater pH followed a diurnal pattern at the MRRTC and IRRI regardless of fertilizer management (Fig. 7). The diurnal fluctuation in pH measured in the floodwater in areas surrounding the circular field was similar to that measured in the floodwater amended with urea at 14 or 21 DT (Fig. 7a).

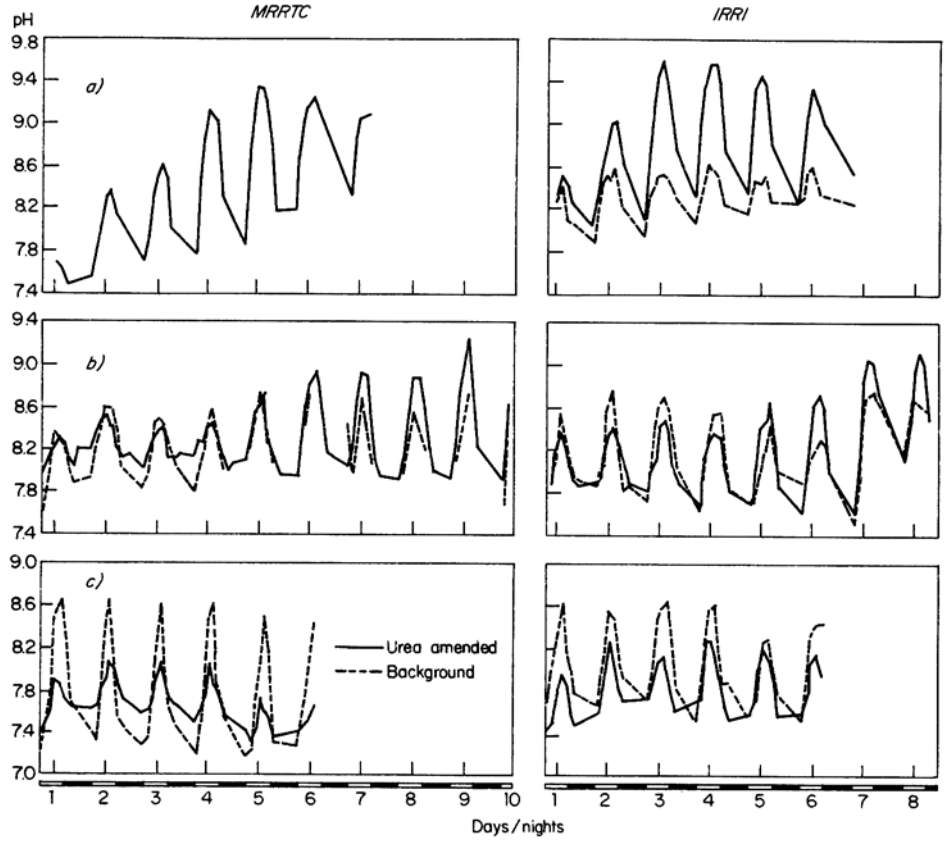
The role of photosynthetic organisms is further highlighted in the pH values obtained from both PI topdress studies (Fig. 7c). In these studies, floodwater pH showed a greater diurnal fluctuation in the surrounding unfertilized areas. The crop canopy was appreciably denser in the circular field where the rice plants had received urea either 14 or 21 DT. As a result, less light reached the floodwater in the circular field area, lowering the amplitude of the pH fluctuation. Only in the IRRI B&I study did the floodwater pH values in the circular field consistently exceed those in the nonfertilized, background areas (Fig. 7b). However, only in the IRRI study was an algal bloom observed after urea application, a fact clearly reflected in the sharply increased diurnal pH fluctuation.

Ammonia fluxes. NH_3 volatilization followed a characteristic diurnal pattern in all the studies (Fig. 8, 9, 10). As a rule, the NH_3 loss peaked between 1200 and 1400 h and was lowest overnight. NH_3 volatilization was always detected soon after urea application.

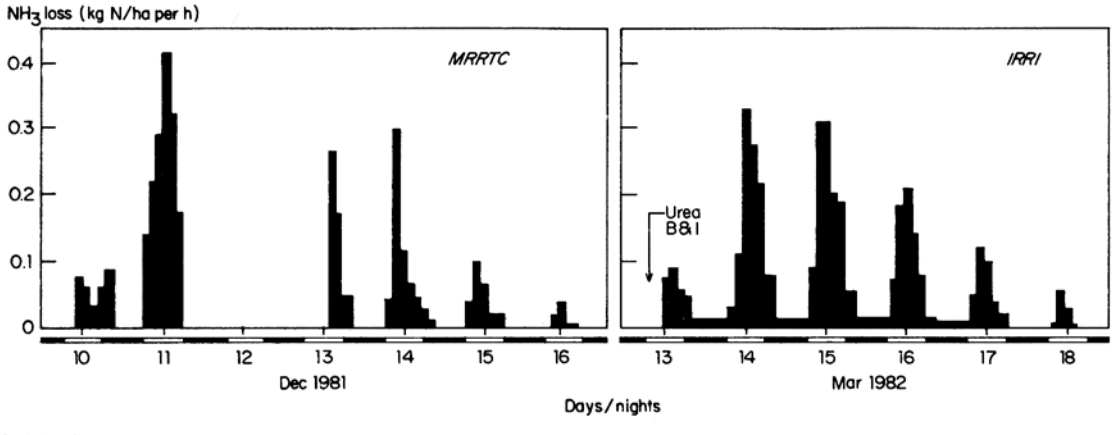
N fertilizer management affecting floodwater AN level (Fig. 4, 5, 6) had a pronounced effect on the daily NH_3 fluxes and the total NH_3 loss measured with time. The NH_3 fluxes measured after the incorporation of 60 kg N/ha urea-N to the Maahas clay are in Figure 8. The peak NH_3 flux (0.34 kg N/ha per hour) occurred on the second day after fertilizer application when 2.5 kg N was lost through NH_3 volatilization. The total measured loss over the 6 d when NH_3 volatilization was detected amounted to 7.7 kg N/ha or 13% of the urea-N applied. A similar pattern of NH_3 loss may have occurred when urea was B&I into the Maligaya silty clay loam (Fig. 8).

Substantially larger NH_3 fluxes were obtained where urea was topdresed into floodwater 14 DT at MRRTC or 21 DT at IRRI (Fig. 9). The peak NH_3 flux for the MRRTC experiment approached 0.84 kg N/ha per hour. On 21 Jan, NH_3 volatilization accounted for 8 kg N/ha or about 10% of the urea-N applied. The total measured NH_3 loss to the atmosphere during the MRRTC experiment was 37.5 kg N/ha from the application of 80 kg N/ha (47% of the urea-N topdressed).

Overall NH_3 fluxes from the flooded Maahas clay after urea was topdressed into floodwater at 21 DT were lower than those from the MRRTC silt clay loam (Fig. 9). NH_3 fluxes exceeded 0.55 kg N/ha per hour at 1200 h on 31 Mar and 1 Apr, but the peak daily fluxes dropped rapidly after the



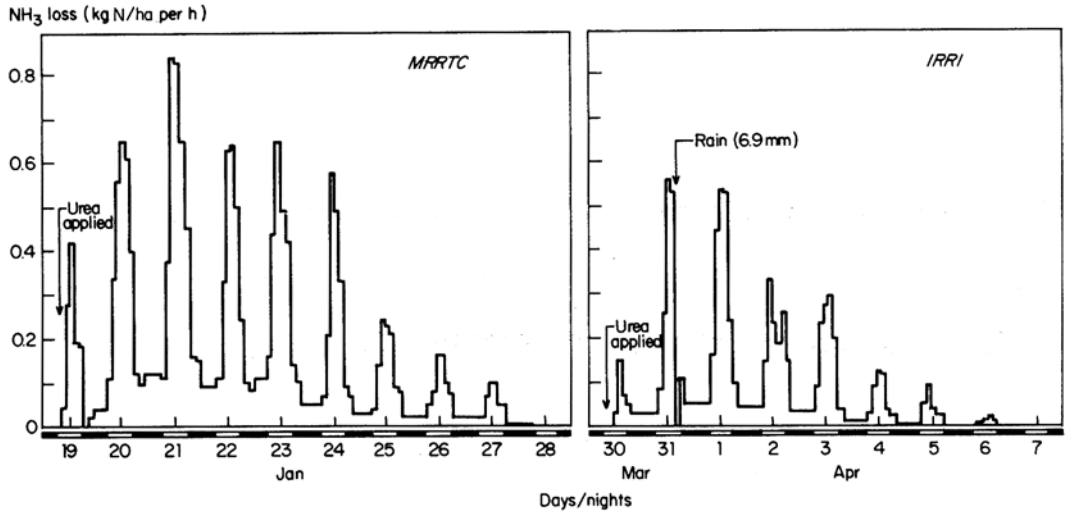
7. Floodwater pH in urea-amended and nonfertilizer areas: *a*, urea applied basally and incorporated; *b*, urea topdressed to floodwater 14 DT (MRRTC) and 21 DT (IRRI); *c*, urea topdressed 5-7 d before panicle initiation. MRRTC and IRRI, 1982.



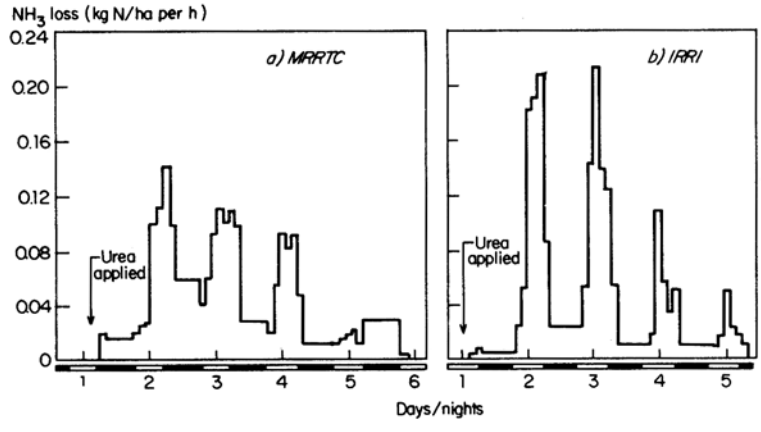
8. NH_3 fluxes following basal incorporation of urea fertilizer at a rate of 87 kg N/ha (MRRTC) and 60 kg N/ha (IRRI). MRRTC and IRRI, 1982.

third day following urea application (3 Apr) and NH_3 volatilization was complete within 7 d. Consequently, the total measured NH_3 loss accounted for only 27% of the N topdressed at 21 DT at IRRI compared with the 47% NH_3 loss at MRRTC.

The AN level (Fig. 5) and floodwater (Fig. 7a)



9. NH_3 fluxes after application of urea to floodwater at 87 kg N/ha 14 DT (MRRTC) and 60 kg N/ha 21 DT (IRRI). MRRTC and IRRI, 1982.



10. NH_3 fluxes following urea application 5-7 d before panicle initiation: *a*, 40 kg N/ha; *b*, 30 kg N/ha. MRRTC and IRRI, 1982.

were comparable in both studies, indicating that other factors limited NH_3 volatilization in the IRRI study. Application of urea at 21 DT instead of 14 DT resulted in increased N uptake by the rice crop, but the difference did not entirely explain the lower NH_3 loss. Floodwater temperature was higher at IRRI, increasing the potential for NH_3 loss. However, wind speed was appreciably lower at IRRI during the crucial stage of the NH_3 loss study and it is likely that the low wind speed restricted gaseous transfer from the floodwater surface. Wave action was also apparent in the floodwater at MRRTC but negligible at IRRI under the low wind speeds and in the presence of a more developed rice canopy. High wind speed could also increase the turbulence in the floodwater, and concomitantly lower the liquid phase resistance in addition to the effect on the gaseous phase resistance. Thus, the prevailing weather at MRRTC during the topdress study may have been ideal for NH_3 volatilization, while that at IRRI was not.

NH_3 loss was also significant where urea was topdressed 5-7 DBPI (Fig. 10). The total measured NH_3 loss accounted for 11% of the urea-N topdressed at MRRTC and 15% at IRRI.

ROLE OF UREASE INHIBITORS IN REDUCING NITROGEN LOSSES IN WETLAND RICE — IRRI-IFDC COOPERATIVE EXPERIMENTS

Agronomy Department

The role of urease inhibitors in improving the efficiency of broadcast urea for wetland rice was evaluated at the IRRI farm. The potential of urease inhibitors for reducing NH_3 volatilization losses from urea surface broadcast into flooded soils was earlier reported. Urea with phenylphosphorodiamidate (PPD) retarded urea hydrolysis and delayed the appearance of aqueous NH_3 in the floodwater.

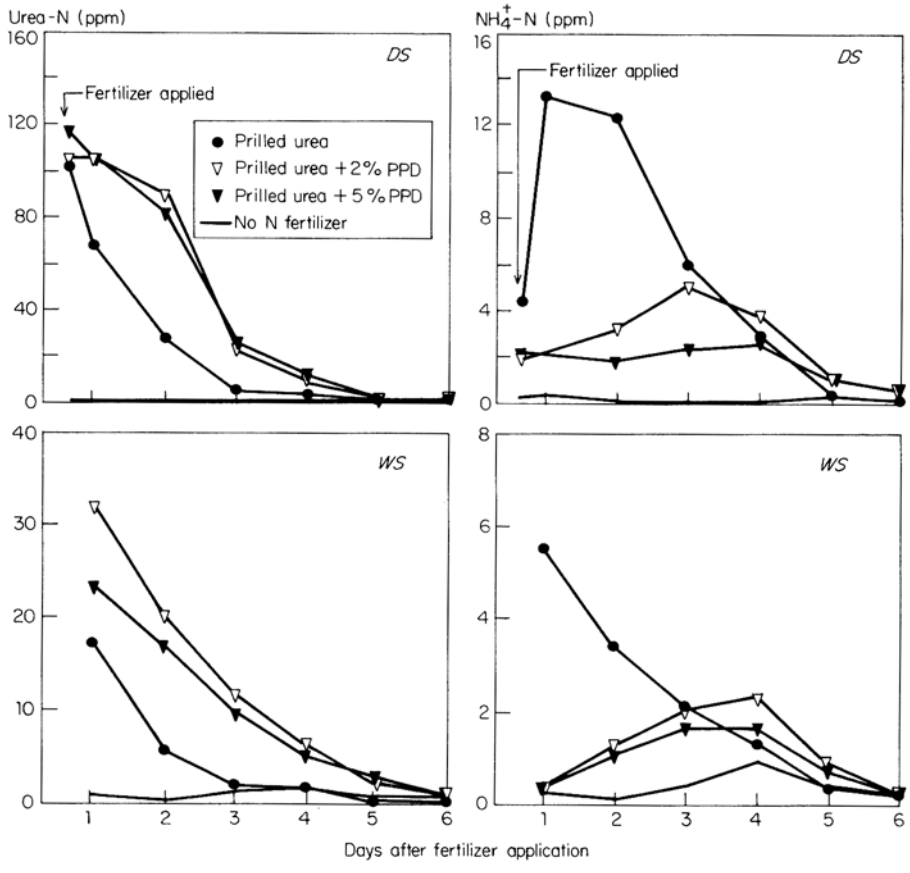
Results of field experiments at the IRRI farm in the DS and WS confirmed that PPD retarded urea hydrolysis to reduce NH_3 volatilization loss, particularly with urea broadcast into the floodwater 20 DT (Fig. 11). However, urea with PPD and urea that did not have the urease inhibitor gave comparable grain yield (Table 5).

In the DS, results confirmed previous reports that incorporation of the first dose of N fertilizer into the soil just before transplanting significantly increased the yield over surface broadcast fertilizer. In the WS, incorporation showed no advantage over surface broadcast urea (Table 6).

DYNAMICS OF BIOMASS-N IN FLOODED SOIL

Soil Microbiology Department

Biomass N is the source of N available to plants. Little is known about the N supply from biomass N fraction to plants and its replenishment in flooded soil. Chloroform-fumigated soil was incubated in flooded condition up to 4 wk and mineralized N



11. Floodwater urea-N and NH_4^+-N after application at 20 DT of prilled urea, and urea with 2% and 5% PPD at 40 kg N/ha (av of two sampling times at 0700 and 1300 h, except during the 5th and 6th days, when samples were taken once at 1300 h). IRRI, 1982 WS and DS.

Table 5. IR36 yield response to various urea sources and application methods. IRRI, 1982 DS and WS.

Treatment[a]	Yield[b] (t/ha)	
	DS	WS
No N fertilizer	2.7 d	3.1 c
2/3 basal, incorporated + 1/3 at PI		
PU	5.1 ab	4.0 ab
Urea + 5% PPD	5.2 ab	4.2 ab
Urea + 2% PPD	5.0 ab	4.6 a
2/3 basal, no incorporation + 1/3 at PI		
PU	4.8 bc	3.5 bc
Urea + 5% PPD	4.8 bc	4.0 ab
Urea + 2% PPD	4.5 c	4.1 ab
2/3 at 20 DT + 1/3 at PI		
PU	5.3 a	4.2 ab
Urea + 5% PPD	5.0 ab	4.0 ab
Urea + 2% PPD	5.2 ab	4.0 ab

[a]N levels were 100 kg/ha in the DS and 60 kg/ha in the WS. [b]Av of four replications.

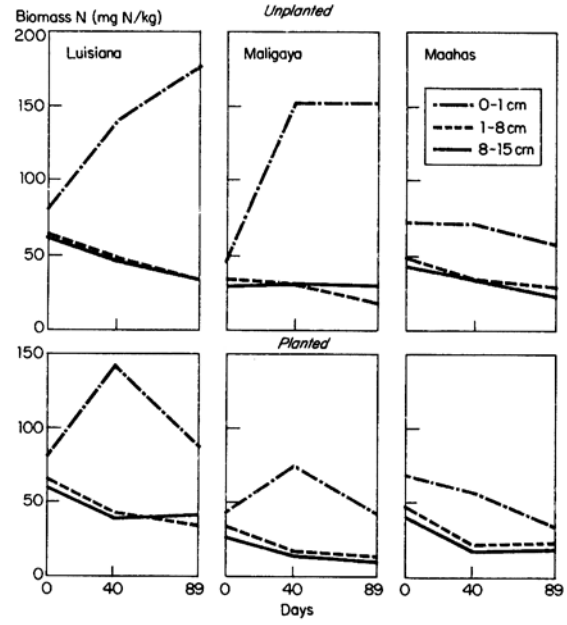
Table 6. IR36 yield response to N application methods. IRRI, 1982 DS and WS.

Application method[a]	Yield[b] (t/ha)	
	DS	WS
No N fertilizer	2.7 c	3.1 b
2/3 basal, incorporated + 1/3 at PI	5.1 a	4.3 a
2/3 basal, no incorporation + 1/3 at PI	4.7 b	3.9 a
2/3 at 20 DT and 1/3 at PI	5.2 a	4.1 a

[a]Total N rate applied was 100 kg/ha in the DS and 60 kg/ha in the WS. [b]Av of four replications and three sources of urea (prilled, urea with 2% and 5% PPD).

released during the incubation was taken as biomass N. Three soils — Maahas clay (pH 6.6, N = 0.15%), Luisiana clay (pH 4.7, N = 0.17%), and Maligaya clay (pH 6.5, N = 0.09%) — were placed in concrete tanks with ^{15}N-AS at 60 kg N/ha. Plots were either planted or unplanted. Soils were sampled periodically at 0-1 cm, 1-8 cm, and 8-15 cm during the growing season, and their biomass-N contents were determined. Except in Maahas soil, biomass N increased at 0-1 cm layers in both planted and unplanted plots. It decreased in soil below 1 cm as the plant grew (Fig. 12). Except in the surface soil, biomass N was almost equal in planted and unplanted soil. That meant that biomass N was replenished in the planted soil after the removal of available N by the rice plant, and that it was enriched from the soil surface.

N contents derived from the soil at harvest were 584 mg N/plant in Luisiana soil, 432 in Maligaya, and 258 in Maahas. These amounts were roughly



12. Biomass N change in three soils planted to IR42 and unplanted. IRRI, 1982.

proportional to the amount of biomass N at later stages of rice growth. A part of ^{15}N was converted to biomass N, particularly in surface soil, but the ^{15}N was transformed gradually to a more stable form.

Soil and crop management

Nitrogen fixation in wetland rice

Soil Microbiology, and Rice Production Training and Research Departments

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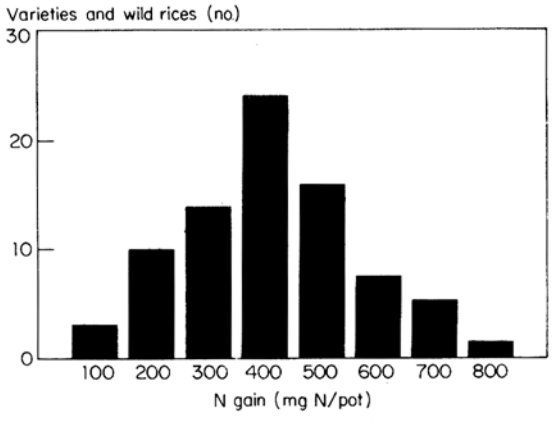
NITROGEN BALANCE IN RICE SOILS

Soil Microbiology Department

Varietal differences in stimulating positive nitrogen balance. The rice plant stimulates positive N balance in flooded soils. Six screening experiments were conducted to find if there are significant differences in this ability among rice varieties. The tests included 84 *Oryza sativa* varieties, other *Oryza* sp., and a few aquatic plants.

Three consecutive rice crops were grown in flooded pots with about 10 kg Maligaya soil (0.08% N) supplemented with 15 g/pot of straw for each crop. Photosensitive varieties received short-day treatments. N gains per pot ranged from 126 mg (*Sphenoclea zeylanica*), 188 mg (Pokkali), and 191 mg (fallow) to 757 mg (BPI-76), 776 mg (Oking Seroni), and 858 mg (Raminad #3). These gains corresponded to a range of 8.4 to 57 kg N/ha per crop. The N-gain frequency distribution (Fig. 1) was not statistically different from a normal distribution.

IR42, BPI-75 (acc #9790), and Taichung 65 were tested in three series of experiments. N gains were 581 ±153 (standard deviation among the three trials), 676 ± 72, and 490 ± 10 mg N/pot. Reproducibility was quite good. N gain and N uptake by plants were highly significantly correlated, meaning that the higher N uptake stimulated N gain. Regression equations showed that a few varieties, including *Oryza barthii*, Hua-chou-chu-mo-mor, Raminad #3, Lemo, Lac-23, and Oking Seroni, had higher-than-predicted N gains.



1. Frequency of distribution of N gains for 84 rice varieties and wild rices. IRRI, 1982.

Soil N always increased after growing three crops of these varieties. This suggests higher N uptake was mostly responsible for higher N gains. The higher N uptake was due to higher biomass production; therefore rice varieties that produce higher biomass may stimulate N gain.

Nitrogen fixation stimulated by neem seed. Neem (*Azadirachta indica*) seed or cake (residues after extracting oil) stimulates photodependent N_2-fixation by suppressing Ostracods that graze on N_2-fixing blue-green algae (BGA). N balance experiments, including various treatments in planted pots, demonstrated that flooded soils exposed to light and amended with neem seed equivalent to 100 kg/ha had significantly higher N gains than those without neem seed (Table 1).

AZOLLA-ANABAENA SYMBIOSIS AND ITS UTILIZATION

Soil Microbiology and Rice Production Training and Research Departments

Antigenic identity of *Anabaena azollae* in azolla (*Soil Microbiology*). *Azolla* is symbiotically associated with the N_2-fixing BGA *Anabaena azollae*. It is not clear if the BGA symbiont is the same one in the various azolla species and strains. Also there is some question as to whether the *Anabaena* strains claimed to be isolated from azolla are the true symbiont.

Because the isolation of *Anabaena* and its reinoculation to *Anabaena*-free azolla is not yet possible, the fluorescent antibody (FA) technique was used to answer these questions. Antibodies for

Table 1. The effect of neem seed and cake on N balance, after five rice crops, in potted soil. IRRI 1982.

Treatment	Nitrogen (mg N/pot)		
	Crop uptake	Change in soil	Balance
Neem seed, 100 kg/ha	421	+ 229	609 a
Neem seed + straw, 1 t/ha	428	+ 140	369 ab
Phosphorus, 10 kg P/ha	359	− 3	356 b
Neem cake, 100 kg/ha	403	− 39	280 bc
Straw	395	+ 22	285 bc
Control	382	− 131	251 bc
Neem seed, black cloth	294	− 231	22 cd
Straw black cloth	304	− 222	−76 d

Anabaena were prepared using algae from the cavity of *Azolla pinnata* (two strains), *A. filiculoides*, *A. caroliniana*, and *A. microphylla* and two free-living *Anabaena* strains reportedly isolated from azolla. All the *Anabaena azollae* freshly separated from 32 specimens of six species of azolla shared identical and highly specific antigens. None of these FAs exhibited cross-reactions with any of the free-living BGA tested. FA absorption results confirmed these findings and also indicated the existence of cross-reactive antigens between azolla leaves and the surface of the symbiont *Anabaena*. Antibodies for free-living *A. azollae* did not cross-react with any of the symbiotic *A. azollae*. This indicates that either

- these *Anabaena* are not true isolates, or
- their antigenic properties were altered during isolation and culture.

Field performance of various *Azolla* species (*Soil Microbiology*). *A. microphylla* from Paraguay (401-420) and Galapagos (421), *A. nilotica* from Sudan (501), and *A. pinnata* var. *pinnata* from Northern Territory, Australia (701-704), were added to the IRRI azolla collection.

Fresh inoculum (100 g) was added to a 1-m^2 frame placed in a flooded rice field. Fresh growth was weighed weekly. When the growth exceeded 1 kg, half the azolla biomass was harvested and grown continuously. Starting in August, P (0.1 g P_2O_5/m^2 as superphosphate) was applied every 3 d. The accumulated dry weight and average frequency of harvest through the 15th wk of the various *Azolla* species are in Table 2. *A. pinnata* var. *pinnata* and *A. microphylla* (Paraguay) seem to be promising species in the tropics. The experiment is still underway.

Table 2. Accumulated dry weight and average frequency of harvest through the 15th wk of various *Azolla* sp. IRRI, 1982.

Strains	Accession no.	Dry weight (g/m^2)	Av harvest frequency (no./15 wk)
A. pinnata var. *pinnata*	701	263	8.3
A. microphylla	417	183	4.7
A. microphylla	418	167	4.7
A. microphylla	407	142	4.0
A. caroliniana	301	144	4.7
A. caroliniana	302	118	4.0
A. pinnata	5	143	4.7
A. pinnata	49	90	3.0
A. pinnata	32	71	2.0
A. pinnata	40	50	1.3

Dual culture and azolla by wide-row spacing (*Soil Microbiology*). The results of the fifth and sixth trials are shown in Table 3. In the sixth trial, no azolla was incorporated so comparison could be made with the fifth trial where five azolla crops were incorporated. The effect of azolla on rice yield was not clear because the rice was heavily damaged by RGSV 2 and showed great variation among plots. After the fifth trial, soil cores up to 20 cm were analyzed. In the control plots with no N fertilizer or azolla, total N was 0.16%; in plots with both N amendments, total N was 0.18%. Total N was 139 g/m^2 in the zero-N plots, 149 g in the N fertilizer plots, and 171 g in the azolla plots. Total N was significantly higher in the azolla plots than in the other plots.

Temperature response of azolla (*Soil Microbiology*). Temperature response of azolla is dependent on plant density. First, the growth and N_2-fixing activity of *Azolla-Anabaena* symbiosis were examined at a low plant density. Based on its growth, chlorophyll content, protein content, and acetylene-reducing activity (ARA), *A. filiculoides* (#101) appeared the most sensitive to high temperature. *A. pinnata* (#9 and 21) and *A. microphylla* (#417) showed good growth and no senes-

Table 3. IR42 yield in azolla-rice culture. IRRI, 1982.

Trial sequence[a]	Cropping duration	Chemical N applied (kg/ha) (split ratio)	Number of azolla incorporations and N content	Grain yield (t/ha)		
				No N	Chemical N	Azolla
5th	Nov - Jan	100 (2 : 1 : 1)	5 crops 75 kg N/ha	5.2	6.8	6.6
6th	Apr - Jul	0	0	3.4	4.1	4.1[ns]

[a]Fifth and sixth crops in B9 plot correspond to eighth and ninth crop from beginning of experiment.

cence even after 6 wk at 37° C (day)/29° C (night) if the plant density was controlled and nutrients were not limiting.

Various *Azolla* species were grown to a maximum biomass in a liquid medium at either 33° C (day)/25° C (night) or at 37°/20° C (Table 4). *A. microphylla* (#417) appears most tolerant to high temperature and *A. nilotica* (#501), the least. *A. pinnata* (#2) and *A. pinnata* var. *pinnata* (#701) also showed relative tolerance to high temperature. These observations are not inconsistent with experiments at low plant density and growth in the field. *A. pinnata* var. *pinnata* (#701) and *A. microphylla* (#417) seem to be promising species in the tropics.

Soil phosphorus availability and azolla growth (*Soil Microbiology and Rice Production Training and Research*). Since 1979, applied research trials have been conducted throughout the Philippines to evaluate azolla in farmers' fields. Only in South Cotabato Province in Mindanao has azolla spread beyond the immediate trial area. Its obvious adaptation to the area encouraged the Ministry of Agriculture to multiply azolla in all available water holes and ponds in and around the irrigated rice lands of Koronadal.

Upon multiplication, azolla was distributed to farmers in Koronadal, and by 1980, azolla had spread to about 1,000 ha. By 1981, an estimated 5,000 ha of irrigated rice lands in the Koronadal area were inoculated with azolla.

The widely publicized success of azolla production and utilization in South Cotabato prompted the question of what distinguished this area from those elsewhere in the Philippines where azolla did not grow well outside the research trials.

Monitoring of the physical environment revealed two important factors.

- Soils in the Koronadal area of South Cotabato contained relatively high levels of P.
- The WS in the Koronadal area extends from April to December, with only 3 dry months. During the DS, the average monthly rainfall remains above 50 mm (Annual report for 1980).

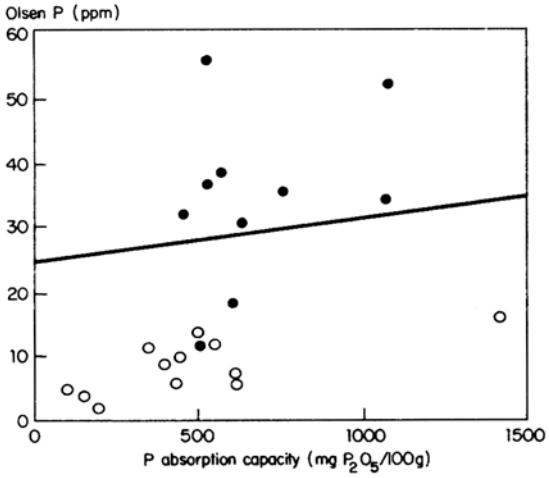
To find if soils can support azolla growth without P application, a bioassay technique was developed. Soil samples were placed into the bottom third of bottles (8.7 cm in diameter and 12 cm deep), flooded, and kept there for 1 wk. *A. pinnata* (#5) was depleted of nutrients. Azolla plants with three main stems were placed in pots, grown in the greenhouse, and harvested either when the soil surface was covered or when 4 wk had elapsed. N and P contents, soil-available P (Olsen's P), P adsorption capacity, and other soil characteristics were analyzed. Eight of nine soils from South Cotabato yielded an azolla biomass higher than 1 g N/m^2. The doubling time was 3 d or less. Soils that supported azolla growth well (higher than 1 g azolla N/m^2) appear to have available P (Olsen's P) higher than 25 ppm (Fig. 2).

Free-living blue-green algae (*Soil Microbiology*). *Inoculation long-term experiment.* A long-term study was started in the 1982 DS on the IRRI farm to examine the fate of BGA inoculum in the field and the effect of inoculation on photodependent N_2 fixation. Special emphasis is being given to the grazers that feed on BGA. Sixteen 4- × 4-m plots were arranged in a Latin square. The four treatments were neem nut application (to control ostracods), inoculated, neem nut application +

Table 4. Maximum N biomass of various *Azolla* strains at the average temperatures of 29° and 33°C. IRRI, 1982.

Strain	Accession no.	N content (g/m^2)[a]	
		29°C	33°C
A. pinnata, Malaysia	2	11.4 ± 0.6 (48)	4.83 ± 0.07 (28)
A. caroliniana, Ohio	301	8.7 ± 0.1 (48)	3.35 ± 0.06 (28)
A. microphylla, Paraguay	417	9.7 ± 0.5 (28)	7.30 ± 0.27 (28)
A. microphylla, Galapagos	421	7.2 ± 0.1 (48)	2.36 ± 0.04 (28)
A. nilotica, Sudan	501	6.2 ± 0.1 (48)	1.28 ± 0.03 (20)
A. pinnata var. *pinnata* Kakadu, Australia	701	11.0 ± 0.2 (48)	4.59 ± 0.08 (34)

[a]The average ± standard deviation of three replicates. Number in parentheses represents no. of days to reach the maximum N biomass.



2. Relation between Olsen-P and P absorption capacity. Closed circles = N in azolla biomass greater than 1 g/m^2. Open circles = less than 1 g/m^2. IRRI, 1982.

inoculated, and the control. N_2-fixing BGA, ostracods, and molluscus were enumerated; ARA, chlorophyll in the floodwater and upper soil, floating algal biomass, and grain yield were measured.

Algal inoculation (with *Tolypothrix tenuis* and a nonmucilaginous *Nostoc* sp. strain) was unsuccessful. There were no significant differences among the treatments except that the number of ostracods was lower in neem-treated plots. Growth of inoculated strains was not detected in soil samples taken after inoculation. The growth of 13 recorded indigenous BGA species reached a fresh weight of 15 t/ha. Grazing-resistant mucilagenous colonies of *Nostoc*, *Gloeotrichia*, and *Aphanothece* dominated the algal biomass. Because of the high water content of such colonies (around 99%), the very impressive N_2-fixing algal bloom contributed minimal N.

Possible reasons for failure of inoculated algae to grow were: grazing by snails, interspecific algal competition and/or environmental conditions unfavorable for the inoculated strains.

Properties and production of algal inoculants. The selection of "super N_2-fixing strains" of BGA is meaningless unless they can be established in the field. Successful field establishment of reliable, dry BGA inocula is essential if the technology is to be effective in N_2 fixation.

Preliminary studies of the composition of multistrain inocula produced in India and Burma and of monostrain inocula produced at IRRI are summarized in Table 5.

- Inocula from India and Burma designed to be "multistrain inocula" contain two dominant strains and very few associated ones. The amount of N_2-fixing colony-forming units (CFU) in the inocula is comparable to that of a soil rich in BGA, which may have between 10^5 and 10^6 CFU counts/g of soil.
- A trial to produce inocula in the field from the original Burma inoculum and other nonindigenous strains was unsuccessful.
- Soil-based inocula contained more non-N_2-fixing CFU than N_2-fixing ones. Inocula produced in a greenhouse from nonspecific strains had N_2-fixing CFU counts similar to those of the multistrain inocula.
- Highest CFU counts were obtained with dried cultures of laboratory-grown BGA; however the variability among the strains was large.

Overall composition of blue-green algae. Little is known about the composition of BGA. Some information is available from physiological studies with a limited number of laboratory strains growing

Table 5. Characteristics of some BGA dried inocula, IRRI, 1982.

Inoculum	CFU[a]/g inoculum		Dominant strains[b] (no.)
	N_2-fixing BGA	Nonfixing BGA	
India[c]	4.6×10^5	4.7×10^6	2
Burma[c]	1.6×10^6	2.8×10^7	2
Burma, 2nd[d]	7.0×10^4	1.6×10^6	2
Tolypothrix[e]	2.8×10^5	6.0×10^6	2
Aulosira[e]	1.9×10^6	8.0×10^6	1
Nostoc[e]	5.0×10^5	4.0×10^6	1
Aulosira[f]	6.1×10^8	none	1
Anabaena[f]	6.3×10^7	none	1
Fischerella[f]	2.4×10^7	none	1
Nostoc[f]	2.3×10^7	none	1
Tolypothrix[f]	1.5×10^8	none	1
Scytonema[f]	2.9×10^8	none	1
Aphanothece[f]	1.0×10^5	none	1

[a]Colony-forming units. [b]No. of strains composing 90% of the N_2-fixing CFU. [c]Multistrain inocula made available to the farmers in India and Burma. [d]Produced in open trays at IRRI using 5 kg Maahas soil, 10 g superphosphate, 2 ml Perthane emulsion, 2 g NaCl, and 140 g Burma inoculum/m^2. [e]Produced in small trays in a greenhouse according to the above method, using dried laboratory cultures as inoculum. [f]Produced in artificial media in the laboratory and dried.

Table 6. Average composition of BGA. IRRI, 1982.

Component	Literature citations (no.)	IRRI strains analyzed (no.)	Percentage of dry wt			CV (%)
			Av	Highest value	Lowest value	
Dry weight[a]	None	46	3.69	13.14	0.18	68
C	13	22	43.90	67.30	29.70	18
N	52	46	6.26	13.40	1.78	42
C:N	13	22	7.47	16.20	3.85	39
P	19	None	0.98	2.00	0.13	64
Ash	7	None	14.60	50.80	5.00	104
Proteins	53	46	38.30	73.00	11.10	40
Sugars	27	46	46.50	105.00[b]	4.40	48
Lipids	21	None	9.35	28.00	1.57	66
Phycocyanin	15	46	6.36	24.10	0.00	77
Chlorophyll	12	46	0.90	2.85	0.08	79

[a]% of fresh wt. [b]Methodological artifact.

under artificial conditions. Systematic studies have not been conducted.

Results from a bibliographic study and from analysis of 46 strains from the IRRI collection are summarized in Table 6. On the average, BGA contained 38% proteins, 46% sugars, and 9% lipids. Their C:N averaged 7.5. A characteristic feature was the composition variability. The coefficients of variation (standard error expressed as a percentage of the mean) of the different components, except C, were higher than 40% and averaged 60%.

Cluster analysis showed no clear relation between the clusters and the taxonomic groups except for *Anabaena* sp. This may indicate that environmental factors and the physiological state are at least as important as the nature of the strain in determining the composition. Table 7 shows an example of the variability of N composition. Literature data refer mainly to laboratory strains grown under low light intensities and harvested during the exponential phase. Such strains had a high N content attributable to a high pigment content, a low mucilage content, and a low percentage of akinetes (which are rich in carbohydrates). On the other hand, strains at the end of the exponential growth phase and older strains had a lower N content. The lowest N content was in field samples of BGA blooms, which are usually poor in pigments, rich in mucilage and spores, and high in ash content. There was a positive correlation between BGA pigments and protein contents, and a negative correlation between carbohydrates and protein contents and between dry weights and C contents.

BGA may have a lower N content than previously thought. High values (7-10%) frequently cited in the literature are not representative of BGA growing in natural environments.

The C:N of BGA averaged 7.5 and ranged from 4 to 16. Mineralization studies indicated that between 33% (C:N = 9) and 64% (C:N = 4) of the N of incorporated BGA was mineralized for 3 wk.

ASSOCIATIVE NITROGEN FIXATION

Soil Microbiology Department

Nitrogen-fixing bacteria from rice plant. *Pseudomonas*. The most dominating N_2-fixing chemolithotrophic bacterial isolates of wetland rice roots

Table 7. N content of BGA. IRRI, 1982.

	N content (% of dry wt)			
	Av	Max value	Min value	Data (no.)
Data from the literature, mainly strains at exponential phase of growth and "laboratory strains"[a]	7.3	13.4	2.4	50
IRRI strains at end of exponential growth phase	5.5	8.3	3.5	22
IRRI strains more than 1 month old	4.5	8.0	1.8	24
Field samples	3.65	6.7	1.8[b]	7

[a]*Anabaena*, *Anacystis*, and *Spirulina* comprise 60% of the genera studies. [b]Ash content was almost 50%.

were identified as a previously unknown species of *Pseudomonas*. Several such isolates were obtained from the histosphere of IR26, Latisail, and Khao-lo and from wild rices *Oryza punctata* and *O. australiensis*. Strains H8 and KLH76, isolated from the histosphere of IR26 and Khao-lo, respectively, were selected for extensive biochemical and immunological characterization.

Ouchterlony gel immunodiffusion showed that H8, KLH76, *Pseudomonas facilis*, *P. cepacia*, *P. putrefaciens*, and *P. aeruginosa* had at least one heat-labile agar-diffusible antigen, suggesting that H8 and KLH76 belong to *Pseudomonas*. The absence in H8 of a strongly positive FA reaction to any of the *Pseudomonas* species tested suggests that H8 is different from any of those species. All isolates from the rice histosphere could be differentiated on the basis of FA reaction into two serogroups, i.e., H8 and KLH76.

The extensive morphological, cultural, and biochemical tests also justify the identification of a new species of diazotrophic *Pseudomonas*. Strains H8 and KLH76 resembled *P. cepacia* more than *P. facilis*. The similarities (simple matching coefficients) among these organisms, based on 81 biochemical characters, are as follows: between H8 and *P. cepacia*, 74.1%; KLH76 and *P. cepacia*, 71.6%; H8 and KLH76, 90.1%; H8 and *P. facilis*, 63%; KLH76 and *P. facilis*, 63%. Some essential differences, however, exist between H8/KLH76 and *P. cepacia*. *P. cepacia* neither fixes N_2 nor utilizes H_2, has a higher guanine + cystosine (G + C) content of DNA than H8, and is negative for arginine dihydrolase. On the other hand, H8 and *P. facilis* have similar G + C contents, H8/KLH76 and *P. facilis* are able to utilize H_2 and have arginine dihydrolase. *P. facilis*, however, does not fix N_2.

A formal description of the *Pseudomonas* sp. type strain H8 follows.

- Cells are short, rod-shaped, Gram negative, motile by a single polar flagellum.
- Colonies are round, white, glistening, entire, and slightly convex on tryptic soy agar, and turn brown in old culture.
- Cells accumulate poly-beta-hydroxybutyrate as a C reserve material.
- The organism is aerobic but fixes N_2 under microaerobic conditions.
- Oxidase and catalase are produced.
- Dinitrification does not occur.
- It is facultatively chemolithotrophic in an atmosphere containing H_2, O_2, and CO_2 gases.
- The G + C content of the DNA is 63.8 % mol.

Enterobacteria. N_2-fixing and acid- and gas-producing enterobacteria were isolated, enumerated, and characterized biochemically and immunologically. Strains of *E. cloacae* were isolated from the roots of both dryland and wetland rices and strains of *K. planticola* from the leaf sheaths of a deepwater rice.

The FA cross reactions of several strains isolated from rice roots and leaf sheaths with FAs against *E. cloacae* and *K. planticola* showed a separation of the two genera into two serogroups. Both FAs were specific to the genus level only. However, the cross reactions in gel immunodiffusion were extensive and widespread. Most of the enterobacteria tested produced at least one heat-labile or heat-stable precipitation band with both the antisera.

The population of N_2-fixing enterobacteria in the rice root and stem ranged from 10^3 to 10^5/g dry weight, which is quite low compared with N_2-fixing *Pseudomonas* and *Azospirillum*. More than 75% of the isolates were found to be *E. cloacae*, as identified by the FA technique.

Direct counting of predominant nitrogen-fixing root bacteria by the fluorescent antibody technique. Conventional microbiological methods for the enumeration of bacteria are tedious, time consuming, indirect, and inaccurate. The FA technique promises to overcome these problems and offer additional advantages for field study.

The populations of N_2-fixing *Pseudomonas*, *Azospirillum lipoferum*, and *A. brasilense* in the root of IR8 (heading stage) were counted by treating the root extract smear with respective FAs. FA counting was compared with the direct plate and most-probable-number (MPN) methods (Table 8). About 100 times higher populations of *Pseudomonas* were recorded by FA counting than by either direct plate count or the MPN method. The population of *Azospirillum* was also higher than that determined earlier by the MPN counts.

Inoculation of nitrogen-fixing bacteria. *Inoculation of sterile rice seedlings*. Major genera of N_2-fixing bacteria (*Pseudomonas, Azospirillum,* and

Table 8. *Pseudomonas* and Azospirilla (*A. lipoferum* and *A. brasilense*) population associated with fertilized and unfertilized wetland rice roots (IR8) as determined by direct plate count, MPN, and FA techniques. IRRI, 1982.

Counting technique	Bacteria (no./ g fresh root)			
	Pseudomonas		Azospirilla[a]	
	Fertilized	Unfertilized	Fertilized	Unfertilized
MPN of N_2 fixers[b]	1.6×10^7	1.4×10^7	nd	nd
Plate count[c]	3.6×10^7	1.5×10^7	nd	nd
FA count[d]	2.61×10^9	1.84×10^9	3.93×10^8	3.18×10^8

[a]nd = not determined. [b]Av of duplicates. Tubes in the highest dilutions mostly contained *Pseudomonas*. [c]Av of duplicates, with four plates in each replicate. The plating medium was 0.1% tryptic soy broth (Difco) with 1.5% Noble agar (Difco). *Pseudomonas* colonies were identified on the basis of colony morphology, pellicle formation and ARA. [d]Av of duplicates. For *Pseudomonas* counting root extract smear was treated with FA of H8 while for the counting of Azospirilla, smear was treated with a mixture of two FAs, 34H, *A. lipoferum*, and 36H2, *A. brasilense*.

enterobacteria) from the rice plant were inoculated to the sterile rice seedlings to compare N_2-fixing activity associated with rice. Sterile germinated IR36 seeds were transferred to a 3-cm diameter test tube containing an inorganic semisolid medium with a small amount of N as NH_4NO_3. Bacteria suspension was inoculated 2 d after the transfer of germinated seeds. After being grown under artificial light for 5-6 wk, the rice plant showed N deficiency. Then the ARA of the rice plant (either whole plant or root) was measured for 24 h at 4% O_2. ARA varied from <5 nmol C_2H_4/tube (uninoculated) to 200 nmol C_2H_4/tube. *Azospirillum lipoferum* showed higher activity than *A. brasilense*. *Pseudomonas* H8 and H3 strains also showed ARA associated with sterile seedlings. In these assays, ARA variation among tubes with the same strain was great and indigenous ethylene evolution was large.

The spermosphere model technique was also used. Rice seeds were germinated in the dark on yeast extract containing a semisolid medium. A thick bacterial suspension was inoculated and ARA was measured in the dark for 6 d. The presence of the germinated seeds greatly stimulated ARA. The ARA of rice seedlings with *Azospirillum lipoferum* 34H, *Pseudomonas*, *A. brasilense*, and *Klebsiella planticola* decreased in this order. The spermosphere technique is being used to screen the N_2-fixing activity of various bacteria-rice associations.

Pot experiments. Cell suspension mixtures of five strains (*Azospirillum lipoferum* FS, *A. brasilense* 36H2, *Pseudomonas* sp. H8, *Klebsiella planticola* LL4, and unidentified slow-growing Gram-negative rods) were solidified in agar. The agar was cut into pieces of about 6-ml volume. Maahas, Maligaya, Pili, Luisiana, and Labo soils were used. The soils were put into 3-liter pots with and without N (60 kg urea N/ha). IR36 was transplanted into pots and 3 wk later one agar piece containing bacteria suspension was deep-placed in each pot. ARA assays were made at heading stage. Then, bacterial populations of washed and macerated roots were counted. ARA was increased by inoculation only in unfertilized Labo soil. Addition of urea did not suppress ARA associated with plant and N_2-fixing population. In Pili soil, plant N fertilizer increased the ARA associated with rice. Plant growth (dry weight of the above-ground part at heading stage) was not stimulated by inoculation.

Inoculation trials were conducted using Luisiana soil (pH 4.7, total N = 0.21%) in which the N_2-fixing activity and bacteria population were lower than those in IRRI's field. *A. lipoferum* 34H, and *Pseudomonas* sp. H8 were inoculated separately. IR36 seedlings were dipped in a bacterial suspension (10^8/ml) overnight. Bacteria were absorbed at 10^3-10^4/seedling. At 10 DT, 5 ml of bacteria suspension was injected along the seedling in each pot. Tillering and booting occurred earlier in inoculated treatments than in the uninoculated control. The inoculated plants had a higher grain-filling rate and, hence, a higher grain weight than the uninoculated control. To study if inoculation increased the contribution of biologically fixed N to N nutrition of the rice plant, ^{15}N ammonium was added in some pots. However, the inoculated and

uninoculated plants had the same ^{15}N contents. ARA associated with rice was measured at maximum tillering, early flowering, and late flowering stages. Only at the early flowering stage was ARA significantly higher in the inoculated treatments (both 34H and H8) than in the control, and the populations of N_2-fixing bacteria in rhizosplane were higher in each inoculated treatment. It appears that the inoculation could enhance N_2-fixation, but this effect was probably too low to be reflected in the N nutrition of rice plant. Therefore, it is likely that the observed yield increase by the inoculation was not due to biological N_2 fixation.

In the field of Luisiana soil (pH 4.7), *Azospirillum lipoferum* 34H, *Pseudomonas* sp. H3, and *Enterobacter cloacae* were inoculated to IR42. The bacteria suspension (10^7/ml) was gelatinized by agar and the rice seedlings were dipped overnight into the semisolid agar. Rice growth was depressed by the inoculation of *Enterobacter* at an earlier stage. At 28, 42, 63, and 89 DT, ARA and populations of N_2-fixing *Pseudomonas*, *Azospirillum*, and *Enterobacter* were counted on selective media for each group of bacteria. No difference in ARA was observed between uninoculated and inoculated treatments. No evidence was obtained that the inoculated bacteria were established in the histosphere of the rice root and the lower portion of shoots.

Probably, in the field, the physicochemical conditions for the survival of the inoculated bacteria were limiting.

Soil and crop management

Management of other nutrients

Agronomy and Soil Chemistry Departments

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Agronomy Department

IRRI. The 37th (DS) and 38th (WS) croppings were completed at IRRI in 1982. In the DS, the yield trends attributed to the addition of various NPK levels were similar for all test varieties. IR42 had the highest yield in plots where 140-13-25 kg (N, P, K)/ha from inorganic sources was applied.

Table 1 shows a highly significant yield response to 140 kg N/ha. When P or K, or both, were also applied, yield was not significantly higher. Yields were statistically similar whether or not 24 kg N from compost was included as part of the N in the 140-13-25 kg (N, P, K)/ha rate. Plots where either P or K was applied alone yielded similarly to the control plots.

During the WS, response to N applied alone or in combination with P or K, or both, was more pronounced with IR36 and IR42. IR8 showed no distinct yield response because of its susceptibility to virus disease. There was no significant response to P or K alone.

High-analysis fertilizers. To investigate the effects of continuous use of high-analysis fertilizers on the soil's natural capacity to supply S, a long-term experiment was initiated during the 1982 WS. IR56 was the test variety. Table 2 shows soil analyses before the experiment began.

N fertilizer alone increased yield significantly. K alone did not increase yield. No marked yield increase resulted from an application of P alone or in combination with N or K (Table 3).

Yield responses were significant in plots receiving NPK treatment. However, there were no significant differences in yield among NPK, NPK + straw, and NPK + azolla.

Philippine Bureau of Plant Industry stations. *Maligaya.* In the 29th (DS) crop, there were no significant responses among the varieties to the NPK levels. There was significant yield response to a 140-kg N/ha application (Table 4). However,

Table 1. Yield response of IR8, IR36, and IR42 to NPK fertilizer application in the 37th (DS) and 38th (WS) consecutive crops. IRRI, 1982.

Fertilizer (kg/ha)			Yield (t/ha)		
N[a]	P	K	IR8	IR36	IR42
			DS		
0	0	0	3.1 f	3.5 ef	4.1 de
140	0	0	5.6 bc	6.3 ab	6.6 a
0	13	0	3.3 ef	4.2 de	4.1 de
0	0	25	3.1 f	3.8 ef	4.1 de
140	13	0	5.6 bc	6.8 a	6.9 a
140	0	25	5.2 c	6.3 ab	6.7 a
140	13	25	5.4 bc	6.8 a	7.4 a
140[b]	13	25	4.9 cd	7.0 a	7.1 a
			WS		
0	0	0	2.0 cd	2.9 b	2.2 bcd
60	0	0	2.4 bcd	4.5 a	4.2 a
0	13	0	2.4 bcd	2.8 bc	2.4 bcd
0	0	25	2.0 cd	2.6 bc	2.4 bcd
60	13	0	2.4 bcd	4.6 a	4.3 a
60	0	25	1.6 d	4.4 a	4.1 a
60	13	25	2.5 bc	4.6 a	4.2 a
60[b]	13	25	2.8 bc	4.6 a	4.1 a

[a]Includes 40 kg N/ha topdressed 5-7 DBP! during the DS and 30 kg N topdressed 5-7 DBPI during the WS. [b]10 t compost/ha applied every cropping season with the balance coming from inorganic N source to make up for the rate stipulated for that season.

Table 2. Chemical and physical properties of soil in Block 421, new IRRI farm. IRRI, 1982 WS.

Soil property	Analysis
pH (1:1, soil:water)	6.2
Organic matter (%)	2.4
Total N (%)	0.12
Available P, Olsen's (ppm)	14.0
Exchangeable cation (meq/100 g)	
K	1.3
Ca	17.0
Mg	8.3
Na	1.3
CEC[a] (meq/100 g)	33.0
Available Zn (ppm)	0.35
Available S (ppm)	40.0
Total S (ppm)	1220
Texture	Silty clay loam

[a]CEC = cation exchange capacity.

Table 3. IR56 yield response to 10 fertilizer treatments. IRRI, 1982 WS.

Treatment[a]	Yield (t/ha)
Check	2.34 bc
N	3.38 a
P	2.30 bc
K	2.43 bc
NP	2.04 c
PK	2.72 b
NK	3.45 a
NPK	3.45 a
NPK + azolla[b]	3.34 a
NPK + straw[b]	3.28 a

[a]N as urea at 60 kg /ha; P as triple superphosphate at 18 kg P/ha, and K as muriate of potash at 33 kg K/ha. [b]2/3 of N came from urea, 1/3 from azolla or straw.

Table 4. Yield response of IR8, IR36, and IR42 to NPK fertilizer application during the 29th (DS) and 30th (WS) consecutive crops at Maligaya Rice Research and Training Center, Maligaya, Muñoz, Nueva Ecija, and Bicol Experiment Station, Pili, Camarines Sur, and in the 11th DS and 15th WS crops at the Visayas Experiment Station, Hamungaya, Jaro, Iloilo. 1982.

Fertilizer (kg/ha)			Yield (t/ha)								
			Maligaya			Bicol			Visayas		
N[a]	P	K	IR8	IR36	IR42	IR8	IR36	IR42	IR8	IR36	IR42
						Dry season					
0	0	0	1.8 g	2.1 g	2.0 g	4.6 f	3.0 g	4.8 f	1.3 cd	1.1 d	1.2 cd
140	0	0	3.8 ef	4.2 de	4.6 de	3.7 fg	6.1 de	6.8 cd	2.2 bc	1.7 bcd	2.2 bc
140	26	0	6.0 bc	6.5 ab	5.2 cd	6.9 cd	6.8 cd	8.2 ab	4.4 a	4.1 a	4.6 a
140	0	50	3.8 ef	2.9 fg	3.8 ef	4.1 f	5.6 e	7.3 bc	1.5 cd	1.7 bcd	2.2 bc
140	26	50	6.7 ab	7.4 a	6.8 ab	7.3 bc	7.7 abc	**8.4** a	4.3 a	4.1 a	4.9 a
140	26	50 + 25	6.9 ab	7.1 ab	6.6 ab	6.7 cd	7.3 bc	8.2 ab	4.9 a	4.0 a	4.8 a
						Wet season					
0	0	0	1.9 f	2.4 ef	2.0 f	2.7 j	2.7 j	2.6 j	2.7 fg	1.8 g	2.6 fg
70	0	0	1.9 f	3.6 bcd	2.5 ef	**4.3** gh	**3.8** hi	**4.6** fg	4.1 e	2.6 fg	4.6 cde
70	26	0	3.4 cde	4.6 ab	4.4 abc	4.6 fg	5.1 ef	5.7 bcd	5.9 ab	4.5 cde	6.7 a
70	0	50	2.2 f	4.2 abc	2.7 def	4.1 ghi	3.6 i	5.9 abc	3.7 ef	2.7 fg	4.7 cde
70	26	50	3.9 bc	4.2 ab	5.2 a	5.3 de	5.5 cde	6.0 abc	5.5 bcd	4.6 cde	6.3 ab
70	26	50 + 25	3.9 bc	5.2 a	4.6 ab	**6.1** ab	**5.6** bcde	**6.3** a	5.6 abc	4.4 de	6.2 ab

[a] Includes 40 kg N during the DS and 20 kg N/ha, during the WS, topdressed 5-7 DBPI.

Table 5. Yield response of IR36 and IR42 to NPK fertilizer application in the 12th (DS) and 13th (WS) consecutive crops, Luisiana, Laguna; and 10th DS and 11th WS consecutive crops, Tanay, Rizal, Philippines, 1982.

Fertilizer treatment[a]	Yield (t/ha)							
	Luisiana				Tanay			
	DS		WS		DS		WS	
	IR36	IR42	IR36	IR42	IR36	IR42	IR36	IR42
Control	3.3 d	3.0 d	2.0 de	2.1 ef	3.1 de	2.5 d	2.3 d	4.0 d
N	4.2 b	4.2 c	2.9 c	3.1 c	4.2 bc	4.8 b	3.9 ab	4.9 bc
P	3.3 d	3.7 c	2.3 d	2.5 de	3.3 d	3.0 c	2.9 c	4.7 c
K	3.4 cd	2.8 d	1.8 e	2.0 f	2.4 f	2.3 d	2.4 d	4.2 d
N + P	4.0 bc	5.2 b	3.4 b	3.7 b	4.6 ab	5.8 a	3.8 ab	5.4 a
P + K	3.9 bc	3.9 c	2.8 c	2.8 cd	2.8 ef	3.1 c	2.9 c	4.7 bc
N + K	3.8 bcd	5.6 b	3.0 c	3.1 c	4.1 c	5.2 b	3.6 b	5.1 ab
N + P + K	5.3 a	6.3 a	4.0 a	5.0 a	4.9 a	5.6 a	4.0 ab	5.5 a

[a]N: 120 kg/ha DS, 60 kg/ha WS; P:18 kg/ha, and K:33 kg/ha both seasons. CV at Luisiana = 8.8% DS, 8.5% WS; at Tanay = 7.4% DS, 7.0% WS.

there was no advantage in applying N and K together. NK even significantly decreased IR36 yield. However, when N and P were applied together, there was a significant yield increase. IR36 had the highest yield with a fertilizer rate of 140-26-50 kg (N, P, K)/ha. Increasing K to 75 kg/ha (25 kg applied with the last N dose at PI) did not provide a significant yield increase over the NP treatment.

During the 30th (WS) crop, the yield response to various NPK levels differed among the varieties. IR36 and IR42 responded favorably to 70 kg N/ha, but IR8 did not. The three varieties had higher yields with NP than with NK treatments. The varieties responded differently to the increased K rate.

Bicol. During the DS, IR42 had the highest yield with a fertilizer rate of 140-26-50 kg (N, P, K)/ha. IR36 and IR42 responded significantly to N application.

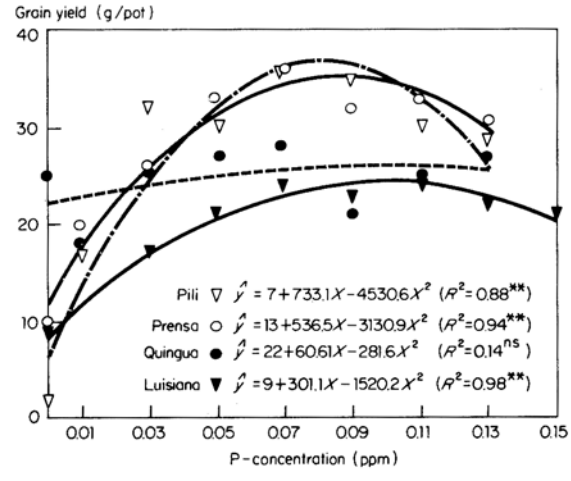
During the WS, highly significant yield increases were obtained with 70 kg N/ha. All three varieties yielded highest when supplied with 140-26-75 kg (N, P, K)/ha (Table 4). Response to various NPK levels differed among varieties.

Visayas. In the DS, the various NPK levels had similar effects on the yields of all three varieties. Yields resulting from NP and NPK application were comparable.

Farmers' fields. The 12th and 13th croppings in Luisiana, Laguna, and the 10th and 11th croppings in Tanay, Rizal, were completed in 1982.

In the DS, yield response to N in both soils was significant (Table 5). In Luisiana soil (pH 5.1), IR42 responded significantly to P alone. However, in Tanay soil (pH 7.1), IR42 also responded significantly to K alone. Significant responses to N, P, and K were consistently observed in Luisiana, but not in Tanay.

During the DS at Tanay, a 2-wk irrigation delay during the spikelet filling stage reduced yields. During both seasons in Tanay and in the DS in Luisiana, IR42 yielded more than IR36 when N was combined with either P or K. Similarly during the WS in Tanay, IR42 outyielded IR36 by more than 1 t/ha when P and K were applied alone or in combination.



1. Response of IR36 to different soil solution P concentrations in four soils. IRRI, 1982.

Table 6. Four test soils and their soil series, textural groups, available P levels, and P requirements to equilibrate at 0.07 ppm and 0.09 ppm soil solution P concentration. IRRI, 1982 WS.

Soil series	Texture	pH	Available P (ppm)		P (ppm) added to increase soil solution concn to	
			Olsen	Bray 2	0.07 ppm	0.09 ppm
Prensa	Sandy loam	5.3	2.9	1.8	29	42
Quingua	Silty loam	5.4	7.3	2.5	90	106
Pili	Clay loam	5.4	4.9	0.9	175	205
Luisiana	Silty clay	4.6	5.0	0.6	359	452

EXTERNAL PHOSPHORUS REQUIREMENT OF RICE BASED ON ADSORPTION ISOTHERMS

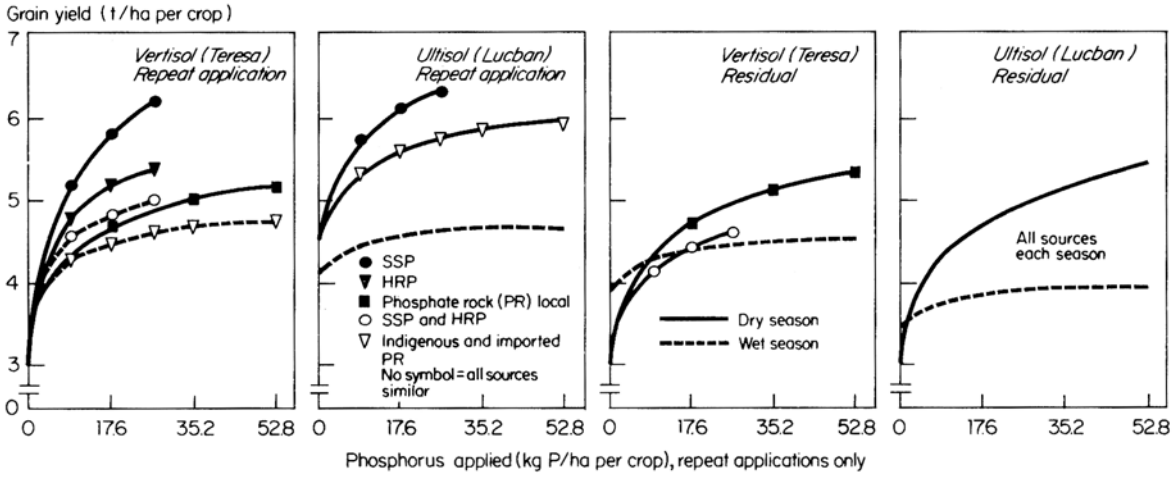
Agronomy Department

During the 1982 WS, a greenhouse experiment was conducted to determine the external P requirement of rice using four P-deficient soils, based on Olsen and Bray 2 P determinations (Table 6), from different parts of Luzon, Philippines. The external P requirement is the optimum soil solution P concentration, which is in equilibrium with soil P, adequate for normal plant growth. The soil solution P concentration was adjusted to different levels based on P-sorption isotherms.

The results indicate the external P requirement of rice is 0.07-0.09 ppm P (Fig. 1). However, Quingua soil gave a higher yield in the control treatment than the other soils, indicating an increased availability under flooding, than determined by the Olsen and Bray 2 methods.

Fertilizer phosphorus sources. Rice yield responses to P fertilizer are becoming more frequent as soils are cropped more intensively and crop yields are increasing from greater use of MVs. Indigenous or imported commercial phosphate rocks (PR) may offer low-cost P fertilizer, but the relative agronomic value of the materials must be determined to identify their potential role as P sources for rice.

Two P source trials initiated during the 1977 WS were terminated in 1982 after 11 successive croppings. Repeated P fertilizer applications for five crops gave mean maximum yield responses of 0.5 t/ha per crop in the WS and 2.0 t/ha in the DS (Fig. 2) on an Ultisol (silty clay, pH - 5.0, Bray 2 P - 5 ppm). During the DS, single superphosphate (SSP) was superior to both HRP (a commercial apatitic) and local PR derived from guano, which gave similar yield responses. During the WS, yields were limited by factors other than P avail-



2. Grain yield responses to fertilizer phosphorus and residual effects in phosphorus source trials in the Philippines.

ability and all sources gave similar yields. Mean yield responses for the three crops during the DS after P application was stopped (responses to residual P fertilizer) were as much as 2.1 t/ha per crop and were similar for all P sources.

On a Vertisol (clay, pH - 6.5, Bray 2 P - 3 ppm), mean yield increases to repeated P fertilizer applications were as much as 1.5 t/ha per crop during the WS and 2.7 t/ha per crop during the DS.

Table 7. Soil characteristics before the trial on rate and method of P application. Lucban, Quezon, Philippines. 1982 DS.

Soil property	Analysis
pH (1:1)	5.0
Total N (%)	0.19
Organic matter (%)	3.3
Available P (ppm Bray 2)	5.0
Perchloric P (ppm)	660
CEC[a] (meq/100 g)	18
Available Zn (ppm, K&P)	2.7
Texture	Clay

[a]CEC = cation exchange capacity.

Table 8. IR36 yield response to rates and methods of P application. Luisiana clay, Lucban, Quezon, Philippines. 1982 DS and WS.

Treatment (kg P/ha)	Yield (t/ha)	
	DS	WS
Control (no P fertilizer)	3.1 c	2.0 b
Band application		
29	4.2 b	2.5 a
57	4.9 a	2.8 a
B&I[a]		
119	5.2 a	3.0 a
238	5.0 a	3.1 a
475	5.1 a	3.0 a
Slurry (seedling-dip)	4.3 b	2.6 a

[a]Residual in the WS.

The relative effectiveness of the P sources were:

WS: SSP > HRP (highly reactive phosphate as calcined iron aluminum phosphate) = PR (guano)

DS: SSP > HRP > PR (guano)

As on the Ultisol, yield responses to residual P fertilizer were similar among sources, but yield increases were greater on the Vertisol.

Source rankings by relative effectiveness for 11 crops were similar to the rankings for five crops because responses to residual P fertilizer were similar among sources.

When 88 kg P/ha was applied during five seasons, more than 22 kg of rice resulted from each kg of P applied as SSP on the Ultisol and 35 kg rice/kg of P on the Vertisol for the 11 crops. In comparison, the PRs produced about 18 and 26 kg of rice/kg of P on the two soils. Thus, the PRs were 75-80% as effective as SSP when considering total yield responses.

RATE AND METHOD OF PHOSPHORUS APPLICATION IN WETLAND RICE

Agronomy Department

In the DS, a new field trial was started on Luisiana clay in Lucban, Quezon, to evaluate rates and methods of P fertilizer application in wetland rice.

The soil analysis in Table 7 shows that the available P was low and under the critical level.

All treatments responded significantly to P in the DS and WS (Table 8). But it was the DS planting that indicated the differences among P-treated plots. Band applying 57 kg P/ha was as good as broadcasting and incorporating 119 to 475 kg P/ha. The yield of IR36 in the slurry (seedling-dip) treatment was significantly higher than that in the control and comparable to that in the band treatment with 29 kg P/ha.

Table 9. Effect of ZnO dip on yield of two rices on Zn-deficient soils. IRRI, 1982 DS.

Soil	Soil characteristic			Yield (g/pot)[a]			
	pH	Org. C (%)	Zn (ppm)	IR26		IR34	
				Zn_0	Zn_1	Zn_0	Zn_1
Bay	7.2	7.1	0.12	40 a	39 a	44 a	39 a
Tiaong	7.7	6.9	0.12	30 bc	29 c	33 ab	36 a
Baluan	7.9	5.1	0.06	24 c	50 ab	37 bc	56 a

[a]Separation of means, in a row, by Duncans multiple range test at the 5% level.

In the WS, typhoons caused the crop to be under water for some time during the spikelet-filling stage, resulting in very low yields. However, there was still significant response to the band and slurry methods. Likewise, the yields in the 119 to 475 kg P/ha B&I (residual P) treatments were superior to the yield in the control (Table 8).

EFFECT OF ZINC APPLICATION ON MARGINALLY ZINC-DEFICIENT SOILS

Soil Chemistry Department

In the Philippines, Zn deficiency is a widespread yield-limiting factor in wetland rice. In some field trials, tolerant varieties either did not respond to Zn application or responded with a yield decrease (Fig. 3). In the greenhouse, an experiment was conducted on three Zn-deficient soils to determine the effect of dipping rice seedling roots in 2% ZnO solution on the growth of resistant IR34 and susceptible IR26.

The two varieties had almost the same yield on marginally Zn-deficient soils to which Zn was applied. Only in the severely Zn-deficient soil from Baluan did both respond significantly (Table 9). Generally, ZnO dip reduced Fe, Mn, Cu, Ca, Mg, and Si uptake in both varieties. Zn application on marginally Zn-deficient soils is generally not advisable, especially when they are planted to resistant varieties.

SULFUR STATUS OF SOME RICE SOILS IN LUZON, PHILIPPINES

Agronomy Department

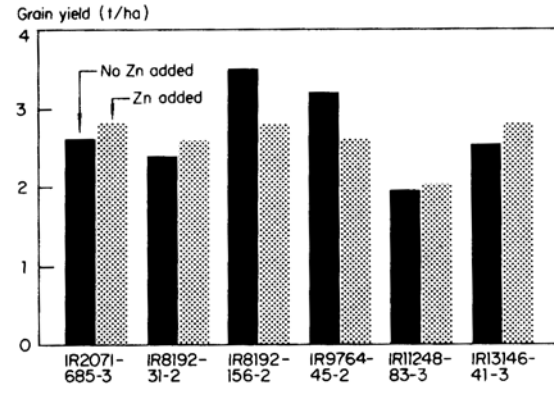
Because of an increasing concern about S deficiency in wetland rice, a survey on the S status of some rice soils in Luzon, Philippines, has been initiated. Soil-profile samples were collected in locations where uneven yellowing of leaves, reduced tillering, and stunted growth of the standing rice crop were observed. The soil samples were analyzed for total S and sulfate-S and other soil properties.

Sulfate-S content varied from 3 to 90, 4 to 97, 3 to 165, and 5 to 122 ppm at 0-20, 21-40, 41-60, and 61-80 cm depths, respectively. Of 43 sites, 3 had SO_4-S lower than 9 ppm on the surface, 9 in the 21-40 cm depth, 8 in the 41-60 cm, and 14 in 61-80 cm depth. Nine parts per million of SO_4-S in soil has been established as the critical level for rice. The 43 sites may be grouped into three categories: 1) decreasing SO_4-S content as depth increases, 2) constant, and 3) increasing SO_4-S content as depth increases (Table 10). Many of the sites in which S decreased with depth had SO_4-S content lower than the critical level of 9 ppm in depths below 20 cm. Similarly, total S was variable and inconsistent with depth. It ranged from 76 to 854 ppm in the topsoil, 64 to 1,210 ppm in the subsoil, and 97 to 833 in the 41-60 cm depth and 81 to 854 ppm in the 61-80 cm depth. Low levels were obtained in light- and heavy-textured soils and in slightly acid and alkaline soils.

RESPONSE OF WETLAND RICE TO APPLIED SULFUR

Agronomy Department

To confirm early reports on the increasing incidence of S deficiency in the Philippines, four areas in Luzon suspected to be S-deficient were initially



3. Effect of Zn on the yield of some rice lines in a peat soil. Famy, Laguna, Philippines, 1982.

Table 10. Three groups of sites in Luzon, Philippines, according to the trend in SO_4-S content by soil profile depth. IRRI, 1982.

SO_4-S trend	Sites (no.)	SO_4-S[a] (ppm) at soil profile depth of			
		0-20 cm	21-40 cm	41-60 cm	61-80 cm
Decreasing	16	23	14	11	9
Constant	11	15	14	15	14
Increasing	6	29	43	61	55

[a] Av value of the sites within each group.

Table 11. Effects of added S on the yield of BG400-1 in four Luzon soils. IRRI, 1982 WS.

Treatment[a] (kg S/ha)	Yield (g/pot)			
	Muñoz, Nueva Ecija	Talavera, Nueva Ecija	Botolan, Zambales	Candelaria Zambales
0	76 a	65 bc	7 f	68 bcd
20	67 ab	69 ab	53 e	54 de
40	71 ab	67 ab	55 de	56 cde

[a]S was added as ammonium sulfate, B&I.

tested for response to added S in the greenhouse (Table 11).

Maligaya clay loam in Muñoz and Quingua clay loam in Talavera, both in Nueva Ecija, and Quingua silt loam in Candelaria, Zambales, which contained 36, 10, and 39 ppm of SO_4-S, respectively, did not respond significantly. However, the Talavera soil which contained 10 ppm SO_4-S showed a tendency to respond to added S. Addition of S in the Candelaria soil tended to depress yield.

Response was significant on a S-deficient Bancal clay (5 ppm SO_4-S) in Botolan, Zambales, where addition of 20 kg S/ha resulted in a 600% yield increase. However, doubling the S rate gave no further yield advantage.

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

The series of trials on N fertilizer efficiency in irrigated, rainfed, medium deep, and deepwater rice under the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) were continued at the IRRI farm. Some of these experiments were also conducted in farmers' fields in the Philippines.

Irrigated. Irrigated trials were conducted on a silty clay soil in Victoria and Famy, Laguna, in the DS and WS.

Soil characteristics based on analyses before trials began are in Table 1.

In both seasons, the yield response of IR36 to N from all sources was significant (Table 2). DS yields were higher in Victoria, but the highest response of 3.3 t/ha was obtained in Famy. Sulfur-coated urea (SCU) in many instances gave higher yields than prilled urea (PU). But in most cases, the yield responses to urea supergranules (USG), PU, and SCU were comparable. In the WS, the crop at Victoria was under water for some time in the active and maximum tillering stages. This caused lodging in the SCU treatments at 87 and 116 kg N/ha. Lodging was not recorded in Famy because the crop was established 1 mo later than in Victoria.

The DS results suggest that 87 kg N/ha was optimum for both sites. But the WS results show that the optimum rate was 58 kg N/ha in Victoria and 116 kg N/ha in Famy. This variability can be related to the initial soil N. Both sites had the same soil total N of 0.20% in the DS, whereas in the WS, Victoria soil had a higher soil N (0.31%) than Famy soil (0.21%). The very high total N of Victoria soil is another factor that caused the lodging.

During the 1982 DS, INSFFER trainees conducted a field trial on different forms of urea and their mode and timing of applications at the IRRI farm to evaluate N fertilizer efficiency in wetland rice. Results with IR9729-67-3 (100- to 105-d maturity) showed that deep placement of two-thirds of the N in the form of USG at transplanting, and topdressing the remaining third in the form of PU at 21 DT gave the highest yield. Broadcast and incorporated (B&I) SCU, and deep-placed USG at transplanting gave the second highest yield (Table 3). Yields obtained with these forms and application techniques were significantly higher than those obtained with researcher's split and farmer's split applications of PU.

Rainfed. In a rainfed rice trial conducted on Binangonan clay soil in Teresa, Rizal (Table 2), response to N was highest (1.4 t/ha) on USG-treated plots at 58 kg N/ha. Because the crop suffered moisture stress at about heading and during spikelet-filling stages, the fertilized plots were affected most. Consequently, yields were much lower than those in irrigated trials. Although the soil N was very low (0.10%), control plots and plots treated with PU at 29 and 58 kg N/ha were

Table 1. Characteristics of soils for INSFFER trials. Farmers' fields in Victoria and Famy, Laguna, and Teresa, Rizal, Philippines, 1982.

Soil property	DS		WS[a]		
	Victoria	Famy	Victoria	Famy	Teresa
pH (1:1)	6.3	4.7	6.5	5.3	6.5
Total N (%)	0.20	0.20	0.31	0.21	0.10
Organic matter (%)	4.1	3.4	5.4	3.4	1.8
Available P[b] (ppm)	4.2	5.8	2.7	5.3	12.0
Exchangeable K (meq/100 g)	0.18	0.10	0.28	0.16	0.47
Exchangeable Ca (meq/100 g)	26	10	26	11	26
CEC[c] (meq/100 g)	43	26	44	28	35
Available Zn (ppm, K and P)[d]	nil	4.0	nil	3.7	0.8
Perchloric Fe (ppm)	46 800	88 500	41 900	88 500	57 000
Texture	Silty clay	Silty clay	Silty clay	Silty clay	Clay
Soil series	Calumpang	Antipolo	Calumpang	Antipolo	Binangonan

[a]Rainfed trial in Teresa. [b]Olsen P for Victoria and Teresa and Bray2 P for Famy. [c]CEC = cation exchange capacity. [d]K and P = Katyal and Ponnamperuma.

Table 2. IR36 yield responses to sources and methods of N fertilizer application. Calumpang silty clay in Victoria, Laguna; Antipolo silty clay in Famy, Laguna; and Binangonan clay in Teresa, Rizal, Philippines. INSFFER, 1982.

Urea form	Application method	Yield (t/ha)				
		Irrigated				Rainfed WS
		DS		WS		
		Victoria	Famy	Victoria	Famy	Teresa
No N fertilizer		4.2 f	3.1 e	3.2 g	2.8 g	3.0 e
		58 kg N/ha		*29 kg N/ha*		*29 kg N/ha*
PU	Split	5.1 e	4.5 d	3.7 efg	3.2 g	3.2 de
SCU	B&I	6.3 abc	4.7 d	4.5 bcd	3.9 f	3.5 cde
USG	Placement	5.3 de	4.7 d	4.0 def	3.7 f	3.7 bcd
		87 kg N/ha		*58 kg N/ha*		*58 kg N/ha*
PU	Split	6.1 bc	5.7 abc	3.6 fg	4.8 de	3.4 cde
SCU	B&I	6.8 a	6.0 ab	5.3 a	4.3 e	3.9 abc
USG	Placement	6.4 ab	5.6 bc	4.9 ab	4.6 de	4.4 a
		116 kg N/ha		*87 kg N/ha*		*87 kg N/ha*
PU	Split	5.7 cd	5.4 bc	4.4 cde	5.0 bcd	3.6 bcd
SCU	B&I	6.6 ab	6.0 ab	4.4 cde	4.9 cd	4.2 ab
USG	Placement	6.3 abc	5.1 cd	5.0 abc	5.0 bcd	4.0 abc
		174 kg N/ha		*116 kg N/ha*		
PU	Split	6.5 ab	6.4 a	4.9 abc	5.5 b	
SCU	B&I	6.5 ab	6.1 ab	4.7 abc	6.0 a	
USG	Placement	6.4 ab	5.5 bc	5.2 ab	5.4 bc	

[a]Split application: 2/3 urea B&I at planting time, and 1/3 topdressed 5-7 DBPI.

also comparable. Only at 58 kg N/ha were differences observed among N sources; USG was superior to PU but comparable to SCU.

Medium deepwater rice. To evaluate N sources, rates, and application methods, a trial was conducted during the 1982 WS at the IRRI farm as part of the second international trial on nitrogen fertilizer efficiency in deepwater rice of the INSFFER Program. IR42 was the test variety and the water depth reached a maximum of 50 cm.

IR42 showed no significant increase in yield with PU, SCU, or USG applied at 29, 58, and 116 kg N/ha (Table 4). Early flooding during stand establishment may have affected IR42 performance with various N treatments.

Urea applied as foliar spray near panicle initiation (PI) showed no advantage over basal or deep-placed urea fertilizers.

Plant N content (%) was higher at 30 DT than at PI because of high N absorption (Table 5). Moreover, N uptake by plants was higher with higher rates of application.

Deepwater rice. An experiment on N fertilizer efficiency in deepwater rice was continued during the 1982 WS at the IRRI farm using RD19 at a maximum water depth of 100 cm. Urea sources were PU, SCU, and USG.

Blanket B&I application of P at 10 kg/ha and K at 33 kg/ha was done during the last harrowing.

The water depth was increased 5 cm/d starting at 30 DT and maintained to the desired depth of 100 cm until harvest.

Table 3. Yield responses to form, mode, and timing of N application. IRRI, 1982 DS.

Treatment[a]	Yield (t/ha)
No N fertilizer	2.7
PU, researcher's split (2/3 basal + 1/3 at PI)	6.2 bcd
PU, farmer's split (2/3 at 21 DT + 1/3 at PI)	5.9 d
SCU, B & I, all at 0 DT	6.7 ab
2/3 SCU + 1/3 PU, B & I, all at 0 DT	6.0 cd
2/3 SCU, B & I at 0 DT + 1/3 PU, topdressed at 21 DT	6.3 abcd
USG deep placement, all at 0 DT	6.6 ab
2/3 USG deep placement at 0 DT + 1/3 PU, topdressed at 21 DT	6.8 a
2/3 USG deep placement at 0 DT + 1/3 PU, topdressed at PI	6.5 abc

[a]N rate = 87 kg/ha.

Table 4. IR42 yield responses to various urea sources, rates, and application methods at a maximum water depth of 50 cm (medium deepwater). Second INSFFER trial, IRRI, 1982 WS.

Urea source	Rate (kg N/ha)	Application method	Yield[a] (t/ha)
Unfertilized control	0	–	2.4 c
PU	29	B & I	2.7 abc
PU	29	2/3 B & I + 1/3 foliar spray of urea	2.7 abc
SCU	29	B & I	2.5 bc
USG	29	Point placement	2.7 abc
PU	58	B & I	2.8 abc
PU	58	2/3 B & I + 1/3 foliar spray of urea	3.0 abc
SCU	58	B & I	3.1 ab
USG	58	Point placement	3.1 ab
PU	116	B & I	3.3 a
PU	116	2/3 B & I + 1/3 foliar spray of urea	3.2 a
SCU	116	B & I	2.7 abc
USG	116	Point placement	2.8 abc

[a] Av of three replications.

Table 5. N content of IR42 at two growth stages as affected by urea sources, rates, and application methods at maximum water depth of 50 cm (medium deepwater). Second INSFFER trial, IRRI, 1982 WS.

Urea source	Rate (kg N/ha)	Application method	N content[a] (%)	
			30 DT	PI
Unfertilized control	0	–	2.54 d	1.46 bc
PU	29	B & I	2.78 cd	1.37 c
PU	29	2/3 B & I + 1/3 foliar spray of urea	2.58 d	1.49 abc
SCU	29	B & I	3.44 ab	1.42 bc
USG	29	Point placement	3.21 bc	1.38 c
PU	58	B & I	3.37 ab	1.56 abc
PU	58	2/3 B & I + 1/3 foliar spray of urea	3.22 bc	1.62 abc
SCU	58	B & I	3.13 bc	1.63 abc
USG	58	Point placement	3.32 abc	1.35 c
PU	116	B & I	3.81 a	1.58 abc
PU	116	2/3 B & I + 1/3 foliar spray of urea	3.31 abc	1.41 bc
SCU	116	B & I	3.25 bc	1.75 ab
USG	116	Point placement	3.57 ab	1.82 a

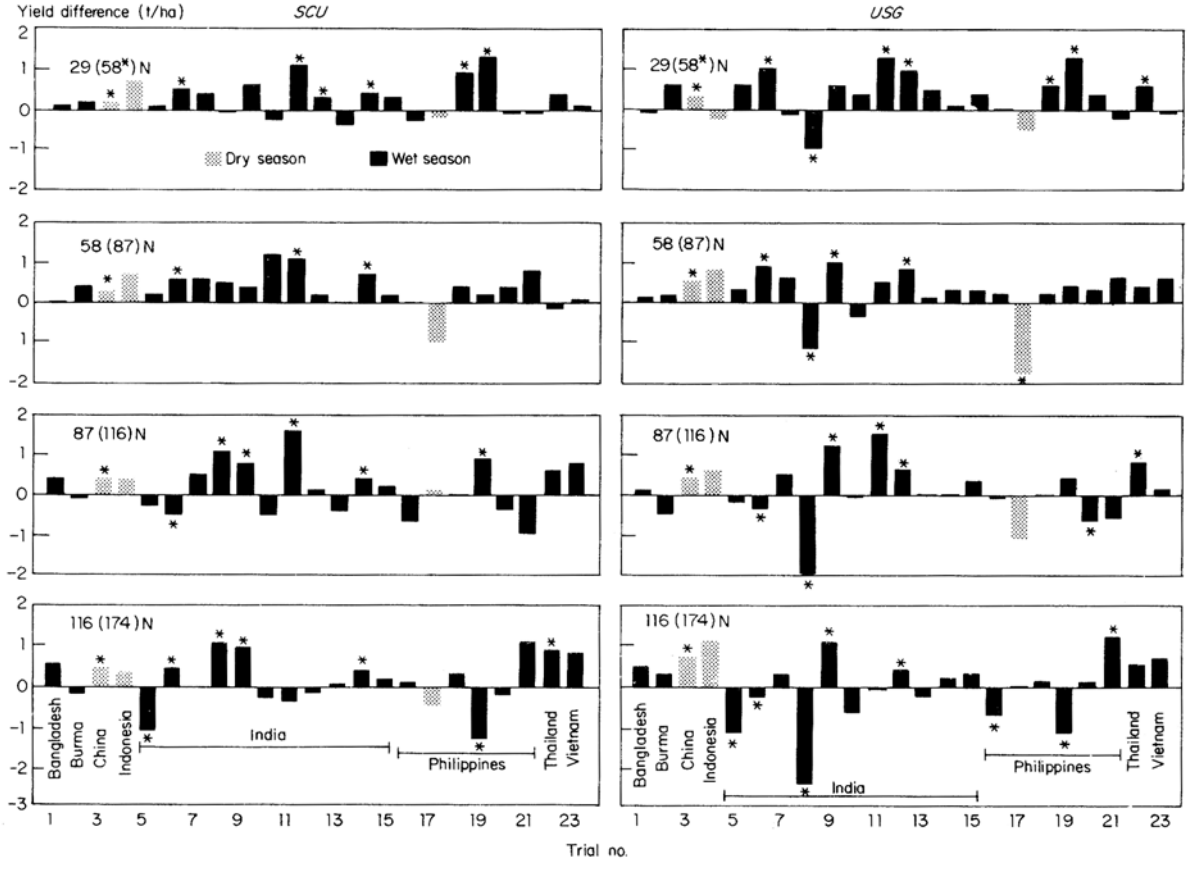
[a] Av of three replications.

At 29 kg N/ha, all N sources performed equally well. However, point-placed USG at 58 kg N/ha gave significantly higher yields than B&I SCU (Table 6). Urea applied as a supplementary foliar spray near PI showed no advantage over urea applied as a full basal dose, B&I.

Deep point-placed USG gave the highest RD19 yield (3.5 t/ha) at 29 and 58 kg N/ha. This suggests that the application of 29 kg N/ha was adequate to obtain that yield; however, RD19 suffered stem borer damage, which resulted in lower yields than reported earlier.

INSFFER INTERNATIONAL TRIALS

Fertilizer efficiency trials. Preliminary results from the fifth international trial on nitrogen fertilizer efficiency in wetland rice were reported. Of the 23 trials at 21 sites in eight countries, three were conducted during the DS and 20 during the WS. In general, the advantage of SCU and USG over PU was more apparent at lower rather than at higher N rates (Fig. 1). With point-placed USG, yields were consistently lower in more trials at higher N rates than with split-applied PU (Table 7). At one Indian



1. Significant yield increase or decrease in 23 trials with N applied as SCU, B&I, or USG, point-placed, compared with PU, best split at four rates. Fifth international trial on nitrogen fertilizer efficiency in irrigated rice, INSFFER, 1981-82.

site, consistently lower yields when USG was applied were attributed to excessive percolation. However, in the same trial, yields were significantly higher with SCU than with PU at the higher N rates (87 and 116 kg N/ha) (Fig. 1).

The effects of SCU and USG were quite variable among trials and inconsistent at all N rates. This response variability in some trials justifies the need for a thorough characterization of the INSFFER sites.

In 9 of 11 N fertilizer efficiency trials in rainfed rice, yield response to N was significant (Fig. 2). The average results of the nine N-response trials show the similarity in effects, of the three N sources at 29 kg N/ha. In some trials, significant differences were observed between SCU or USG and PU applied in split doses recommended by researchers at 58 and 87 kg N/ha (Fig. 2).

Thirteen trials on N fertilizer efficiency in deepwater rice were conducted at seven sites in five

Table 6. RD19 yield responses to urea sources, rates, and application methods at maximum water depth of 100 cm (deepwater). Second INSFFER trial, IRRI, 1982 WS.

Urea source	Rate (kg N/ha)	Application method	Yield[a] (t/ha)
Unfertilized control	0	–	2.6 bc
PU	29	B & I	3.1 ab
PU	29	2/3 B & I + 1/3 foliar spray of urea	3.0 abc
SCU	29	B & I	3.2 ab
USG	29	Point placement	3.5 a
PU	58	B & I	2.8 abc
PU	58	2/3 B & I + 1/3 foliar spray of urea	2.8 abc
SCU	58	B & I	2.5 bc
USG	58	Point placement	3.5 a
PU	116	B & I	3.3 ab
PU	116	2/3 B & I + 1/3 foliar spray of urea	2.6 bc
SCU	116	B & I	3.2 ab
USG	116	Point placement	2.3 c

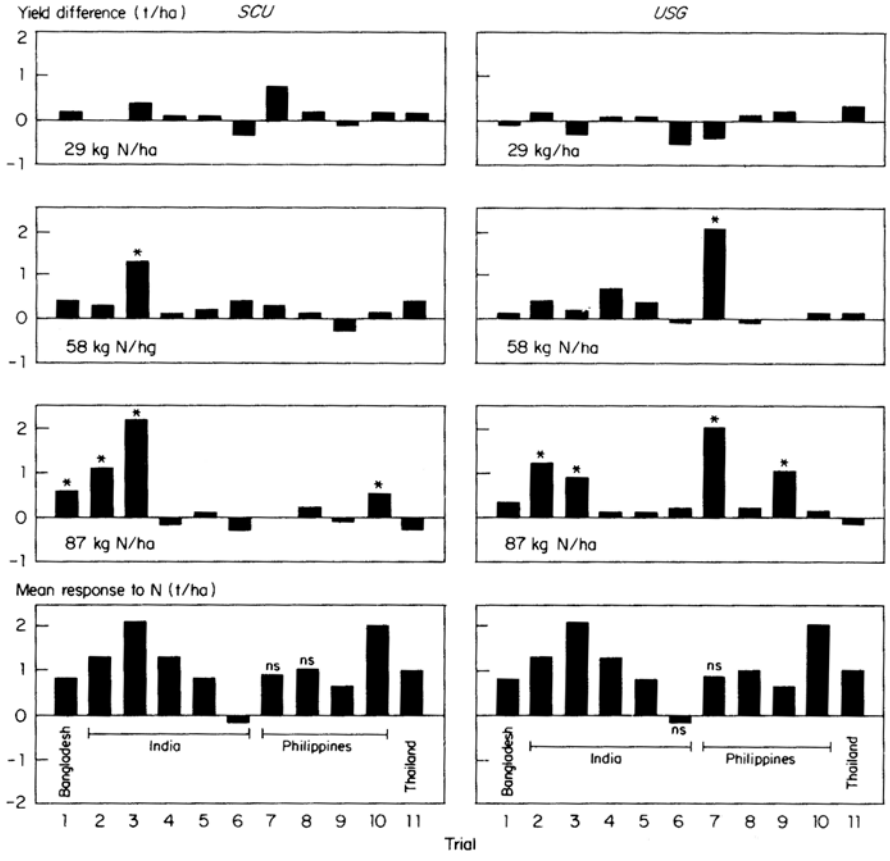
[a] Av of three replications.

countries. While rice at three sites did not respond significantly to any form of urea, it responded significantly to all N treatments in three trials (Fig. 3). Although yield increases were consistently significant in nine trials in treatments that involved application of SCU, B&I, either alone or in combination with PU, B&I or foliar, yield increases were not significant with PU, B&I alone.

The average yield data of the nine treatments tested in 69 long-term fertility trials at 12 sites in

Table 7. Mean yield difference between SCU and USG over PU at 23 sites of fifth international trial on nitrogen fertilizer efficiency in irrigated wetland rice, 1981 cropping seasons.

Treatment	Yield (t/ha)			
	29 kg N/ha	58 kg N/ha	87 kg N/ha	116 kg N/ha
SCU vs PU				
All sites	0.2	0.4	0.2	0.2
Sites with significant (+) differences	0.8	0.8	1.0	0.8
USG vs PU				
All sites	0.4	0.3	0.2	0.0
Sites with significant (+) differences	1.0	0.9	1.0	0.9



2. Significant yield increase or decrease in 11 trials with N applied as SCU, B&I, or USG, point-placed, compared with PU, split doses at three rates; and mean response to N. Third international trial on nitrogen fertilizer efficiency in rainfed rice, INSFFER, 1981 cropping seasons.

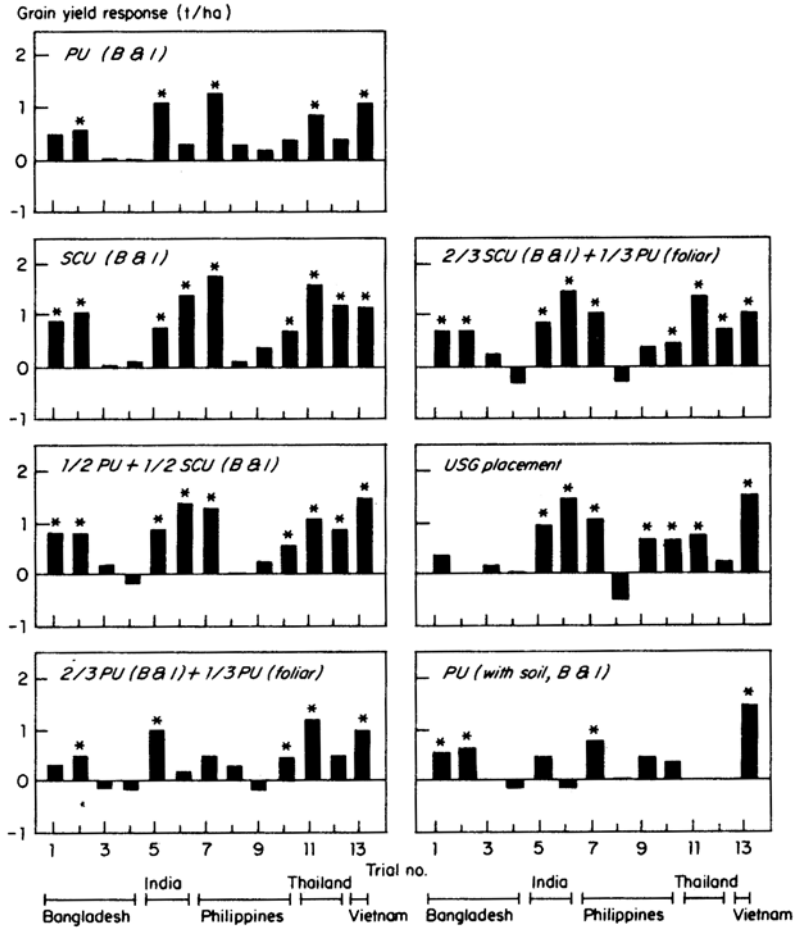
seven countries during 1976-81 are summarized in Table 8. Yield increases were higher in the DS than in the WS trials. With single applications of N, P, and K, 47 of 69 trials showed significant responses to N, 14 to P, and 11 to K. Responses to N, either alone or in combination with P or K, were greater than responses to P or K alone. Although higher yields could be maintained with continuous application of NPK, lower yields could result from a continuous application of NPK with Zn (Table 8).

The effects of three P sources on yield are apparent in the DS trials only (Table 9). Responses to heavy applications of mildly and highly reactive rockphosphates, and to ordinary superphosphate

Table 8. Yield responses to nine treatments tested in 69 trials in the international long-term fertility trial in rice, INSFFER, 1976-81.

Fertilizer treatment	Av yield (t/ha)[a]	
	DS	WS
Control	3.1	2.7
N	4.1	3.7
P	3.5	3.1
K	3.4	3.0
NP	4.4	3.8
PK	3.6	3.1
NK	4.2	3.7
NPK	4.8	4.1
NPK + zinc[b]	3.3	3.2

[a] Av of 29 trials in DS and 40 trials in the WS. [b] Tested in 10 DS and 12 WS trials.



3. Yield responses to different urea forms and application methods. First international trial on nitrogen fertilizer efficiency in deepwater rice, INSFFER, 1980-81 WS.

Table 9. Yield responses to different P sources and rates. International trial on sources of phosphorus in flooded rice, INSFFER, 1977-81.

Source	Rate[a] (kg P/ha)	Av yield (t/ha)[b]		
		Dry	Wet	Residual
Control	–	4.0	3.6	2.8
Superphosphate	8.8	4.8	3.9	3.6
	17.6	5.2	3.9	4.1
	26.4	5.3	4.0	4.3
Highly reactive rockphosphate[c]	8.8	4.5	3.9	3.6
	17.6	4.9	4.0	4.0
	26.4	5.0	3.9	4.1
Less reactive rockphosphate[d]	17.6	4.3	4.0	4.0
	35.2	4.7	4.0	4.3
	52.8	4.8	4.0	4.4

[a]Based on total P content of the material. [b]Yield of 71 regular (24 dry and 47 wet seasons) and 13 residual crops. [c]Phosmak was applied to soils with pH < 6.0, and phospal to soils with pH >6.0. [d]Local rockphosphate or Christmas Island was applied to soils with pH < 6.0, and local rockphosphate, guano, or Christmas Island to soils with pH >6.0.

at a low P rate were comparable. Phosphatic materials did not differ in agronomic effectiveness in 13 residual trials conducted in the Philippines and Thailand. The magnitude of response to residual P increased as the amount of P applied was increased.

Azolla trials. In 13 trials conducted in seven countries, the effects of plant spacing on the response of rice to N, applied as urea or azolla, or their combination, were evaluated in the third international trial on the use of azolla in rice. Plant spacing did not affect yield response. Positive responses obtained from 12 of 13 trials were due to added N and not to plant spacing. Average yields of all 13 trials showed no significant differences among treated plots (Table 10).

INSFFER TRAINING

The fourth 4-mo INSFFER training course held 8 Feb-28 May was attended by 23 representatives of Bangladesh, Burma, China, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand, and Vietnam. Eighty-seven participants have now completed the course since 1979.

In the 1982 training course, a slight modification was made in the number of fertilizer field trials

Table 10. Yield responses of wetland rice to N fertilizer, azolla, and their combination, as affected by plant spacing. INSFFER, 1981-82 cropping seasons.

Treatment	Plant spacing (cm X cm)	Av yield[a] (t/ha)
Control	20 X 20	2.7
60 kg N	20 X 20	3.8
60 kg N	10 X 40	3.8
30 kg N + azolla	20 X 20	3.8
30 kg N + azolla	10 X 40	3.9
Azolla grown before and after transplanting, then incorporated after full cover	20 X 20	3.6
Azolla grown before and after transplanting, then incorporated after full cover	10 X 40	3.7
Azolla grown twice after transplanting	10 X 40	3.6

[a]Av of 13 trials.

conducted by the trainees. Each of four trainee groups was assigned to one experiment. IR9729-67-3 was the test cultivar in the following trials:

- Fifth international trial on nitrogen fertilizer efficiency in wetland rice (irrigated). In general, yields were higher with USG placement than with urea best split and SCU broadcast, but when urea was incorporated at lower levels of applied N, yield differences were not significant.
- First international long-term fertility trial in rice. N alone or combined with P or K, gave a significant increase in yield; plots with P and K alone or with P and K in combination gave lower yields than with the control (without fertilizer) plots. Complete fertilizer treatment (NPK) gave no further yield increase over N treatment alone unless the seedlings were treated with Zn.
- Azolla INSFFER trial. Regardless of plant spacing, azolla incorporation before transplanting plus split application of 30 kg N/ha as PU and split application of 90 kg N/ha as PU gave comparable yields. Similarly, application of azolla alone and split application of 60 kg N/ha as PU gave comparable yields but no significant yield increase over control.
- Forms of urea and their mode of application. Results of this experiment were reported earlier in this section.

Soil and crop management

Rice crop cultural practices

Agronomy and Soil Chemistry Departments

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CONTINUOUS CROPPING (1968-1982)

Agronomy Department

The continuous cropping experiment was first established in 1962. It was redesigned in 1968; since then the same design has been used. The treatments included four N fertilizer levels, six rice entries, and two planting methods. IR8 yields were compared with those of modern varieties (MVs) or promising breeding lines. Three rice crops per year were grown in the same area. The DS crops were grown January-May, early WS crops during May-September, and the late WS crops during September-January. Soil analyses of the experimental area are in Table 1.

Dry season. For the past 15 yr (1968-82), DS yields were consistently higher than the WS yields (Fig. 1). Solar radiation during the reproductive and ripening stages were higher during the DS than in the WS. IR661-1-140-3-117, a sister line of IR24 had the highest yield (10 t/ha) recorded in 1971 (Table 2). In the 1972 DS, IR24 produced 9.9 t/ha.

IR36 had the highest yield (7.8 t/ha) in 1981. Without N fertilizer application, the highest yield (7.4 t/ha) was obtained in 1971. During 1980 and 1982, yields without N fertilizer varied from 3.6 to 3.7 t/ha (Table 3).

Wet season. Figure 1 shows that the May-September plantings outyielded the September-January plantings. The highest yield for both early and late WS was recorded in 1969. Lodging and diseases caused the low yields. In the late WS, the intermediate N rate generally gave the highest yields. Like the DS yields, the WS yields have declined over the years.

Based on averages for 15 yr (1968-82), yield differences between broadcast seeded and transplanted plots were not significant.

Table 1. Chemical analyses of the soil from continuous cropping experiment. IRRI, Blocks B5-B8, 1982.

	1963	1978	1981
pH	–	6.6	7.0
Organic C (%)	1.84	2.05	1.75
Total N (%)	0.19	0.21	0.17
CEC[a] (meq/100 g)	–	–	38
Exch. K (meq/100 g)	–	0.60	0.69
Available P (ppm)			
by: Bray II	–	34	28
Olsen	–	20	21
Available Zn (ppm)	–	–	0.34

[a]CEC = cation exchange capacity.

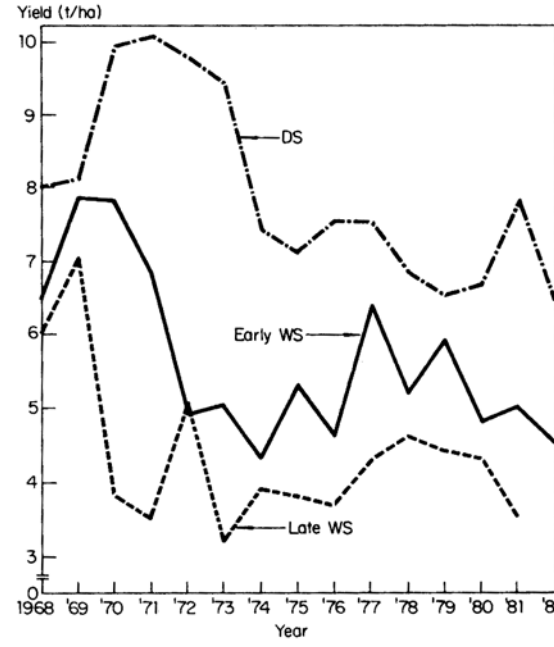
ONE-, TWO-, AND THREE-CROP CYCLES PER YEAR (1970-82)

Agronomy Department

An experiment was established in 1970 to monitor long-term yield trends under one-, two-, and three-crop cycles in wetland rice. These three cropping cycles represent large areas where one, two, and three rice crops are grown. Fertilizer application rates were lower in 1975-82 than in 1970-74 because of concern about higher energy costs.

Total yield was 2.5 times larger for two crops (one DS and one WS) and 3.5 times larger for three crops (continuous rice production) than for one WS crop (Table 4).

Highest yields by year are in Table 5. In 1970 and 1971, IR790-28-6 yielded between 8.7 and 8.8 t/ha. High-protein IR480-5-9-3-3 yielded 8.6 t/ha in 1972. Recently, IR44 yielded 8.1 t/ha. In 1982, IR42 yielded highest (7.1 t/ha). These data suggest that, like most experiments at the IRRI farm, yields decreased over time. Lodging susceptibility, increased pest pressures, and other soil factors



1. Highest rice yields for three planting seasons. Continuous cropping experiment, IRRI, 1968-82.

Table 2. IR8 yield and the highest-yielding entry in the continuous cropping experiment. IRRI, Blocks B5-B8, 1968-82.

Year	Crop no.	Yield (t/ha) IR8	DS, MV or line	Crop no.	Yield (t/ha) IR8	Early WS, MV or line	Crop no.	Yield (t/ha) IR8	Late WS, MV or line
1968	16	6.9	8.0 (IR262-43-8-1-1)	17	6.4	6.0 (IR400-28-4-5)	18	5.4	6.0 (IR262-43-8-11)
1969	19	8.1	7.9 (IR593-3-1-7)	20	a	7.8 (IR593-3-17)	21	6.0	6.1 (IR24)
1970	22	8.7	9.9 (IR24)	23	6.8	7.8 (IR22)	24	3.6	3.8 (IR24)
1971	25	8.0	10.0 (IR661-1-140-3-117)	26	5.9	6.8 (IR22)	27	3.1	3.5 (IR22)
1972	28	8.7	9.9 (IR24)	29	4.7	4.9 (IR22)	30	4.2	5.0 (IR1561-228-3)
1973	31	7.9	8.4 (IR1529-680-2)	32	2.8	5.0 (IR1514A-E666) (IR1541-76-3)	33	2.4	3.2 (IR1541-26-3)
1974	34	7.1	7.3 (IR1574A-E597-2)	35	4.3	4.3 (IR26)	36	3.8	4.1 (IR36)
1975	37	7.1	6.9 (IR26)	48	5.3	4.8 (IR30)	39	3.2	3.8 (IR30)
1976	40	7.0	7.5 (IR36)	41	3.6	4.6 (IR36)	42	2.6	3.7 (IR36)
1977	43	3.2	7.6 (IR4432-52-6-4)	44	3.1	6.4 (IR36)	45	1.5	4.7 (IR36, IR4432-52-6-4)
1978	46	3.3	6.8 (IR4432-52-6-4)	47	4.6	5.2 (IR36)	48	4.6	4.6 (IR36)
1979	49	6.4	6.5 (IR4568-86-1-3-2)	50	5.6	5.9 (IR4432-52-6-4)	51	3.7	4.4 (IR4432-52-6-4)
1980	52	5.1	6.6 (IR50, IR5853-162-1-2-3)	53	1.1	4.8 (IR36)	54	1.1	4.3 (IR36)
1981	55	5.8	7.8 (IR36)	56	3.2	5.0 (IR15314-43-2-3-3)	57	1.2	3.5 (IR36, IR54)
1982	58	5.9	6.4 (IR54)	59	1.6	4.5 (IR36)			

[a]Completely damaged by RGSV.

Table 3. Highest yields without N fertilizer for 15 yr consecutive croppings. IRRI, Blocks B5-B8, 1968-82.

Year	Yield (t/ha)[a] DS		Early WS		Late WS	
	T	B	T	B	T	B
1968	6.2	5.7	4.6	4.5	4.6	4.6
1969	4.6	5.7	4.6	5.7	6.8	5.3
1970	6.5	7.0	6.5	6.6	3.1	3.4
1971	7.4	7.2	4.9	5.8	3.2	2.8
1972	6.3	6.8	4.1	4.4	4.2	3.8
1973	4.8	4.8	3.4	3.6	2.6	2.7
1974	4.1	4.6	3.7	3.5	2.7	2.7
1975	3.8	3.9	3.7	3.9	2.9	2.7
1976	4.6	4.5	3.6	3.6	2.8	2.6
1977	4.7	4.0	5.4	5.9	3.6	3.7
1978	4.5	4.5	4.1	4.2	3.5	3.4
1979	3.2	3.6	4.6	4.0	3.1	3.0
1980	3.6	3.4	3.4	3.7	3.6	3.7
1981	3.4	3.0	2.9	3.0	2.4	2.4
1982	3.6	3.4	3.3	3.1		

[a]T = transplanted, B = broadcasted.

would explain some of the decline. However, pest pressures were not higher in the continuous croppings (three-crop cycle) than in a single WS crop.

Since 1970 the yield advantage of the MVs over traditional variety Binato has been pronounced during the entire cropping period.

MANAGEMENT OF NITROGEN FERTILIZER FOR EFFICIENT USE IN EARLY-MATURING RICE

Agronomy Department

Research was continued during the 1982 crop seasons to evaluate the productivity, percentage of brown-rice protein (BRP), and lodging resistance of 4 varieties and 10 promising early-maturing lines with various rates and methods of N application.

In the DS, eight rices had the same average yield as IR36 or higher. IR21015-80-3-3-1-2 produced the highest yield (7.4 t/ha) when treated with either slow-release SCU at 87 kg N/ha or split-applied with PU at 150 kg N/ha. This line also gave the highest average yield (6.7 t/ha); IR25588-32-2 gave the next highest (6.6 t/ha) and the highest productivity of 73 kg/ha per day.

The BRP contents of IR36 averaged 8.9%; those of the 10 rices tested ranged from 8.5 to 9.7% during the DS. Early-maturing rices have retained high BRP contents and yielded similarly to IR42.

Results confirmed previous findings (Annual report for 1980) that N application increases BRP content and that using slow-release SCU can further increase BRP content over split-applied PU.

Table 4. Total yields at different cropping frequencies. One-, two-, three-crop cycle/year experiment. IRRI, Block B4, 1970-82.

Year	Yield[a] (t/ha)					
	One crop		Two crops		Three crops	
	T	B	T	B	T	B
1970	4.2	3.2	11.7	10.6	15.7	14.4
1971	4.5	3.9	11.9	10.9	19.3	17.9
1972	3.8	3.2	10.8	3.1[b]	12.3[c]	10.8[c]
1973	M	M	6.2[d]	5.7[d]	7.9[de]	7.8[de]
1974	4.3	2.7	10.5	9.6	12.2	11.6
1975	3.8	2.6	8.9	7.6	11.8	11.6
1976	3.0	3.2	9.6	10.2	12.3	11.7
1977	3.8	3.4	9.9	10.1	15.4	14.4
1978	3.0	2.8	8.9	7.3	12.2	11.2
1979	3.9	3.3	9.2	7.6	11.5	10.3
1980	3.3	3.0	9.1	9.0	11.9	11.2
1981	2.5	2.7	7.9	7.7	11.6	10.2
1982	4.2[f]	3.7[f]	9.4[f]	8.2[f]	g	g
Av	3.7	3.1	9.5	8.3	12.8	11.9
Av	3.4		8.9		12.4	

[a]Av of Binato and MV or line. T = transplanted, B = broadcast-seeded on puddled field. [b]No harvest during the DS. [c]One rice entry was affected by bacterial leaf blight and was harvested at hard-dough stage. [d]No harvest during the WS. [e]IR24 severely damaged by rats. [f]Av of three MVs. [g]Complete rat damage.

The data on lodging resistance factor (cLr) in the DS indicate the relative field lodging behavior in the WS. Among the four varieties, IR8 consistently had the highest cLr, indicating high-level resistance to lodging; IR50 had the lowest. The promising line IR25588-32-2 had a comparable cLr to IR8 (Table 6). Results further suggest that the susceptibility of the rice crop to lodging increases with an increasing N rate.

In the WS, eight lines matured 4-13 d earlier than IR36 but only two lines produced similar or higher yields. IR9729-67-3 yielded highest (6.4 t/ha) in plots treated with urea at 90 kg N/ha in split doses. This line also had the highest average yield (5.7 t/ha) and productivity of 64 kg/ha per day.

Without N fertilizer, IR42 yielded 4.1 t/ha during both seasons; IR25588-32-2 yielded 5.3 t/ha and IR21015-80-3-3-1-2, 5.0 t/ha during the DS, and IR9729-67-3, 5.0 t/ha during the WS.

In both seasons, slow-release SCU and deep-placed USG did not generally increase yields over split-applied urea.

PLANT-GROWTH REGULATORS

Agronomy Department

Application before herbicides for control of volunteer rice in ratoon crop. Volunteer rice is considered a weed in the ratoon crop, but it resists herbicides,

Table 5. Yields of transplanted Binato and MVs at different cropping frequencies. Dry-season plantings, One-, two-, three-crop cycle/year. IRRI, Block 4, 1970-82 DS.

Year	Yield (t/ha)			
	Two crops		Three crops	
	Binato	MV[a]	Binato	MV[a]
1970	4.9	8.6 (IR790-28-6) (IR790-28-2)	5.4	8.8 (IR790-28-6)
1971	4.4	8.7 (IR790-28-6)	4.3	8.6 (IR22)
1972	3.9	8.2 (IR22)	4.0	8.6 (IR480-5-9-3-3)
1973	4.6	7.6 (IR24)	4.8	7.2 (IR24)
1974	5.1	7.8 (IR3265-112-1-3)	5.1	8.4 (IR3265-112-1-3)
1975	3.3	6.5 (IR3265-112-1-3)	2.5	6.6 (IR3265-112-1-3)
1976	3.8	6.9 (IR46)	4.6	6.7 (IR46)
1977	3.9	7.8 (IR44)	4.7	8.1 (IR44)
1978	3.1	5.7 (IR44)	2.8	5.6 (IR44)
1979	3.8	6.8 (IR42)	3.7	4.8 (IR46)
1980	3.6	6.9 (IR44) (IR46)	2.8	6.6 (IR42)
1981	0.9[b]	6.2 (IR42)	1.1	5.6 (IR44)
1982	3.7	7.1 (IR42)	2.0	5.9 (IR42)

[a]Highest yield among MVs. [b]Damaged by rats and birds.

making its control more difficult.

A main rice crop grown in the field was cut 15 cm from the ground and transplanted in drums as a ratoon crop. One hundred newly harvested seeds of IR9752-71-3-2 were broadcasted in each drum as volunteer rice.

Treatment with plant-growth regulators, such as GA_3, kinetin, CCC, and TIBA before herbicide application satisfactorily controlled volunteer rice and improved the performance of the ratoon rice (Table 7).

Butachlor application alone at 2.0 kg ai/ha at early postemergence of volunteer rice and at preemergence of weeds controlled the volunteer rice, grasses, and other weeds. However, reduction in number of tillers reflected a slight inhibition of

Table 6. The cLr of four rice varieties and 10 early-maturing rices as affected by N fertilizer application. IRRI, 1982 DS.

Entry	cLr[a]					
	O N	87 kg N/ha			150 kg N/ha	Mean
		Urea split	SCU	USG	Urea split	
IR8	0.22	0.20	0.20	0.20	0.20	0.20 a
IR36	0.10	0.09	0.09	0.10	0.10	0.10 d
IR42	0.20	0.19	0.18	0.17	0.18	0.18 b
IR50	0.10	0.09	0.09	0.08	0.08	0.08 e
IR9729-67-3	0.11	0.10	0.11	0.10	0.10	0.10 d
IR9752-71-3-2	0.10	0.10	0.11	0.10	0.10	0.10 d
IR15429-268-1-2-1	0.10	0.10	0.10	0.10	0.10	0.10 d
IR19735-5-2-3-2-1	0.20	0.19	0.18	0.17	0.17	0.18 b
IR19743-25-2-2	0.10	0.09	0.08	0.08	0.08	0.08 e
IR19743-46-2-3-3-2	0.10	0.09	0.09	0.09	0.09	0.09 de
IR19746-28-2-2	0.11	0.10	0.09	0.09	0.08	0.09 de
IR19774-23-2-2-1-3	0.10	0.10	0.10	0.10	0.10	0.10 d
IR21015-80-3-3-1-2	0.17	0.16	0.15	0.14	0.14	0.15 c
IR25588-32-2	0.19	0.19	0.20	0.18	0.18	0.19 ab
Mean	0.14 a	0.13 b	0.13 b	0.12 c	0.12 c	

[a]Av of four replications. Urea split = 2/3 B&I and 1/3 topdressed 5-7 DBPI; SCU = sulfur-coated urea, B&I; USG = urea supergranules placed 10-15 cm deep.

$$cLr = \frac{\text{total wt of freely suspended chain links + hook (g)}}{\text{culm length (cm)}}$$

Table 7. Effect of sequential application of plant growth regulators and herbicides on volunteer rice and weed control and ratoon yield. IRRI, June-August, 1982.

Treatment	Rate[a]		Volunteer rice control (%)	Weed dry wt (g/m^2)	Yield (g/plant)	Panicles (no./plant)
	Growth regulators (ppm)	Herbicides (kg ai/ha)				
Butachlor	–	2.0	98	53	15	19
GA_3 fb butachlor	100	2.0	95	39	18	21
Kinetin fb butachlor	50	2.0	95	32	21	
2,4-D	–	2.0	94	100	13	18
CCC fb 2,4-D	5000	2.0	96	26	17	21
TIBA fb 2,4-D	500	2.0	96	22	20	21
Hand weeding	–	–	64	29	23	21
Unweeded	–	–	0	530	3	6

[a]Plant-growth regulators were applied when the coleoptiles of broadcasted seeds of volunteer rice had just emerged. Herbicides were applied 1 d after plant growth regulators.

rice growth. Foliar application of GA_3 or kinetin 1 d before butachlor application prevented this adverse inhibition. Yields from these treatments were as good as that from the hand-weeded control. Results were similar when CCC or TIBA was applied before 2,4-D (Table 7).

Effect on growth and yield of ratoon and direct-seeded crops. The three-replication experiment on IR9752-71-3-2 was conducted in a split-plot design with ratoon and direct seeding in the main plots and plant-growth regulators in the subplots. The plot was 4 m × 2.6 m (10.4 m^2) and spacing was 25 cm for the direct-seeded crop and 20 × 20 cm in the ratoon crop.

The treatments were 1) CCC — 5,000 ppm, 2) TIBA — 500 ppm, 3) GA_3 — 40 ppm, 4) B9 — 5,000 ppm, 5) CCC fb kinetin — 5,000 ppm fb 20 ppm, and 6) control.

Plants treated with CCC and TIBA at the seedling stage showed leaf yellowing within 2-3 DAT in direct-seeded plots with no tillage. Plants did not show any growth during this period. However, plants recovered after 5 d, became even more vigorous, and produced tillers with greener leaves.

B9 showed less adverse effect after treatment as plant leaves did not show yellowing. Postflowering treatment with GA_3 prolonged leaf senescence and delayed maturity by 2-4 d compared with the control. The application of CCC at seedling stage followed by kinetin after flowering delayed leaf senescence and maturity by 2-3 d.

In general, ratoon rice plants were shorter than direct-seeded plants.

Plant height was reduced significantly in direct-seeded plants treated with CCC and TIBA (Table 8).

In general, the ratoon crop yielded much lower than the direct-seeded crop without tillage. Ratoon yields varied from 1.9 to 2.2 t/ha (Table 8) and were only 48% of the direct-seeded crop (3.9-4.5 t/ha). The lower yield in the ratoon crop might be mainly due to the lower number of panicles and higher sterility. Plants given a foliar application of CCC followed by spraying of kinetin after flowering yielded the highest. In the ratoon crop, they yielded 12% higher and in the direct-seeded crop 15% higher than the control.

METHODS OF RAISING SEEDLINGS AND PLANTING ON ACID-SULFATE SOIL

Soil Chemistry Department

Methods of raising seedlings and of planting IR26 and IR4683-54-2 were compared in the DS on acid-sulfate soils at Balza and Burabod in Malinao, Albay, Philippines. The four methods were:

1. Direct seeding of pregerminated seeds.
2. Dapog: raising seedlings with high seeding rate without soil; transplanting after 14 d.
3. Semi-dapog: raising seedlings with high seeding rate with soil in a wet seedbed; transplanting after 14 d; the seedlings were removed by slicing off the upper 3-5 cm of the seedbed, cutting portions of the root.
4. Conventional method: transplanting 21-d-old seedlings raised on a wet seedbed at moderate seeding rates.

No fertilizers were applied to the seedbeds.

Table 8. Plant growth regulator effect on the height and yield of IR9752-71-3-2 as ratoon and direct-seeded crops.[a] IRRI, 1982 WS.

Growth regulator	Concn (ppm)	Yield				Plant ht	
		Ratoon crop		Direct seeded crop		Ratoon crop (cm)	Direct seeded crop (cm)
		t/ha	% of control	t/ha	% of control		
CCC	5000	2.0 a	106	4.3 ab	110	61 a	69 b
TIBA	5000	2.1 a	109	4.3 ab	109	54 b	69 b
GA_3	40	1.9 a	98	4.0 c	102	57 ab	79 a
B9	5000	1.9 a	101	4.1 bc	104	60 a	77 a
CCC fb kinetin	5000 fb 20	2.2 a	112	4.5 a	115	62 a	72 ab
Control		1.9 a	100	3.9 c	100	64 a	77 a

[a] Av of four replications.

Toxicity scores. Scores for tolerance to injury caused by acid-sulfate soil, based on foliar symptoms and general appearance of the plants, were in the same range for both sites (2.7-6.3 and 3.3-5.8). Varietal mean comparison showed lower toxicity scores for IR4683-54-2. Direct-seeded rice had the poorest growth, regardless of varietal tolerance. The other three methods showed comparable growth (Table 9).

Yield. IR4683-54-2 had a highly significant yield advantage over IR26 of 1.1 t/ha at Balza and 0.9 t/ha at Burabod. There was no significant yield difference among dapog, semidapog, and conventional method. Direct-seeding significantly resulted in the lowest yield (3.9 t/ha at Balza and 3.7 t/ha at Burabod) and is not recommended on acid-sulfate soils.

Table 9. Effect of four methods of raising seedlings and transplanting on toxicity tolerance scores at 7 WT[a]. IRRI, 1982.

Method	Score	
	Balza	Burabod
Direct seeding	6.0 a	5.6 a
Dapog method	3.8 b	4.6 b
Semidapog method	3.5 b	4.1 bc
Conventional method	3.0 b	3.8 c

[a]Av of three replications and two varieties.

PERFORMANCE OF MODERN DRYLAND RICES IN FARMERS' FIELDS

Agronomy Department

Four Batangas dryland farmers were invited to try five modern dryland rices in their fields along with their traditional variety. The farmers used their own cultural practices.

One farmer each from Santo Tomas and Tanauan had successful crops; one had a crop failure because of a flood; and the last one failed to seed the materials.

Farmers' test. At Santo Tomas, IR43 yielded 5.1 t/ha and UPL Ri-5, 4.8 t/ha. However at Tanauan, UPL Ri-5 yielded 4.7 t/ha and IR43, 4.1 t/ha (Table 10). Both had higher grain yields than their respective checks, which have similar growth durations. The lower yields of IR6115-1-1-1 (mean of 2.5 t/ha) and IR9782-111-2-1-2 (mean of 2.6 t/ha) were attributed to rat damage and sheath blight disease in Santo Tomas and typhoon-caused shattering in Tanauan. The two lines were the shortest entries; UPL Ri-5 was the tallest.

Researchers' trial. IR43 yielded 4.0 t/ha at Santo Tomas; UPL Ri-5 yielded 4.1 t/ha at Cuenca (Table 10). These yields were lower than those in farmers' trials probably because a higher N rate was applied at Santo Tomas and apparently the field at Tanauan was more fertile.

Table 10. Performance of modern dryland rices utilizing farmers' practices in comparison with experimental result. Batangas, 1982 WS.

Designation	Yield (t/ha)			Maturity (DAS)		Plant ht (cm)	Panicles per m^2
	Santo Tomas	Tanauan	Mean	Santo Tomas	Tanauan	Mean	Mean
Farmers' practice							
IR43	5.1	4.1	4.6	129	121	100	351
UPL Ri-5	4.8	4.7	4.8	129	121	126	275
IR3839-1	4.4	3.2	3.8	120	118	104	368
IR6115-1-1-1	2.1	2.9	2.5	114	114	80	334
IR9782-111-2-1-2	2.9	2.4	2.6	114	114	85	375
C1 (Tanauan chk)	–	3.3	3.3	–	121	121	211
Palay IRRI (Santo Tomas chk)	3.6	–	3.6	131	–	112	181
Experimental result	Santo Tomas	Cuenca	Mean	Santo Tomas	Cuenca	Mean	Mean
IR43	4.0	3.8	3.9	126	136	84	235
UPL Ri-5	2.9	4.1	3.5	125	135	109	223
IR3839-1	3.9	3.3	3.6	114	126	96	259
IR6115-1-1-1	2.8	2.9	2.8	115	129	88	209
IR9782-111-2-1-2	3.4	2.9	3.2	114	128	77	258
K. Patong (chk)	2.0	2.9	2.4	121	129	142	155

The farmers' yields indicate the high potential of MVs even when farmers' practices are used.

The use of a kalmut (a metal-spiked harrow) caused severe damage to the shallow roots of MVs such as IR6115-1-1-1 and IR9782-111-2-1-2 but did not hurt the local varieties. This suggests that some local practices may deter acceptance of modern dryland rice technology in farmers' fields.

Climatic environment and rice

Plant Physiology Department

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In a study of the interaction between N response and solar radiation the crop canopy was shaded with sinamay cloth in the field during the whole-growth period, reproductive growth stage, and ripening period. Sunlight was adjusted to 100% (no shading, S_0), 60% (one layer of sinamay cloth, S_1), and 40% (two layers of sinamay cloth, S_2). N was applied at 0, 60, and 120 kg/ha.

Whole-growth period. Yields ranged from 2.59 t/ha for 0 N-S_2 to 7.74 t/ha for 120 N-S_0 (Table 1). The harvest index (HI) tended to be slightly higher at the lower levels of solar radiation (S_1 or S_2) and it did not account for any difference in yield or N response.

Figure 1 shows that N response was most pronounced at the highest level of solar radiation and decreased as the level of solar radiation decreased. At the lowest solar radiation level (S_2), there was no increase in yield at 60 and 120 kg N/ha.

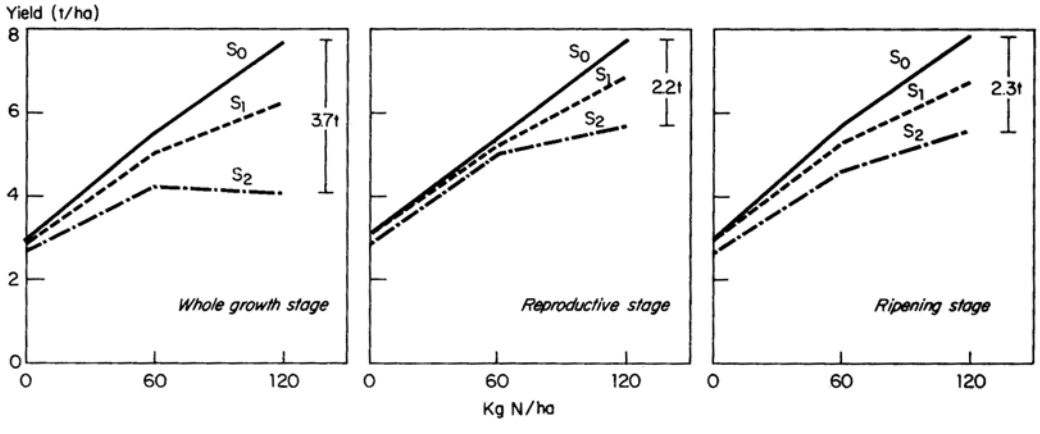
At 0 N, solar radiation had very little effect on yield. However, at 120 kg N/ha it had a pronounced effect on yield — a difference of 3.7 t/ha between S_0 and S_2. Yield was closely related to total dry matter production (Fig. 2a). Total dry matter and spikelet number were also closely correlated (Fig. 2b). These relationships indicate that solar radiation primarily affected yield through total dry matter production, which in turn affected spikelet formation. Among the yield components, spikelet number was the major yield determinant ($r = 0.975$). However, at 120 N-S_2, the decrease in filled spikelets and 1,000-grain weight also contributed to the decreased yield.

Reproductive stage. Solar radiation had a positive effect on N response at 120 kg N/ha. The yield difference of 2.2 t/ha between S_0 and S_2 (Fig. 1) was largely attributed to the increased spikelet number (Table 1).

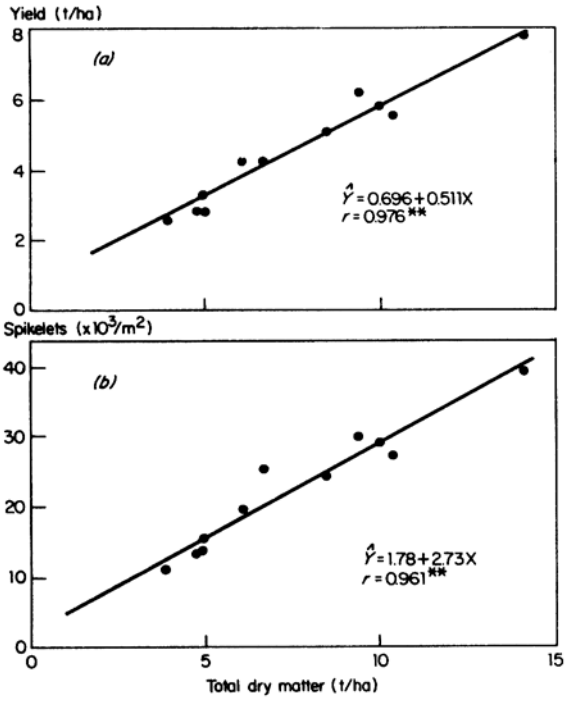
Ripening period. Solar radiation had a clear effect on N response at both 60 and 120 kg N/ha (Fig. 1). At 120 kg N/ha, the maximum yield difference between S_0 and S_2 was 2.3 t/ha and was largely attributed to the percentage of filled spikelets and 1,000-grain weight. To a lesser extent, the number of spikelets also contributed to that difference (Table 1).

Unfilled spikelets were examined with I_2-KI solution to differentiate between unfertilized spikelets and partially filled spikelets. As shown in Table 2, both unfertilized and partially filled spikelets increased with increasing N levels and with decreasing solar radiation levels. A combination of high N and low solar radiation apparently caused a high percentage of empty spikelets.

The experiment indicates that a high N response can be obtained only at a high solar radiation level. A moderate yield of 4-5 t/ha can be obtained with 60 kg N/ha at about 300 cal/cm^2 per day, which is average at many locations in monsoon Asia. Higher yields can be obtained with a higher N application combined with a higher radiation level. An optimum N application rate should be based



1. Interaction between N response and solar radiation at different growth stages. S_0, S_1, and S_2 represent 100, 60, and 40% sunlight. IRRI, 1982.



2. Relationship between total dry matter, yield, and spikelet number at three levels of solar radiation. IRRI, 1982.

not only on the inherent soil fertility level and variety used, but also on the solar radiation level.

MOISTURE STRESS AND GRAIN FILLING

Moisture stress affects rice yield differently depending on the growth stage at which it occurs. During the grain-filling period, moisture stress (50% field capacity) decreased panicle weight by 29% at a low N level (N_1) and by 40% at a high N level (N_2) (Fig. 3). Moisture stress, however, did not influence the duration of grain filling. Thus, the yield reduction due to moisture stress can be attributed to either reduction in current assimilates or reduced translocation of reserve carbohydrate, or both.

Starch content in the culm and the leaf sheath at flowering was almost two times higher at a low N level than at a high N level (Table 3). Assuming that 70% of the reserve starch present at flowering in the culm and leaf sheath was translocated to the panicle and knowing the amount of starch accumulated in the panicle, it is possible to calculate the contribution of the reserve starch and current

Table 1. Effect of shading at different growth stages on grain yield and yield components of IR36 grown at three levels of applied N. IRRI, 1982 DS.

N level (kg/ha)	Solar radiation level[a]	Grain yield (t/ha)	Total dry wt (t/ha)	HI	Spikelets (no./m² × 10³)	Filled spikelets (%)	1,000-grain wt[b]
			Whole-growth stage				
0	S_0	2.92	4.79	0.53	13.1	92.7	20.6
	S_1	2.93	4.96	0.51	13.6	94.2	20.5
	S_2	2.59	3.94	0.56	11.0	93.6	20.0
60	S_0	5.51	10.41	0.46	27.3	90.0	20.5
	S_1	5.07	8.50	0.51	24.7	89.5	20.0
	S_2	4.16	6.07	0.59	19.8	85.2	18.9
120	S_0	7.74	14.10	0.47	39.7	85.6	19.8
	S_1	6.22	9.44	0.57	30.0	85.5	19.0
	S_2	4.03	6.67	0.52	25.2	72.0	17.8
			Reproductive period				
0	S_0	2.99	4.98	0.52	13.5	93.2	20.5
	S_1	3.02	5.54	0.47	13.0	95.5	20.2
	S_2	2.77	5.11	0.46	10.9	95.8	20.9
60	S_0	5.28	10.20	0.44	28.6	86.4	20.5
	S_1	5.16	9.70	0.46	25.3	94.4	20.6
	S_2	5.08	9.47	0.46	24.7	94.3	20.7
120	S_0	7.75	13.89	0.48	39.9	86.8	20.1
	S_1	6.84	12.41	0.47	32.6	92.5	19.9
	S_2	5.59	10.56	0.46	26.3	93.9	18.8

Continued on next page

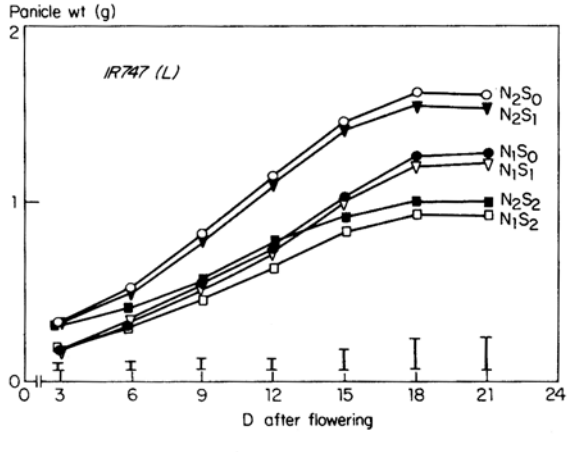
Table 1 continued

N level (kg/ha)	Solar radiation level[a]	Grain yield (t/ha)	Total dry wt (t/ha)	HI	Spikelets (no./m^2 x 10^3)	Filled spikelets (%)	1,000-grain wt[b]
			Ripening period				
0	S_0	2.87	5.17	0.48	13.6	93.0	20.1
	S_1	2.91	5.23	0.48	14.3	90.0	19.7
	S_2	2.53	4.34	0.50	12.6	81.6	19.9
60	S_0	5.68	10.19	0.48	29.5	87.7	20.3
	S_1	5.18	9.60	0.46	28.1	84.7	19.5
	S_2	4.53	8.46	0.46	27.0	76.7	19.1
120	S_0	7.80	13.09	0.51	38.3	85.7	20.3
	S_1	6.63	13.71	0.42	40.9	74.7	19.6
	S_2	5.47	12.47	0.38	37.5	68.6	18.2

[a] S_0 = 100% sunlight, S_1 = 60%, S_2 = 40%. [b] Oven-dried at 105°C for 48 h.

Table 2. Effect of shading during the ripening period on percentage of unfertilized and partially filled spikelets. IRRI, 1982 DS.

N level (kg/ha)	Solar radiation level (%)	Spikelets (%)			
		Filled	Unfilled	Partially filled	Unfertilized
0	S_0	93.0	7.0	2.2	4.8
	S_1	90.0	10.0	3.2	6.8
	S_2	81.6	18.4	9.9	8.5
60	S_0	87.7	12.3	5.0	7.3
	S_1	84.7	15.3	5.7	9.6
	S_2	76.7	23.3	12.0	11.3
120	S_0	85.7	14.3	5.1	9.2
	S_1	74.7	25.3	13.7	11.6
	S_2	68.6	31.4	18.2	13.2



3. Panicle weight of IR747 at various harvests, as affected by moisture stress and N levels. Vertical bars indicate standard errors of the mean. IRRI, 1982.

Table 3. Starch content in the culm and leaf sheath of IR747(L) at flowering and harvest, as affected by moisture stress and N level. IRRI, 1982.

Treatment[a]	Starch (%)	
	Flowering	Harvest
N_1S_0	19.4	3.0
N_1S_1	19.4	2.8
N_1S_2	18.6	2.7
N_2S_0	10.7	3.5
N_2S_1	10.6	3.7
N_2S_2	10.3	5.8

[a] N_1 = low N; N_2 = high N. S_0 = submergence, S_1 = 100% field capacity, S_2 = 50% field capacity.

assimilates to the panicle (Table 4). During the grain-filling period, current photosynthesis is reduced by moisture stress and appears to be partially compensated for by translocation of the reserve starch from the culm and leaf sheath. This explains the greater reduction in panicle weight at the high N level. Because much less starch accumulates before anthesis in high-N plants than in low-N plants, the yield reduction is greater in high-N plants.

The study suggests that N application and variety choice be geared to greater accumulation of reserve starch when drought is anticipated during the grain-filling period.

OXYGEN RELEASE FROM RICE ROOTS

Studies on the O_2 release characteristics of rice roots have been continued (Annual report for

Table 4. Contribution of reserve starch and of current assimilates to the panicle, as affected by moisture stress and N level[a]. IRRI, 1982.

Treatment[b]	Reserve starch (mg/panicle)	Current assimilates (mg/panicle)	Panicle starch (mg/panicle)
N_1S_0	139 (17)	693 (83)	832 (100)
N_1S_1	137 (18)	623 (82)	760 (100)
N_1S_2	132 (30)	303 (70)	435 (100)
N_2S_0	73 (8)	845 (92)	918 (100)
N_2S_1	69 (8)	790 (92)	859 (100)
N_2S_2	49 (12)	351 (88)	400 (100)

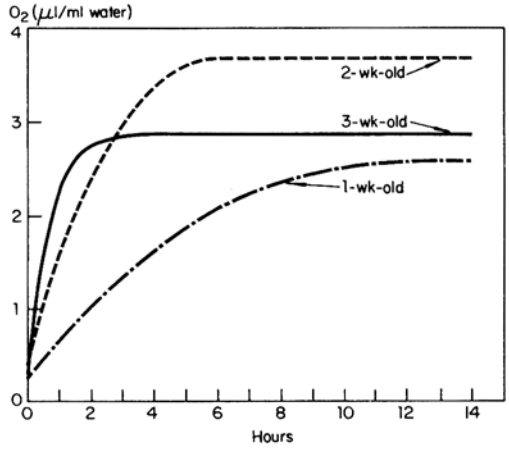
[a]Figures in parentheses indicate percentages taking panicle starch as 100. [b]N_1 = low N, N_2 = high N. S_0 = submergence, S_1 = 100% field capacity, S_2 = 50% field capacity.

1980). At present, scientists believe that rice roots release O_2, which in turn may detoxify harmful substances produced under highly reductive soil conditions. It was found that only young roots release O_2; old roots do not.

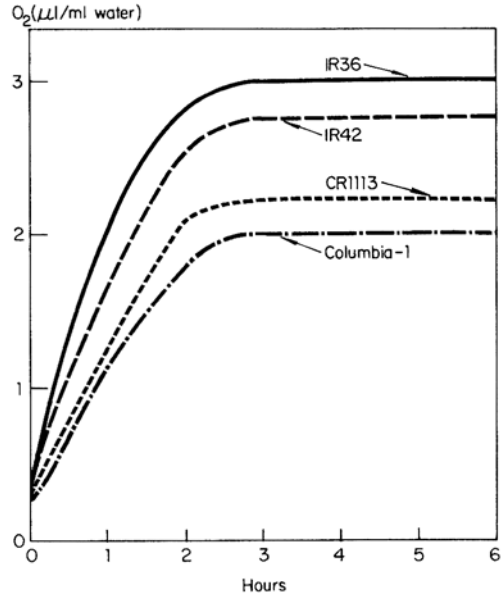
Measuring technique. In the previous study, the O_2 release rate (μl O_2 per unit of time) was measured with a biological oxygen monitor. However, during the repeated measurements, erroneous values were occasionally found. To overcome the problem, an equilibration method for measuring O_2 release was adopted. Roots are placed in O_2-free water in a vial until the partial pressure of O_2 reaches a constant value. The O_2 content of the water, measured with a biological oxygen monitor, is in equilibrium with O_2 content of the air at the end of the root air passage system. So, in this study O_2 release was expressed in microliters per milliliter of water. This method is much simpler and gives consistent values for the same set of samples. The time required to reach equilibrium varies with plant age (Fig. 4). Three week-old seedlings reached an equilibrium in 3 h when a 50-ml vial was used; 1-wk-old seedlings took about 12 h.

Varietal difference. As shown in Figure 5, there were clear differences in O_2 release among four rice varieties. Fe-tolerant IR36 had the highest equilibrium value and Fe-susceptible Columbia-1, the lowest.

Effect of nitrogen nutrition and temperature. O_2 release from 3-wk-old IR36 roots was greatly affected by N supply and temperature (Table 5). At the same temperature, plant roots supplied with high N released significantly larger quantities of O_2 than those supplied with low N. Lower O_2 release from plant roots supplied with low N could be in part attributed to the greater length of N-deficient roots that carry O_2 from root base to tip. As the length of the O_2 path increases, more O_2 diffuses into actively respiring tissue along the pathway. At the same N supply, O_2 release decreased sharply as temperature increased presumably because more



4. Time requirement for equilibrium values of O_2 release from IR36 seedlings at 20° C. IRRI, 1982.



5. Varietal differences in equilibrium values of O_2 release from 3-wk-old seedlings at 20° C. IRRI, 1982.

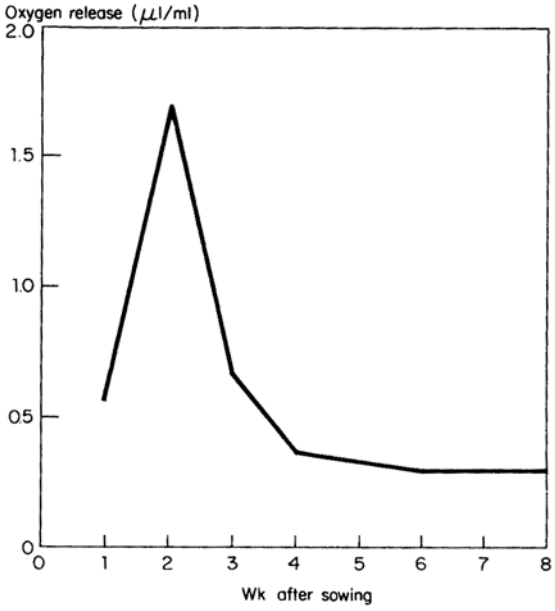
Table 5. O_2 release from 3-wk-old IR36 roots as affected by N supply and temperature. IRRI, 1982.

Temp (°C)	O_2 release (μl/ml)	
	High N[a]	Low N[b]
15	3.11	1.70
20	2.48	0.73
25	1.64	0.00
30	0.84	0.00

[a]40 ppm N. [b]10 ppm N.

O_2 is consumed by root-tissue respiration at higher temperatures. N-deficient plants did not release O_2 at 25° and 30° C, the dominant soil temperatures in the tropics.

Growth stage. O_2 release of rice roots was relatively low at 1 WAS; it peaked at 2 WAS, after which it declined to a stable low value (Fig. 6). Possibly, O_2 release is controlled by the extent to which the air passage system is developed in individual roots and new roots release O_2 while old roots do not within the root system. At the initial stage of root elongation, the air passage system may not be fully developed and hence O_2 transport is relatively low. O_2 release peaks at 2 WAS, when the air passage system is fully developed. It declines afterwards as root elongation is completed.



6. O_2 release from IR36 roots at different growth stages (25° C). IRRI, 1982.

In rice, active tillering starts at around 3 WAS and new roots begin to develop along with new tillers. The weight ratio of new roots to old roots decreases with plant age. A stable low O_2 release at 4 WAS and beyond may be attributable to O_2 uptake by old roots.

New roots vs old roots. To verify if only new roots release O_2, an experiment was set up so that roots of 7-wk-old plants were divided into two equal parts. One part was bound with thin wire and designated old roots; the other part was cut at the base, and any new roots developing from higher nodes were designated new roots. O_2 release from old and new roots was measured 3, 5, 7, and 9 d after partition of old and new roots (Table 6). O_2 release of new roots was moderately high 3 d after the root cutting, peaked 2 d later, and declined to zero 9 d after the roots were cut. Apparently, when new roots are elongating they release O_2 very actively, but when fully elongated they stop; old roots do not release O_2 at all.

The study suggests that O_2 release may protect newly developing roots against harmful substances produced under highly reductive soil conditions, but does not protect fully elongated mature roots. However, O_2 transported to old roots from shoot is used for respiration through which some other mechanisms can be generated to protect root tissue against harmful substances.

CALCIUM PEROXIDE AS AN OXYGEN SUPPLIER

Calcium peroxide-seed ratio. Rice seeds are normally coated with CaO_2 at 1:1 by weight. It would be highly desirable if the amount of CaO_2 was reduced. In a 1981 pot experiment, it was found

Table 6. O_2 release from old roots and new roots.[a] IRRI, 1982.

Days after cutting	Length (cm)		Wt (mg)		O_2 (μl/ml)	
	New	Old	New	Old	New	Old
3	6	27	67	743	0.27	0
5	12	23	395	701	0.68	0
7	16	23	654	969	0.18	0
9	19	23	1395	1015	0.00	0

[a]Measurement was done at 25°C. Seven-week-old plants after seeding were used. Each value represents the mean of four samples.

that the CaO_2-seed ratio could be reduced to 0.5:1. In 1982, two field experiments were conducted to verify if the reduced CaO_2-seed ratio would ensure the same yield as the recommended 1:1.

DS data showed that the CaO_2-seed ratio can be reduced to 0.3:1 for seeds broadcast into a puddled soil (Table 7). In the WAS, a manually-operated row seeder was used in a similar test. Decreasing the CaO_2-seed ratio decreased the number of emerged seedlings per square meter to some extent, but did not affect yield. Thus, CaO_2-seed ratio can be reduced to 0.3:1 with no loss in yield in either broadcast or row-seeded plots.

Yield response to seed rate and nitrogen level. Seeding of CaO_2-coated seeds into wet puddled soil and traditional broadcasting of uncoated seed on a drained field were compared at four N levels. Yields were comparable for each N level whether the seeds were coated with CaO_2 or not (Table 8). A 20 kg/ha seed rate is extremely low compared with the conventional 50 kg/ha, yet the two rates produced similar yields at all N levels. The average number of emerged seedlings at 20 kg seed/ha was about 62/m^2 compared with 110/m^2 at 50 kg seed/ha. Even 62/m^2 is more than two times greater than the number of hills spaced at 20 × 20-cm by transplanting. This indicates that the conventional seed rate can be greatly reduced provided seedling emergence percentage is high, even seedling distribution is assured, a high tillering variety is used, and weeds are adequately controlled.

Manual seeder for calcium peroxide-coated seeds. One person can sow 1 ha/d with the two-row manual seeder now commercially available. The seeder is easy to use, but the operator must have some experience in its use to make it perform effectively. One factor affecting performance is the physical surface conditions of a puddled field. As shown in Figure 7, when used immediately after final harrowing, the manual seeder performed erratically. However, the number of seedlings per linear meter became quite uniform when seeding was done 2 d after final harrowing. Because physical surface conditions vary with soils, the optimum time to use the manual seeder after the final harrowing must be determined individually by site.

Seeding depth is an important factor affecting lodging resistance at high-N levels. A collaborative project was set up at the Daet Farm of the Philippine Ministry of Agriculture in Camarines Sur to compare use of the manual row seeder with broadcasting. Seeding depths ranged from 11-13 mm for the manually seeded plots to 3-6 mm for the broadcast plots. In a flooded condition, the row-seeded crop yielded as well as the broadcast crops (Table 9).

Table 7. Effect of different thicknesses of CaO_2 seed coating on number of emerged seedlings and on yield. IRRI, 1982 DS.

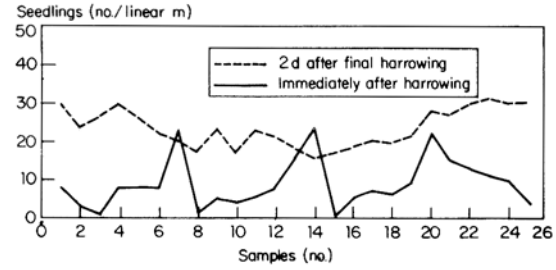
CaO_2 treatment[a] (% coated)	Yield (t/ha)	Emerged seedlings (no./m^2)
30	4.93	149
50	4.60	145
100	4.91	154

[a] g CaO_2/g dry IR36 seeds.

Table 8. Effect of seeding rate and level of applied N on yield of CaO_2-coated and drained wet-seeded IR36. IRRI, 1982 dry season.

N level (kg/ha)	Yield (t/ha) at seeding rate of 20 kg seed/ha	50 kg seed/ha	Difference
	Uncoated, seeded on drained soil surface		
0	3.56 a	3.91 a	−0.35[ns]
50	5.05 b	5.82 b	−0.77[ns]
100	5.35 b	5.38 b	−0.03[ns]
150	5.60 b	4.33 a	1.27**
	CaO_2-coated, seeded into puddled soil		
0	3.67 a	3.23 a	0.44[ns]
50	4.73 b	5.05 b	−0.33[ns]
100	5.73 c	5.54 b	0.19[ns]
150	5.81 c	5.12 b	0.69[ns]

[a] Separation of means.



7. Seedling emergence in 25-m × 15-row plots of CaO_2-coated seeds sown at different times after final harrowing using the DO-1 manual seeder. IRRI, 1982 WS.

Table 9. A comparison between broadcast and row-seeded crops, Daet, Camarines Sur, Philippines, 1982 WS.

Seeding method	CaO_2 coating	Water regime at seeding	Yield (t/ha)	Seedlings emerged (no./m^2)
Broadcast	Coated	Flooded	5.8	234
	Uncoated	Flooded	3.8	46
	Uncoated	Drained	6.7	231
Row-seeded	Coated	Flooded	6.1	227

Seed treatment with systemic insecticides. It would be highly desirable to treat seeds with systemic insecticides before they are coated with CaO_2. In collaboration with the Entomology Department, work began to study seed treatment with carbosulfan and carbofuran to control BPH and GLH. Preliminary work conducted in the insectary has shown carbosulfan to be promising.

Constraints on rice yields

Agricultural Economics and Agronomy Departments

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THE RESEARCH SITES

Agronomy and Agricultural Economics Departments

The three sites currently being used for IRRI constraints research in the Philippines (Tarlac in Central Luzon and San Fernando and Libmanan, Camarines Sur, in the Bicol region of Luzon) were described in the Annual report for 1981. In summary, low rice yields, averaging less than 2 t/ha per crop, are a feature of the Bicol region. Fertilizer use is low, averaging less than 20 kg N/ha; expenditures on insecticides and herbicides rarely exceed $10/ha per crop. Rice yields are somewhat higher in Tarlac with mean yields exceeding 3 t/ha; fertilizer and chemical use is considerably higher than in the Bicol region. IR36 and IR50 are the dominant varieties at all three sites.

The 1982 rainfall pattern for 1982 is in Figure 1. Late rains in Tarlac resulted in most of the rice crops being transplanted in July and early August. Below-average rainfall in October and November caused moisture stress in crops, particularly in upper landscape positions. However, because no typhoons occurred during the crop season, farmers regarded 1982 as a reasonably favorable year. Rainfall in Bicol was favorable for the 1982-83 crop. However, the region experienced in September a severe typhoon that caused extensive flooding and crop loss in low areas of the Bicol River Basin. Several experiments were also lost.

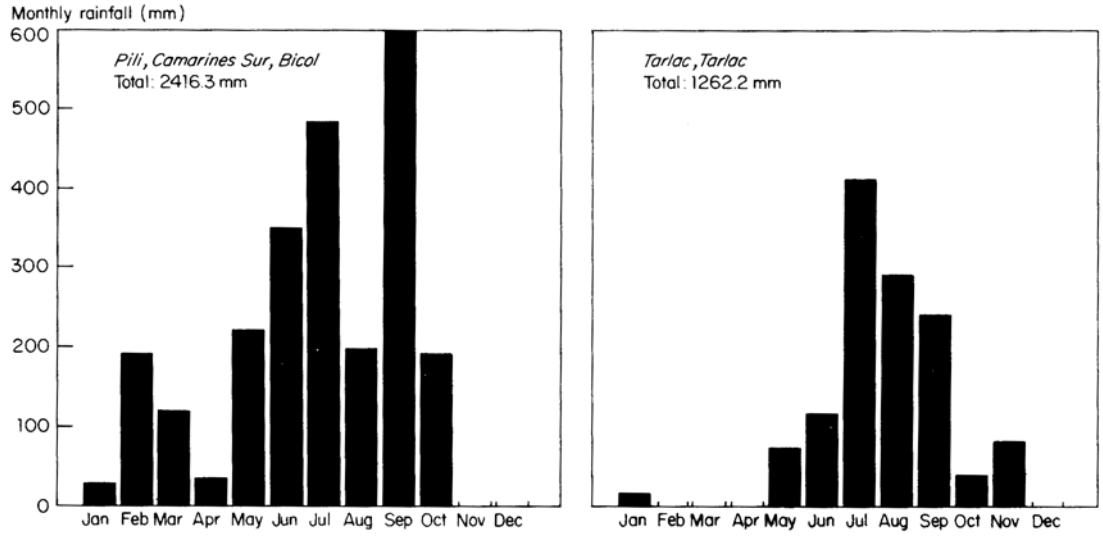
As in previous years, constraints research involves the integration of on-farm experiments and farm surveys. In 1982, two types of experiments were conducted. Type 1 compared the on-farm performance of prilled urea (PU) and urea supergranules (USG); and estimated the yield gap caused by fertilizer, weed, and insect control; and type 2 quantified the response to N, P, and K.

RETURNS TO CROPPING INPUTS

Agronomy and Agricultural Economics Departments

Forms of urea fertilizer and application methods in farmers' fields (*Agronomy*). *Tarlac sites, 1982 dry season*. Experiments evaluated three forms of urea — USG, sulfur-coated urea (SCU), and PU — applied with different methods. No yield differences were observed with various rates and application methods (Table 1). Yields with and without fertilizer treatment were similar because of moisture stress brought about by insufficient irrigation.

Tarlac sites, 1982 wet season. In experiments under rainfed conditions, deep-placed USG was compared with split-applied PU using the re-



1. Monthly rainfall in Pili, Camarines Sur, and Tarlac, Tarlac, Philippines, 1982.

searchers' practice. The experiment was conducted on nine high-elevation and nine low-elevation rainfed farms. Soil type was clay loam with a pH range of 5.0 to 6.4.

Yields at the low N rate were higher at low elevations than at high elevations; at the high N rates, yields tended to be higher at high elevations (Table 2). Yields also tended to be higher with PU

Table 1. Yield response to source and method of N application in irrigated farms at three areas in the Philippines, 1982 DS.

Treatment	Yield[a] (t/ha)			
	Tarlac	Camarines Sur		
		Libmanan		San Fernando
		Old area	New area	
No N Fertilizer	4.9 a	3.8 c	5.0 c	5.4 d
58 kg N[b]/ha				
Farmers' split[c]	5.3 a	3.6 c	5.3 b	6.0 c
Researchers' split[d]	5.3 a	4.9 b	5.9 ab	6.4 bc
USG point-placed[e]	5.0 a	5.6 a	6.6 a	6.7 ab
USG surface application[f]	5.1 a	4.9[g]	5.6 ab	7.0[h]
SCU B&I	5.5 a	5.3 ab	6.5 a	7.2 a
87 kg N[b]/ha				
Farmers' split[c]	5.0 a	3.8 c	5.3 b	6.4 bc
Researchers' split[d]	5.0 a	5.5 ab	6.1 ab	7.2 a
USG point-placed[e]	5.0 a	5.8 a	6.6 a	7.1 a
USG surface application[f]	4.9 a	5.2[g]	6.5 a	7.4[h]
SCU B&I	5.3 a	5.8 a	6.7 a	7.2 a
116 kg N[b]/ha				
Researchers' split	5.1 a	5.4 ab	6.5 a	6.9 ab

[a]Av of three farms in Tarlac, five farms in Libmanan (three in old area and two in new area), and four in San Fernando. [b]As urea. [c]Tarlac — 7 and 32 DT; Libmanan site — 18 DT and early booting stage; San Fernando site — 25 and 55 DT. [d]1/3 basal B&I, 1/3 20-30 DT, and 1/3 5-7 DBPI. [e]10- to 12-cm soil depth placed at 2-4 DT. [f]Broadcast immediately after transplanting. [g]Av of two farms. [h]Av of three farms.

Table 2. Yields as influenced by source and method of N application under rainfed conditions in three areas in the Philippines, 1982 WS.

Treatment	Yield[a] (t/ha) by elevation						
			Camarines Sur				
	Tarlac		Libmanan		San Fernando		
	Low	High	Low	High	Low	Intermediate	High
29 kg N[b]/ha							
Researchers' split[c]	4.6 a	4.4 bc	4.4 b	4.1 b	3.7 a	4.9 b	4.5 b
USG point-placed[d]	4.6 a	4.2 c	4.7 ab	4.4 ab	3.8 a	5.1 b	4.5 b
58 kg N[b]/ha							
Researchers' split[c]	4.8 a	4.9 ab	4.8 ab	4.3 b	3.8 a	5.5 a	5.0 a
USG point-placed[d]	4.6 a	4.8 abc	5.0 a	4.6 ab	3.8 a	5.6 a	5.0 a
87 kg N[b]/ha							
Researchers' split[c]	4.9 a	5.0 a	4.9 a	4.7 ab	3.7 a	5.7 a	5.0 a
USG point-placed[d]	4.8 a	5.0 a	5.0 a	4.9 a	3.7 a	5.6 a	4.8 ab

[a]Tarlac, av of nine farms in low-elevation and nine farms in high-elevation areas; Libmanan, av of seven farms at low-elevation and five farms at high elevation; San Fernando, five farms in low-elevation, ten farms in intermediate, and nine farms in high-elevation. [b]As urea. [c]1/2 basal and 1/2 at 5-7 DBPI. [d]10- to 12-cm soil depth placed at 2-4 DT.

than with USG at both elevations with various rates. USG prolonged the vegetative stage; moisture stress during the reproductive stage caused lower yields. However, the comparative performance of the two N sources and site-related factors could not be significantly related. Yields with deep-placed USG were higher at a high level of insect control than those at farmers' level of insect control (Table 3). Prevalent insects were caseworm, leaf folder, and stem borer.

Camarines Sur (Libmanan) sites, 1982 dry season. Experiments were conducted on five irrigated sites — three in the old area and two in the new.

At both sites, yields were generally higher with deep-placed USG than with the researchers' PU split application regardless of N rate. The yields, however, significantly differed only at 58 kg N/ha and only in the old irrigated area (Table 1). Results also showed that the researchers' timing of N application consistently gave higher yields than the farmers' timing (18 DT and early booting stage) at both 58 and 87 kg N/ha although the yield differences in the new area were not significant. Yields with SCU were comparable to those of USG placement and researchers' split regardless of site and N rate. The various N application methods showed no further yield response at 87 kg N/ha.

Camarines Sur (Libmanan) sites, 1982 wet season. Deep-placed USG and PU split application were compared at three N levels in rainfed and irrigated farms. Twelve trials (seven low-elevation and five high-elevation) were conducted in the rainfed area. Fourteen trials (six each in the old and new irrigated sites, and two in the flood-prone site) were conducted in the irrigated area.

In rainfed sites, three of five trials in the high elevations were direct-seeded on puddled soil; the rest were transplanted. In the lower landscape, only one of seven trials was direct-seeded. Yields in the low elevations were generally higher than those in the high elevations regardless of application method and N rate (Table 2). This could be attributed mainly to more nonflood days at most sites in the upper landscape. Yields with deep-placed USG were generally higher than the yields with split-applied PU, regardless of N rate and landscape. However, the yield differences were not significant nor was it possible to relate the comparative performance of the two N-sources to site factors. In both low and high elevations, the yields were 0.5 t/ha higher with USG placement at a high level of insect control than with farmers' level of insect control (Table 3). The quality of insect control may influence the performance of deep-placed USG. Insects were mainly whorl maggots, leaf folders, and stem borers.

In irrigated sites, the researchers' split application of PU was as effective as the deep placement of USG regardless of N level (Table 4). A typhoon during the late reproductive and ripening stages caused severe lodging in both treatments, particularly in the plots with USG placement. High

Table 3. Yield response to deep-placed USG at two levels of insect control under various water regimes in three areas in the Philippines, 1982 WS.

Location	Water regime	Sites (no.)	Yield[a] (t/ha)		
			Farmers' insect control	High insect control	Difference
Tarlac	Low-elevation, rainfed	9	4.0	4.7	0.7
Tarlac	High-elevation, rainfed	9	3.9	4.7	0.8
Camarines Sur					
Libmanan	Low-elevation, rainfed	7	4.4	4.9	0.5
Libmanan	High-elevation, rainfed	5	4.1	4.6	0.5
Libmanan	Old irrigated area	6	5.3	5.6	0.3
Libmanan	New irrigated area	6	4.8	4.8	0
Libmanan	Flood-prone irrigated area	2	4.4	4.9	0.5
San Fernando	Low-elevation, rainfed	5	3.1	3.7	0.6
San Fernando	Intermediate, rainfed	10	5.0	5.5	0.5
San Fernando	High-elevation, rainfed	9	4.4	4.8	0.4

[a] Av of 29, 58, and 87 kg N/ha.

insect control over the farmers' level had more influence on the performance of deep-placed USG in the flood-prone area than in the old irrigated area (Table 3). In the new irrigated area, yields with deep-placed USG were similar at both insect control levels.

Camarines Sur (San Fernando) sites, 1982 dry season. Results of experiments in four irrigated farms showed significant yield responses to added N from both N source and application method (Table 1). At 58 and 87 kg N/ha, yields with USG placement were similar to those with SCU and researchers' split application of PU. Yields with SCU were significantly higher than those with the researchers' split at the lower N rate, but not at the higher rate. The researchers' N application timing gave generally higher yields than the farmers' timing (25 and 55 DT). However, the yields differed significantly only at 87 kg N/ha.

Camarines Sur (San Fernando) sites, 1982 wet season. Trials compared the performance of point-placed USG with that of split-applied PU at three N rates under three water regimes in rainfed farms. Thirty trials were conducted in the study area — nine at high elevations, 11 at intermediate elevations, and 10 at low elevations. Six trials were flooded out (one from the intermediate and five from the low elevation). Of 30 trials, three (high-elevation) were direct-seeded on puddled soil; the rest were transplanted. IR50 and IR36 were dominant varieties.

Table 4. Yield response to source and method of N application under irrigated conditions in Libmanan, Camarines Sur, Philippines, 1982 WS.

Treatment	Yield[a] (t/ha)		
	Old irrigated area	New irrigated area	Flood-prone irrigated area
29 kg N[b]/ha			
Researchers' split[c]	5.1 a	5.4 a	5.4 a
USG point placement[d]	5.7 a	4.9 a	4.7 a
58 kg N[b]/ha			
Researchers' split[c]	5.7 a	5.5 a	5.2 a
USG point placement[d]	5.6 a	4.9 a	5.1 a
87 kg N[b]/ha			
Researchers' split[c]	5.5 a	5.1 a	5.6 a
USG point placement[d]	5.4 a	4.7 a	5.0 a

[a]Av of six farms in the old area, six farms in the new area, and two farms in the flood-prone area. [b]As urea. [c]1/2 basal, and 1/2 5-7 DBPI. [d]10- to 12-cm soil depth placed at 2-4 DT.

Yields were generally higher at the intermediate landscape than those from the other sites, regardless of N rate and application method (Table 2). In the intermediate- and high-elevation sites, yields significantly increased by 0.5 t/ha when the N rate was increased from 29 to 58 kg/ha for both deep-placed USG and researchers' split-applied PU. There was no additional yield response at 87 kg N/ha for either application method. In all cases at the low-elevation site, yields at the three N levels were similar. In no case did deep-placed USG significantly outyield the researchers' split application of PU. The deep-placed USG performed better with the high level of insect control at the three sites. Yield increases ranged from 0.4 to 0.6 t/ha (Table 3).

Yield response to major farm inputs (*Agronomy*). *Tarlac sites, 1982 dry season.* Complete fertilizer application, Zn treatment, fungicide treatment, and three insect control strategies were evaluated.

Farmers' N applications averaged 54 kg/ha; insecticide applications averaged one foliar spray. Three of six farmers applied granular insecticides; only one farmer practiced weed control. Yields with farmers' level of fertilizer, without N, and with 80 kg N/ha were similar. Yield with 120-19.8-37.4 kg (N, P, K)/ha was similar to that with 80-19.8-37.4 kg (N, P, K)/ha, but significantly higher than that without N fertilizer. Removing P caused a significant yield reduction; removing K did not. Removing N caused a significant yield reduction of 1.7 t/ha. Dipping the seedlings in 2% ZnO suspension before transplanting did not increase yield. High-level insect control and insect control at the farmers' and intermediate levels resulted in similar yields. Bacterial leaf streak and sheath blight were observed on some farms, but fungicide-treated plots yielded similarly to the untreated check plots.

The magnitude of the yield gap in the study area was determined from six representative farms. Farmers' input levels (Table 5) resulted in yields ranging from 3.0 t/ha to 4.6 t/ha (Fig. 2) averaging 3.7 t/ha. High inputs brought about yields ranging from 3.1 t/ha to 6.8 t/ha and averaging 5.0 t/ha. The average yield gap was 1.3 t/ha.

In a separate experiment, the average yield gap from three farms was 1.1 t/ha. A high fertilizer

level did not contribute to the yield gap because of severe lodging at one site. High insect control contributed 0.7 t/ha to the yield gap and high weed control an additional 0.7 t/ha.

Tarlac sites, 1982 wet season. Trials were conducted in 14 rainfed farms — seven each at high and low elevations. At both elevations, yields with application at 58-13.2-24.9 kg (N, P, K)/ha were significantly higher than the yields with no N fertilizer. The removal of either P or K reduced yield, but not significantly. Similar to previous results, Zn application ($ZnSO_4$) did not increase yield.

The yield gap between farmers' inputs and high inputs was determined from 32 farms (Fig. 2), but the relative contribution of each test factor to the yield gap was determined only from 18 rainfed farms (nine each in the high and low elevations). Farmers' N rates were similar to the intermediate N level (Table 6). Insecticide applications averaged two foliar sprays, and only 3 of 18 farmers practiced weed control.

In high areas, yields with farmers' inputs averaged 3.0 t/ha; yields with high inputs, 4.9 t/ha. The average yield gap was 1.9 t/ha. In low areas, high inputs increased yield 1.7 t/ha and intermediate inputs 1.0 t/ha over farmers' inputs. Fertilizer contributions to the yield gap were 67% in high elevations and 59% in low elevations. High insect control contributed 33% to the yield gap in high elevations and 29% in low elevations.

Camarines Sur (Libmanan) sites, 1982 dry season. Experiments were conducted on seven irrigated farms (two in the old area and five in the new). In the old irrigated area, fertilizer applications of two farmers averaged 53-1.7 kg (N,P)/ha. In the new area, the farmers' fertilizer applications averaged a low 19-4.8-2.5 kg (N, P, K)/ha because two farmers applied no fertilizer. In both areas, farmers mainly used foliar insecticide sprays and either preemergence or postemergence herbicides. Two of five farmers in the new area did no weed control.

Despite their application of 53 kg N/ha, farmers in the old area averaged 5.1 t/ha, similar to the plots with no N application. In the new area, farmers' applications averaged 19 kg N/ha, which resulted in yields similar to those in plots without N, indicating that the farmers' timing and method are inefficient. At both test areas, yields significantly increased at least 1.0 t/ha with the application of 80 kg N/ha using the researchers' practice. Increasing the N rate to 120 kg/ha did not increase yield any further.

Only N was limiting in the old area. Plots without added N yielded only 4.8 t/ha; plots with 120-19.8-37.4 kg (N, P, K)/ha yielded 6.1 t/ha. Plots without added P or K yielded similarly to the NPK plots. In the new area, there were significant responses to applied N and P but not to K.

Dipping rice seedling roots in 2% ZnO suspension before transplanting did not increase yield anywhere. However, soil tests based on the available Zn contents showed that all the sites, except one, were Zn deficient. Because all the sites were slightly acidic, the results suggest that pH may at times be a more reliable soil parameter than Zn content in determining Zn deficiency.

Sites with high-level insect control averaged 0.6 (old) and 0.3 (new) t/ha, better than sites with farmers' insect control. In the old area, intermediate insect control gave a modest yield increase over the farmers' control. Fungicide application did not significantly increase the yield anywhere. There were no serious rice diseases during the DS.

Farmers used predominantly IR36 and applied low inputs, particularly fertilizer (Table 5). In the old area, farmers' yields ranged from 2.5 to 5.0 t/ha (Fig. 2) and averaged 3.7 t/ha. Yields with high inputs varied from 5.0 to 7.0 t/ha, and averaged 5.9 t/ha. The average yield gap was 2.2 t/ha. Similar results were obtained in the new area. In both areas, yields with intermediate-level inputs were 1.4 t/ha higher than the farmers'.

The contributions of fertilizer, insect control, and weed control to the yield gap were determined from five trials each in the old and new areas. Farmers' yields averaged 3.7 (old), and 3.9 (new) t/ha. The yield gap averaged 2.2 t/ha for both sites. Improved fertilizer application accounted for more than 75% of the gap; improved insect control accounted for most of the remainder. Farmers adequately controlled weeds.

Camarines Sur (Libmanan) sites, 1982 wet season. Trials were conducted in various water regimes — low and high elevations in the rainfed area, and old, new, and flood-prone sites in the irrigated area.

At rainfed sites in both low- and high-elevation

Table 5. Input levels used in farmers' irrigated fields in three areas in the Philippines. 1982 DS.

Water regime	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P	K	M	C	F	G
Tarlac									
Irrigated	Farmers'	6	54	4.8	8.3	0	0.2	1.2	0.5
Irrigated	Intermediate	6	80	19.8	37.4	1.0	1.0	0	2.0
Irrigated	High	6	120	19.8	37.4	1.0	1.0	3.0	3.0
Camarines Sur (Libmanan)									
Old irrigated area	Farmers'	5	42	2.6	3.3	0	0.8	2.0	0
Old irrigated area	Intermediate	5	80	19.8	37.4	1.0	1.0	1.2	0.2
Old irrigated area	High	5	120	19.8	37.4	1.0	1.0	3.0	2.0
New irrigated area	Farmers'	8	19	4.0	2.5	0	0.6	1.8	0.2
New irrigated area	Intermediate	8	80	19.8	37.4	1.0	1.0	1.1	0.2
New irrigated area	High	8	120	19.8	37.4	1.0	1.0	2.4	2.0
Camarines Sur (San Fernando)									
Irrigated	Farmers'	11	25	0.4	0.8	0.5	1.1	2.2	0
Irrigated	Intermediate	11	80	19.8	37.4	1.0	1.0	2.5	0
Irrigated	High	11	120	19.8	37.4	1.0	1.0	3.4	2

[a]Av no. of mechanical (M) weedings, either by hand or by rotary weeder, and chemical (C) herbicide applications. [b]Av no. of foliar (F) sprays (azodrin, gusathion, etc.) or granular (G) applications (furadan, diazinon, etc.) to rice field water.

Table 6. Input levels used in rainfed farms in Tarlac, Philippines, 1982 WS.

Landscape position	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a] (no.)		Insect control[b] (no.)	
			N	P	K	C	M	F	G
High	Farmers'	9	23	4.4	5.0	0.2	0	2	0.2
	Intermediate	9	29	13.2	24.9	1	1	2	1
	High	9	58	13.2	24.9	1	1	3	2
Low	Farmers'	9	32	16	7.5	0.1	0	2	0.1
	Intermediate	9	29	13.2	24.9	1	1	2	1
	High	9	58	13.2	24.9	1	1	3	2

[a]Av no. of mechanical (M) weeding, either by hand 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 rice field water.

areas, yields with 29 kg N/ha did not significantly differ from those with 44 and 58 kg N/ha, but were significantly lower than those with 87 kg N/ha. Trials at all N levels significantly outyielded the farmers' level regardless of elevation because most farmers did not apply fertilizer. In nine low-elevation trials, there were significant responses to N and P applications but not to added K. At the high elevations, there was a significant yield response to N application only. There was no yield response to basal application of zinc sulfate (commercial grade) at 10 kg/ha, suggesting that the rainfed sites were not Zn deficient.

Yield-gap magnitude at the rainfed sites was determined from 11 trials in the low elevations and seven trials in the high elevations. Four high-elevation and two low-elevation farmers direct-seeded on puddled soils. IR36 and IR747 were predominantly planted at the low elevations and IR50 at high elevations.

At high elevations, yields with farmers' inputs ranged from 1.7 to 4.1 t/ha (Fig. 2), averaging 2.9 t/ha; yields with high inputs ranged from 3.2 to 5.9 t/ha, averaging 4.5 t/ha. At the low elevations, yields with farmers' inputs ranged from 2.4 to 4.6 t/ha, averaging 3.4 t/ha; yields with high inputs

ranged from 4.0 to 5.8 t/ha, averaging of 4.7 t/ha.

Average yield gaps in the rainfed trials were 1.6 (high-elevation) and 1.3 (low-elevation) t/ha. Regardless of elevation, low yields with farmers' inputs were associated mainly with little or no fertilizer application. Five of seven high-elevation farmers and eight of 11 low-elevation farmers did not apply fertilizer. Moisture stress at various growth stages further reduced yields in the high elevations.

Farmers used few inputs, particularly fertilizer (Table 7). At low elevations, fertilizer contributed to 52.6% of the 1.5-t/ha yield gap, insect control contributed 31.6%, and weed control 15.8%. At high elevations, fertilizer contributed to 69% of the 1.6-t/ha yield gap, insect control contributed 19%, and weed control 12%.

At the irrigated sites, yields at all N levels were comparable. Severe typhoon damage at the late reproductive and ripening stages resulted in serious yield losses particularly at high N levels. A significant yield response to N application occurred in the old area, but not in the new and flood-prone areas. In all areas, responses to P and K applications were not significant. There was no significant yield response to Zn application (10 kg $ZnSO_4$/ha) although soil analyses revealed zinc deficiency at most sites.

Yield-gap magnitude at the irrigated sites was determined from eight trials in the old area, 10 in the new, and three in the flood-prone. The various input levels are in Table 7 and yield-gap variations are shown in Figure 2. IR50 and IR36 were the predominant varieties.

Input contributions to the yield gap in the irrigated areas were determined from six trials each in the old and new areas and two in the flood-prone area. Old-area farmers applied more fertilizer. The average yield gap between farmers' and high inputs was 1.2 t/ha in the old area, 0.7 t/ha in the new, and 1.6 t/ha in the flood-prone. Fertilizer contributed to 54% of the yield increase in the old area, 57% in the flood-prone, and 60% in the new. The remainder of the yield gaps in the new and flood-prone areas was attributed to improved insect control. In the old area, insect control accounted for 31% of the gap and weed control 15%.

Camarines Sur (San Fernando) sites, 1982 dry season. Experiments were conducted on four irrigated farms. Two trials were direct-seeded on puddled soil; two were transplanted. The cooperating farmers applied N fertilizer only, averaging 33 kg/ha; used mainly foliar insecticide sprays, averaging 2.8 applications; and controlled weeds by hand or with herbicides.

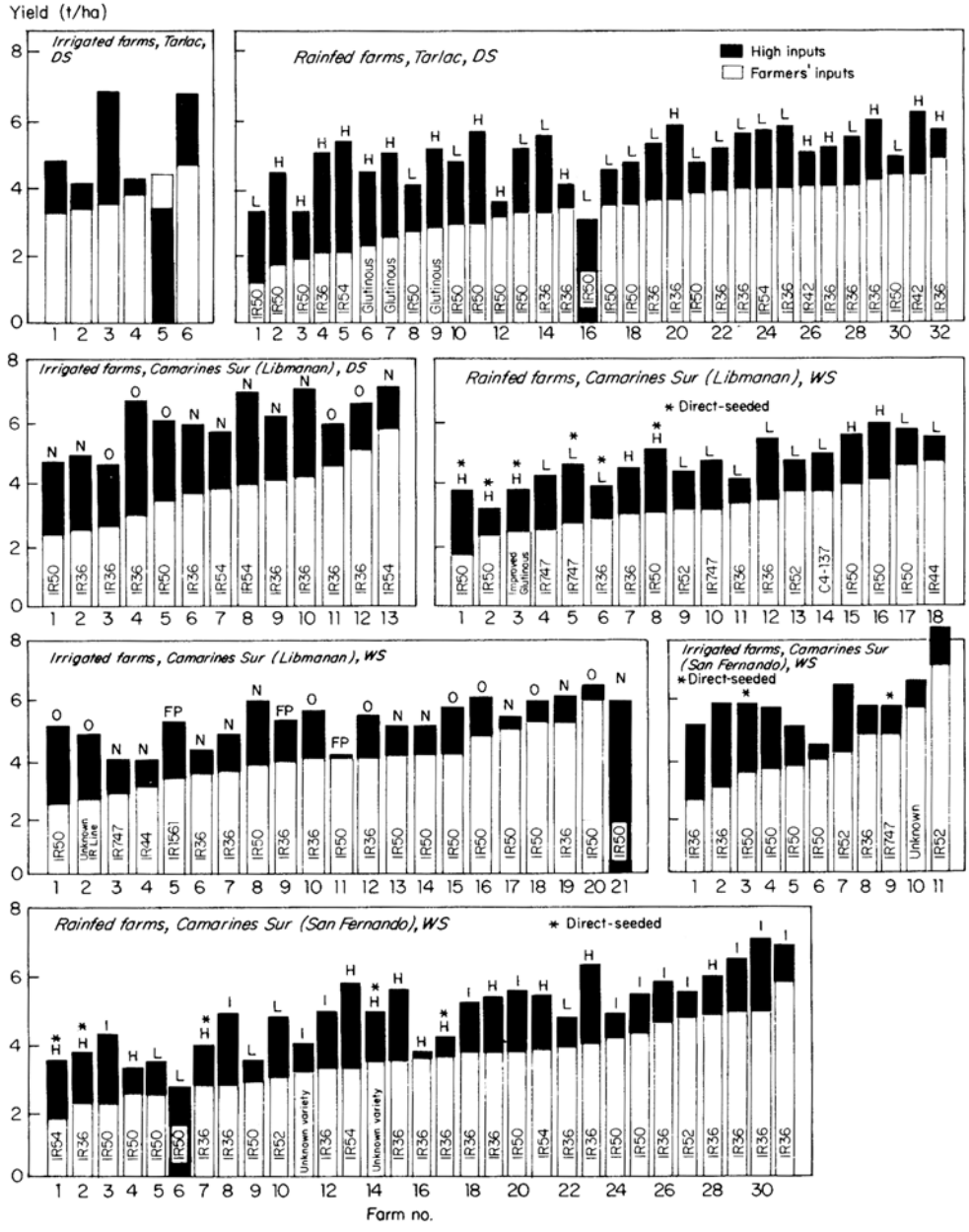
Yields with farmers' inputs averaged 5.1 t/ha, 0.4 t/ha higher than those from plots without added N; however, the increase was not significant.

Table 7. Input levels in farmers' fields with various water regimes in Libmanan, Camarines Sur, Philippines, 1982 WS.

Water regime	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P	K	M	C	F	G
Low-elevation, rainfed	Farmers'	7	8	1.8	3.3	0.3	0.8	2.0	0
	Intermediate	7	29	13.2	24.9	1.0	1.1	1.6	0
	High	7	58	13.2	24.9	1.0	1.1	3.4	2.0
High-elevation, rainfed	Farmers'	5	13	0	0	0	0.8	0.8	0
	Intermediate	5	26	13.2	24.9	1.0	1.6	1.2	0
	High	5	52	13.2	24.9	1.0	1.6	3.4	2.0
Old irrigated area	Farmers'	6	40	6.2	5.0	0	1.0	2.2	0
	Intermediate	6	29	13.2	24.9	1.0	1.0	1.0	0.2
	High	6	58	13.2	24.9	1.0	1.0	4.0	2.0
New irrigated area	Farmers'	6	33	3.5	1.7	0.3	0.8	1.5	0
	Intermediate	6	29	13.2	24.9	1.0	1.0	1.5	0.2
	High	6	58	13.2	24.9	1.0	1.0	3.5	2.0
Flood-prone, irrigated area	Farmers'	2	14	1.8	0	0	1.0	1.5	0
	Intermediate	2	22	13.2	24.9	1.0	1.0	0.5	0
	High	2	44	13.2	24.9	1.0	1.0	2.5	2.0

[a] Av no. of mechanical (M) weeding, either by hand or 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 rice field water.

Yields from plots with 80 and 120 kg N/ha were comparable and significantly higher than yields from the farmers' N level and the unfertilized plots. Yield responses to 125-19.8-37.4 kg (N, P, K)/ha were comparable with those to either NK or NP treatments. Reduced yields in plots without added N averaged 1.5 t/ha. Only added N was needed to achieve high yield. There was no response to Zn treatment (as a seedling dip in 2% ZnO suspension before transplanting) anywhere. High insect control gave no significant yield increases. Helminthosporium leaf spot at the late reproductive stage did not



2. Yield gap variations among farmers' fields and varieties in irrigated and rainfed farms at three sites in the Philippines, 1982 DS and WS. H = high elevation, L = low elevation, I = intermediate elevation, O = old irrigated area, N = new irrigated area, FP = flood-prone area.

affect yields. Yields of plots with and without fungicide were similar.

The average yield gap from 11 farms was 1.6 t/ha. Yields with farmers' inputs were low (Fig. 2) because most of the farmers applied no fertilizer. In seven farms, yields with farmers' inputs averaged 4.0 t/ha, 1.6 t/ha lower than those with high inputs. Fertilizer contributed 78% to the gap; improved insect control accounted for 16%. Weed control contributed a modest 6%, indicating that the farmers adequately controlled weeds.

Camarines Sur (San Fernando) sites, 1982 wet season. Trials were conducted mainly on rainfed farms (10 each at high-elevation and intermediate areas and nine at low-elevation areas). Five low-elevation trials were flooded out.

Yields with farmers' inputs at the intermediate and high elevations were significantly lower than the yields with all test N levels because most farmers applied no fertilizer. At the intermediate elevations, yields significantly increased up to 58 kg N/ha. At the high elevations, the average yield with 29 kg N/ha was not statistically different from that with 44 kg N/ha, but significantly lower than that with 58 kg N/ha. There was no further yield response to 87 kg N/ha. At low elevations, yields were comparable at all N levels. Response to added P was significant only at the intermediate elevations. At low elevations, response to NPK fertilizer was not significant. Application of 10 kg $ZnSO_4$/ha stimulated no additional yield anywhere.

Yields with farmers' inputs were 0.7 t/ha lower than those with intermediate inputs at all elevations. Farmers obtained low yields because most of them did not apply any fertilizer.

Yield-gap magnitude in the rainfed areas was determined from 5 trials in the low elevations, and 13 each in the intermediate and high elevations. Input levels are in Table 8 and yield gap variations are in Figure 2. Yields with high inputs ranged from 2.4 to 7.3 t/ha. The average yield gap was 1.4 t/ha. In a separate experiment, the average yield gaps from representative farms were 0.9 t/ha at low elevations, 1.6 t/ha at intermediate elevations, and 1.7 t/ha at high elevations. Fertilizer contributed from 63% (low) to 80% (intermediate) to the gap.

Profitability of researchers' and farmers' practices (*Agricultural Economics*). *Reducing the yield gap.* At each site, researchers' and farmers' practices were compared for profitability. In monetary terms, researchers' yields were higher, from $90 to $230, than farmers'. However, the added cost of the researchers' practice exceeded that of the farmers' by about $140-$225/ha. The incremental cost of the researchers' practice was less in Tarlac than at the rainfed Camarines Sur sites because farmers' input levels at Tarlac were closer to the researchers' levels.

Table 9 shows that farmers would have been worse off by adopting the researchers' practice as a package at the Camarines Sur sites. However, at the plateaus in Tarlac, farmers could have made a profit using the researchers' practice.

The profitability of shifting each technology component to the researchers' practice was computed using partial budgeting (Table 10). Two

Table 8. Input levels in rainfed farms in San Fernando, Camarines Sur, Philippines, 1982 WS.

Landscape position	Input level	Sites (no.)	Fertilizer (kg/ha)			Weed control[a]		Insect control[b]	
			N	P	K	M	C	F	G
Low-elevation	Farmers'	5	6	0	0	0.8	1.2	2.0	0
	Intermediate	5	26	13.2	24.9	0.6	1.0	2.0	0
	High	5	52	13.2	24.9	0.6	1.0	2.0	1.8
Intermediate	Farmers'	10	14	0.4	0.8	0.9	1.1	2.5	0
	Intermediate	10	28	13.2	24.9	0.8	1.1	2.0	0
	High	10	55	13.2	24.9	0.8	1.1	2.0	1.9
High-elevation	Farmers'	9	2	0	0	0.4	1.9	2.2	0
	Intermediate	9	27	13.2	24.9	0.8	1.3	2.0	0
	High	9	55	13.2	24.9	0.8	1.3	2.0	1.6

[a]Av no. of mechanical (M) weeding, either by hand 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 rice field water.

profitability measures were used. Net benefits had to be positive and the B:C ratio had to exceed 2.5. On the average, it was profitable to increase fertilizer to 58-30-30 kg (N,P,K)/ha except in the bottomlands of San Fernando. It was not profitable to close the yield gap with insect or weed control.

Farmers are concerned with profit level and stability. The dispersion of the benefits of the

Table 9. Economic performance of anticipated high-level combination of three inputs and farmers' level of those inputs in three areas of the Philippines, 1982 WS.[a]

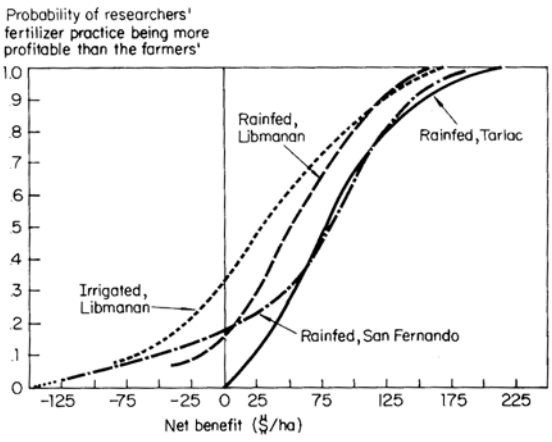
Location, water regime	Sites (no.)	Increase (decrease) ($/ha) over farmers' level from high inputs[b]		
		Output value	Input cost	Profit
Camarines Sur				
Libmanan				
Irrigated (new)	13	108	198	(90)
Irrigated (old)	14	156	179	(23)
Irrigated[c] (bottomland)	5	131	214	(83)
Rainfed (plateau)	6	200	220	(20)
Rainfed (plain)	14	181	215	(34)
San Fernando				
Rainfed (plateau)	16	212	221	(9)
Rainfed (plain)	21	190	215	(27)
Rainfed[d] (bottomland)	7	88	224	(136)
Tarlac				
Rainfed (plateau)	16	227	151	76
Rainfed (plain)	16	129	138	(9)

[a]Analysis based on type 1 and type 2 experiments. [b]US$1 = ₱ 9. [c]Two sites had no yields because of floods. [d]Six sites had no yields because of floods.

Table 10. Economic performance of anticipated high levels of three inputs and farmers' current practices in three areas of the Philippines, 1982 WS.

Location, water regime	Sites (no.)	Increase (decrease) over farmers' level								
		Fertilizer[a]			Insect control[b]			Weed control[c]		
		Farmers' [kg (N, P, K)/ha]	Profit[d] ($/ha)	B:C ratio	Farmers' ($/ha)	Profit ($/ha)	B:C ratio	Farmers' ($/ha)	Profit ($/ha)	B:C ratio
Camarines Sur										
Libmanan										
Irrigated (new)	6	33-3.5-1.7	15	1.4	5	(98)	0.2	7	(17)	0.4
Irrigated (old)	6	40-6.2-5.0	58	3.2	10	(82)	0.3	7	(6)	0.8
Irrigated (bottomland)	2	14-1.8-0	63	2.1	7	(67)	0.5	5	(18)	0.4
Rainfed (plateau)	4	10-0-0	85	2.4	2	(99)	0.2	4	(6)	0.8
Rainfed (plain)	6	5-0.9-1.7	52	1.8	8	(60)	0.5	9	(7)	0.7
San Fernando										
Rainfed (plateau)	8	6-0-0	104	2.6	5	(92)	0.3	4	(21)	0.3
Rainfed (plain)	11	7-0-0	73	2.2	5	(102)	0.2	7	(2)	0.9
Rainfed (bottomland)	4	2-0-0	(1)	1.0	5	(127)	neg	3	(19)	0.4
Tarlac, Tarlac										
Rainfed (plateau)	9	23-4.4-5.0	101	3.3	42	(13)	0.8	15	(5)	0.7
Rainfed (plain)	9	32-2.6-7.5	81	3.2	41	(12)	0.9	14	7	0.4

[a]Researchers' fertilizer level, 58-30-30 kg (N, P, K)/ha; farmers' levels of fertilizer are average of surveys conducted at different locations and water regimes. [b]Researchers. insect control, two granular applications plus 2 foliar sprays costing $132/ha (US$1 = ₱9). [c]Researchers' weed control, one granular application of butachlor, 1 foliar application of 2,4-D plus 1 hand weeding costing $33/ha. [d]At rough-rice price of $139/t in Camarines Sur and $144/t in Tarlac.



3. Smoothed cumulative frequency distribution of net benefits of researchers' fertilizer practices over the farmers', Libmanan and San Fernando, Camarines Sur, and Tarlac, Philippines, 1982.

researchers' fertilizer practice over the farmers' is shown in Figure 3. In all cases, it was profitable to use the researchers' fertilizer rates at Tarlac. However, in Camarines Sur, 15-30% of the farmers would have been worse off by increasing fertilizer rate. Income stability and variability as determinants of farmers' fertilizer management are being examined.

Soil nutrient sources (*Agricultural Economics*). In most circumstances, it was profitable to apply N rates as high as 58 kg/ha. It was not profitable at the bottomlands in San Fernando and Libmanan, where the probability of losing the crop to flooding is substantial, nor at the new irrigated area in Libmanan.

P application was marginally profitable at most sites. A positive response to K was recorded at all but the rainfed plains in Libmanan. At four sites it was clearly profitable to apply K and at two sites, marginally profitable.

RAINFED RICE PRODUCTION

Agricultural Economics Department

Crop response, site, and managed factors. *Experimental sites.* The difference in productivity of managed inputs among experimental locations and the relationship of these differences to site-specific parameters were examined in a set of rainfed rice experiments at San Fernando.

A quadratic response function was estimated for the plateau, plain, and bottomland areas. The form of the function was:

$$Y_i = a_j + b_{1j} X_{1i} + b_{2j} X_{2i} + b_{3j} X_{3i} + b_{4j} X_{4i} + b_{5j} X_{5i} + b_{6j} X_{6i} + b_{7j} X_{7i} + e \quad (1)$$

where Y_i is yield rough rice in kilograms per hectare for site i:

X_1 is kilograms of N per hectare;

X_2 is the square of N applied (X_1^2);

X_3 is expenditures for insect control ($/ha);

X_4 is expenditures for weed control ($/ha);

X_5 is pooled early and late moisture stress days;

X_6 interaction between N (X_1) and moisture stress (X_5);

X_7 variety dummy equal to 1 for farms planted to IR747 and 0 otherwise;

e is an error term with normal properties.

The procedure used to obtain estimates of the parameters of the production functions involved construction of a dummy variable for each water regime and fitting a multisite regression model:

$$Y_i = \sum_{j=1}^{3} a_j D_j + \sum_{j=1}^{3} \sum_{k=1}^{7} b_{kj} D_{kj} X_k + u \quad (2)$$

where $D_1 = 1$ if farm is on plateau, 0 otherwise;

$D_2 = 1$ if farm is on the plain, 0 otherwise;

$D_3 = 1$ if farm is on the bottomlands, 0 otherwise;

a_j, and b_{kj} are parameters; and u is an error term.

Site production functions. The estimates of the pooled production function are in Table 11. Differences in values of coefficients between production functions are observed in each row of coefficients in Table 11. The base yield increases from the bottom land area to the plateau. Alternatively, the moisture stress by N coefficient (b_6) — a measure of the negative complementarity between moisture stress and N — is highest at the plateau. The same is true with the stress coefficient.

Marginal analysis. The yield effect of a one-unit change in each input is in Table 12. At the average

Table 11. Rainfed rice production functions for different landscape positions, San Fernando, Camarines Sur, 1981-82.

Variable	Unit	Rice production function		
		Plateau	Plain	Bottomland
Constant: a		3057.04	2873.32	2272.83
N: b_1	kg/ha	37.77*	34.96*	39.69*
N^2: b_2	kg/ha	-0.11	-0.13	-0.34*
Insecticide: b_3	$/ha	0.55*	0.85*	0.47
Weed control: b_4	$/ha	1.28*	0.93	1.16
Moisture stress: b_5	d	-37.13*	-18.04*	-19.57*
N X moisture stress: b_6	N.d	-0.60*	-0.34	-0.40*
Variety dummy: b_7	0, 1	-924.04*	-656.79*	-325.41
$\bar{R}^2$		0.51		
F-ratio		32.05		
Standard error of Y	kg/ha	691.37		
n		696		

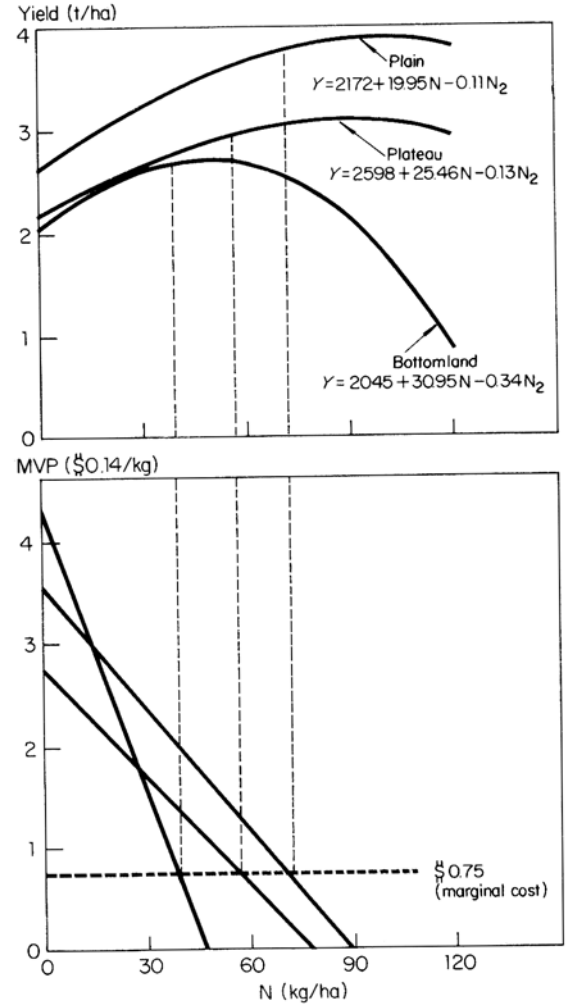
Table 12. Mean marginal productivities of all variables for different landscape positions, San Fernando, Camarines Sur, Philippines, 1981-82.

Landscape position	Marginal productivity				
	N	Insecticide	Weed control	Stress	Variety
Plateau	13.20	0.55	1.28	-55.20	-924.04
Plain	17.80	0.84	0.93	-28.20	-656.79
Bottomland	10.60	0.47	1.16	-31.40	-325.41

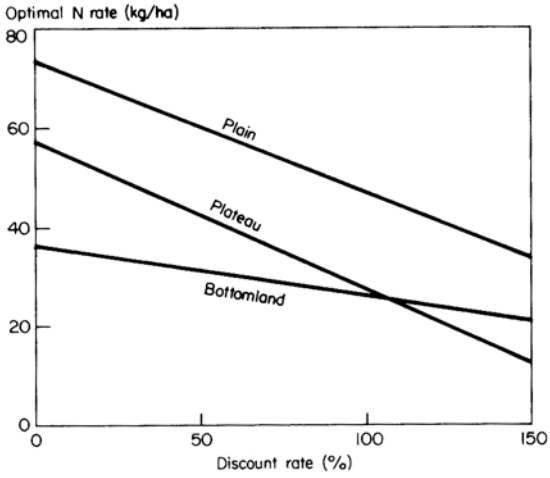
N level and other inputs during the year, 1 kg of added N resulted in 13 kg of additional yield on the plateaus, 18 kg in the plains, and 11 kg in the bottomlands. The average productivities of inputs in 1981-82 were similar to those obtained during 1980-81 (Annual report for 1981).

The yield reduction attributed to an extra day of drought was highest on the plateaus, indicating a more intense moisture stress effect than on the plains and bottomlands (Table 12). The yield difference between IR36 and IR747 (a short-season cultivar) was more pronounced in the high landscape; IR36 yielded 0.9 t/ha more than IR747.

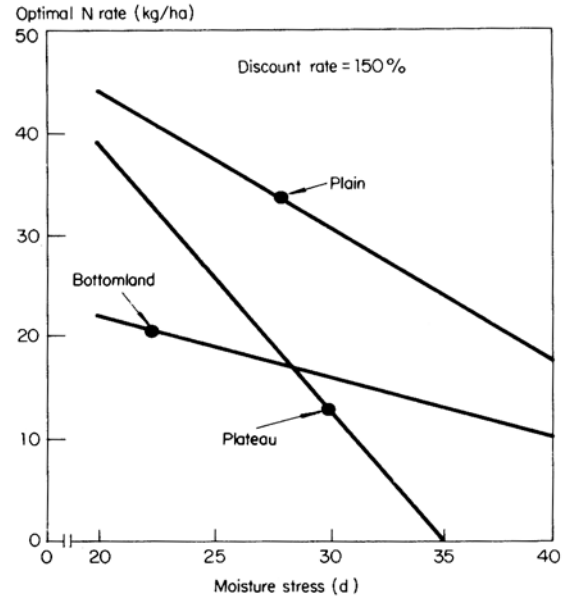
Optimal nitrogen rates. N response functions were derived from the production function using average values of other variables for each water regime. The implied optimal N levels were computed using prevailing fertilizer and rice prices — $0.75/kg N and $0.14/kg rough rice (Fig. 4). The implied optimal N levels, assuming all site factors were at their mean values, were 36 kg/ha for bottomlands, 71 kg for the plains, and 55 kg for plateaus.



4. Marginal value produce (MVP) curves for three water regimes, rainfed rice. San Fernando, Camarines Sur, Philippines, 1981-82.



5. Implied optimal N use with three water regimes and rates of discount, rainfed rice. San Fernando, Camarines Sur, Philippines, 1981-82.



6. Optimal N rates at various levels of moisture stress with three water regimes, rainfed rice. San Fernando, Camarines Sur, Philippines, 1981-82.

High-profit N rates were recalculated with prevailing interest rates. This cost of capital may reflect the cost of borrowing money (often in excess of 100% in the region) as well as a premium for risk. The optimal N level was sensitive to the capital cost (Fig. 5). For example, at a discount rate of 150%, optimal N use decreased to 21 kg/ha on the bottomlands, 34 kg on the plains, and 13 kg on the plateaus.

The negative interaction between crop response to N and the incidence of moisture stress implied that optimal N rates decreased as moisture stress increased (Fig. 6). At the high elevation, moisture stress is most likely to occur and the optimal N rate is most sensitive to the incidence of moisture stress. Returns from applying fertilizer were higher on the plains than on the bottomlands or plateaus. More farmers applied fertilizer on the plains, and at higher rates, than on the bottomlands or the more drought-prone plateaus (Table 13).

Farmers' fields. The preceding analysis of yield variability was related to experimental conditions where the managed factors were controlled. Rice production variability among farms was evaluated similarly. The data were derived from agroeconomic surveys of farmers at the research site. During each season, a sample of 80 farmers was selected. Farm visits were made after crop establishment and after harvest to collect data on crop management, input use, and crop output.

Regression models were estimated to relate farm-specific rice yields to managed and site-related factors. The final set of variables included in the model were

- Expenditure on variable cash inputs in $/ha (CI);
- Total moisture stress, in days (SS);
- Dummy variables equal to 1 for IR747, 0 otherwise (V);
- Dummy variable equal to 1 for farms larger than 3 ha and 0 otherwise (A1);
- Season dummy equal to 1 for second crop and equal to 0 for first crop (SD);
- Crop establishment dummy equal to 1 for WSR and equal to 0 for TPR (ED).

Results are presented in Table 14.

Total moisture stress was the most important factor identified as affecting yield variability among farms — it accounted for more than 70% of the unadjusted R^2. Cash input differences accounted for another 15% of the variation, which implied that it would be profitable for farmers to use high levels of herbicides and insecticides. A one-dollar expenditure would increase yield by about 18 kg — a marginal B:C ratio of more than 2 to 1. Crop establishment accounted for about 7% of the yield

Table 13. Farmers' adoption of N fertilizer and levels of use, by landscape position, rainfed rice, San Fernando, Camarines Sur, Philippines, 1981-82.

Landscape position	Adoption (%)			Level of use (kg N/ha)		
	1st crop	2nd crop	Both 1st and 2nd	1st crop	2nd crop	Both 1st and 2nd
Plateau	20	23	22	22 a	25 a	23 a
Plain	35	30	32	36 b	38 b	37 b
Bottomland	25	20	22	20 a	22 a	21 a
All positions	25	18	23	26	30	25
X^2	6.01*	2.77^{ns}	3.70^{ns}			

Table 14. Least-square regression estimates of yield response function fitted to survey data, San Fernando, Camarines Sur, Philippines, 1981-82.

Variable	Unit	Estimated coefficient	Proportion of explained variability due to factor (%)
Constant	kg/ha	2852.22	
Variable cash inputs (CI)	$/ha	2.06	15
Total moisture stress (SS)	days	-26.30*	73
Variety dummy (V)	0, 1	-280.54*	4
Area dummy (A1)	0, 1	-233.77	2
Season dummy (SD)	0, 1	312.37*	2
Crop establishment dummy (ED)	0, 1	-477.99*	7
R^2		0.41	
$\bar{R}^2$		0.38	
F-ratio ($n_1 = 7$, $n_2 = 152$)		15.36*	
Standard error of y	kg/ha	834.95	
n		160	

Table 15. Comparison of mean marginal productivities of all variables between constraints survey and field experiments, rainfed rice, San Fernando, Camarines Sur, Philippines, 1981-82.[a]

Variable	Marginal productivity	
	Survey	Experiment
Cash inputs[b]	2.06	1.74
Moisture stress	-26.03	-38.27
Variety 1 dummy	-280.54	-635.41

[a]Av of plateaus, plains, and bottomlands. [b]Summed marginal productivities of insect control and weed control comparable with the specification of cash inputs in the survey production function.

variability, which implied that transplanted rice outyielded direct-seeded rice by about 0.5 t/ha. This value is similar to that implied by tabular analysis (0.6 t/ha) and to last year's finding.

The effects of the two most important explanatory variables in the survey and experimental production function were strikingly similar (Table 15). The relationships in the farm survey agree with those in the experimental data.

Farm size and resource productivity. Patterns of resource productivity among rainfed rice farms were investigated at the San Fernando site.

Agroeconomic surveys were conducted to determine how farmers managed their rice crop. During each season, an 80-farmer sample was selected. Data on land, capital, labor, draft animals, and other expenses were obtained during farm visits after crop establishment and after harvest. For analytical purposes, respondents were stratified into small (less than 0.7 ha of rice, 35% of sample); medium (0.7-1.5 ha, 40%); and large holdings (more than 1.5 ha, 25%).

A Cobb-Douglas model of production was estimated for each of the three groups. With five variable inputs, the production function of each farm in any group was expressed as:

$$Y_{ij} = a_j X_{1i}^{b_{1j}} X_{2i}^{b_{2j}} X_{3i}^{b_{3j}} X_{4i}^{b_{4j}} X_{5i}^{b_{5j}} u^{e_i} \quad (1)$$

where Y_i is the gross income from rice,
X_1 is land value;
X_2 is the value of stock of farm implements (capital stock);
X_3 is the value of labor services;
X_4 is the value of draft animal services;
X_5 is the value of agrochemicals;
i denotes the ith farm;
j denotes the jth size group;
a is a technical efficiency parameter, given the nature of the production function;
B_js are the elasticities for the jth farm group; and
e_i is an error term with normal properties.

Equation 1 was transformed to express output per unit of land as a function of a unit of land measured in value terms. This was obtained by dividing all elements in equation 1 by the measure of land input, X_1. Rearranging and dropping the group subscript:

$$\frac{Y}{X_1} = aX_1 \left(\sum_{i=1}^{5} b_i - 1\right) \left(\frac{X_2}{X_1}\right)^{b_2} \left(\frac{X_3}{X_1}\right)^{b_3} \left(\frac{X_4}{X_1}\right)^{b_4} \left(\frac{X_5}{X_1}\right)^{b_5} . \quad (2)$$

Because the sample was sorted by farm size, the variation in X_1 within a group is small. Thus, the coefficient for this variable is unlikely to be significant. Assuming constant returns to scale, the coefficient of X_1 in equation 2 is the sum of the elasticities minus one, that is zero. The model reduces to:

$$\frac{Y}{X_1} = a \left(\frac{X_2}{X_1}\right)^{b_2} \left(\frac{X_3}{X_1}\right)^{b_3} \left(\frac{X_4}{X_1}\right)^{b_4} \left(\frac{X_5}{X_1}\right)^{b_5} , \quad (3)$$

and the model to be estimated using the farm-survey data becomes:

$$y = a_j + b_{2j}x_2 + b_{3j}x_3 + b_{4j}x_4 + b_{5j}x_5 + u \quad (4)$$

where

$$y = ln\left(\frac{Y}{X_2}\right),$$

$$a_j = Ln\, A_j,$$

$$x_2 = Ln\left(\frac{X_2}{X_1}\right),$$

$$x_3 = Ln\left(\frac{X_3}{X_1}\right),$$

$$x_4 = Ln\left(\frac{X_4}{X_1}\right),$$

$$x_5 = Ln\left(\frac{X_5}{X_1}\right),$$

u = the disturbance term.

Dummy variables were constructed for each size category. The pooled model estimated is:

$$y = \sum_{j=1}^{3} a_j D_j + \sum_{j=1}^{3} \sum_{k=2}^{5} b_{kj} D_{kj} x_k + u \quad (5)$$

where $D_1 = 1$ if land area is less than 0.7 ha, 0 otherwise;
$D_2 = 1$ if land area is at least 0.7 ha but less than 1.5 ha, 0 otherwise;
$D_3 = 1$ if land area is 1.5 or larger, 0 otherwise.

The estimates of equation 5 for the San Fernando farm data are in Table 16.

The constant term, a, an estimate of the technical efficiency of each farmer group, was highest for the small farms. The output elasticity of capital was not significantly different from zero for any group. The labor coefficient, b_3, increased as farm size increased. Thus, increasing labor inputs on large farms implied a higher productivity than increasing labor use on small farms. The draft animal elasticity was significant for the small and medium farms, but not for the large farms. The coefficient for expenditure on chemicals was similar for the small and medium farms, but smaller for large farms.

The values of the marginal productivities of the significant input factors are in Table 17. The values confirmed that the marginal productivity of labor is lower for small farms. For small and medium farms, it appeared that labor may be employed beyond the point at which the value of its contribution to output exceeds its wage. By contrast, farms

Table 16. Ordinary least-squares estimate of the production from survey data for different-sized farms, San Fernando, Camarines Sur, Philippines, 1981-82.

Factor	Elasticity		
	Small farm	Medium farm	Large farm
Constant (a)	89.658	26.709	25.790
Capital (b_2)	0.003^{ns}	−0.048^{ns}	−0.001^{ns}
Labor (b_3)	0.203**	0.318**	0.573**
Draft animal (b_4)	0.124*	0.192*	0.017^{ns}
Chemical expense (b_5)	0.265**	0.332**	0.128*
R^2	0.428	–	–
$\bar{R}^2$	0.373	–	–
F ($n_1 = 14$, $n_2 = 146$)	7.803**	–	–
Standard error of y	0.916	–	–
n	160	–	–

Table 17. Value marginal products of factors at the mean, Camarines Sur, Philippines, 1982.

Factor	Value marginal product[a]		
	Small farm	Medium farm	Large farm
Labor	0.554	0.848	1.514
Draft animal	0.248	1.013	0.110
Agrochemicals	4.732	5.119	3.925

[a]The marginal product in the context of the Cobb-Douglas may be expressed as: $MPX_i = b_i \frac{Y}{X_i}$ where b_i is the elasticity of output with respect to ith factor and Y/X_i is the yield per unit of the factor; it also defines the marginal value product per unit value of X_i.

larger than 1.5 ha appeared to be employing labor below the optimal level. However, the marginal productivities of fertilizer, insecticides, and herbicides were uniformly high across farm sizes.

Rice supply response and labor demand. Most estimates of rice supply and input demand relate to irrigated and favorable rainfed environments. Supply estimates also tend to be based on response to changes in input use. There are few reports on supply response or input demand as prices, either of input or output, vary. Fewer studies still focus on less favorable rainfed rice environments. These parameters were estimated for such an environment — the Bicol region of the Philippines — using profit function analysis.

The production process of Bicol rainfed rice farmers was assumed to follow a translog specification for this analysis. By duality, the profit function is also translog and was specified as

$$ln\,\pi^* = \alpha_0 + \alpha_1 D_1 + \sum_{i=2}^{4} \alpha_i\, ln\, P_i^* + \sum_{j=1}^{2} b_j\, ln\, Z_j + \frac{1}{2}\sum_{i=2}^{4}\sum_{k=2}^{4} \gamma_{ik}\, ln\, P_i^*\, ln\, P_k^* + \frac{1}{2}\sum_{j=1}^{2}\sum_{l=1}^{2} \sigma_{j_l} \ln Z_l + \sum_{i=2}^{4}\sum_{j=1}^{2} \delta_{ij}\, ln\, P_i^*\, ln\, Z_j + u \quad (1)$$

where π^* = the restricted profit which is total revenue less total variable costs, normalized by the unit price of paddy (UOP);

D_1 = crop establishment dummy taking value 1 for transplanted paddy and 0 otherwise;

P_2^* = real wage rate for labor man-days, calculated by dividing the total wage paid to labor, including imputed family labor, by the total number of labor used, all divided by the UOP.

P_3^* = normalized pesticide price per 100 ml, obtained by dividing the total expenditure on pesticides used by the total amount of chemicals, in liters, and normalizing this ratio by UOP;

P_4^* = normalized wage rate per day for land preparations, obtained by dividing the total expenditure on land preparation by days of land preparation, and dividing this ratio by UOP;

Z_1 = area in hectares of the surveyed farm;

Z_2 = capital flow, in ₱, calculated as the sum of depreciation, maintenance, and op-

Table 18. Efficient estimates of the translog profit function and factor demand functions for sample farmers in Camarines Sur, Philippines, 1981-82.[a]

Characteristic	Efficient estimate												
	α_0	α_1	α_2	α_3	α_4	β_1	β_2	γ_{22}	γ_{23}	γ_{24}	γ_{33}	γ_{34}	γ_{44}
Profit function	2.44	0.23	−0.41	−0.22	−0.55	−2.02	0.91	−0.33	0.08	−0.25	−0.16	−0.03	−0.43
	(5.48)	(0.11)	(0.20)	(0.37)	(0.46)	(1.80)	(1.23)	(0.15)	(0.04)	(0.12)	(0.08)	(0.02)	(0.23)
Labor demand function			−0.41					−0.33	0.08	−0.25			
			(0.18)					(0.13)	(0.03)	(0.10)			
Pesticide demand function				−0.22					0.08		−0.16	−0.03	
				(0.32)					(0.03)		(0.07)	(0.01)	
Machinery demand function					−0.55					−0.25		−0.03	−0.43
					(0.38)					(0.10)		(0.01)	(0.22)
	σ_{11}	σ_{12}	σ_{22}	δ_{21}	δ_{22}	δ_{32}	δ_{32}	δ_{41}	δ_{42}				
Profit function	−0.29	0.47	−0.42	0.13	−0.09	0.06	−0.09	0.16	−0.19				
	(0.18)	(0.26)	(0.24)	(0.06)	(0.04)	(0.03)	(0.05)	(0.09)	(0.10)				
Labor demand function				0.13	−0.09								
				(0.05)	(0.03)								
Pesticide demand function						0.06	−0.09						
						(0.03)	(0.04)						
Machinery demand function								0.16	−0.19				
								(0.08)	(0.09)				

[a] Figures in parentheses are asymptotic standard errors of the estimates.

portunity costs of capital stock, excluding the capital flow of land preparation equipment; and

u = disturbance terms with normal properties.

The factor demand functions for variable inputs were obtained by differentiating the normalized restricted profit function with respect to the normalized factor price. From the translog profit function in equation 1, the factor share functions are derived as:

$$\frac{-P^*_i x_i}{\pi^*} = \alpha_i + \sum_{k=2}^{4} \gamma_{ik} \ln P^*_k + \sum_{j=1}^{2} \sigma_{ij} \ln Z_j + u_i \quad (2)$$

$$i = 2, 3, 4.$$

where x_is are quantities of variable inputs: labor (2), chemicals (3), and animal and machine power (4) measured in man-days, liters, and animal-days, respectively.

Aitken's estimation procedures were used to simultaneously obtain asymptotically efficient estimates of equations 1 and 2 (Table 18). The data used in this analysis were derived from the agro-economic farm survey for the 1981-82 crop year.

The profit elasticity for crop establishment (α_1) was positive and shows that transplanting results in higher profit than direct seeding. This confirms the budget analysis reported in the Annual report for 1981. The coefficients of the demand functions for labor, chemicals, and land preparation were statistically significant with expected signs. These functions are nonlinear and decrease in slope as input levels increase.

An advantage of the formulation jointly specified by equations 1 and 2 is that demand elasticities of variable inputs and output supply are estimated directly. A particular advantage of the translog model is that output supply and input demand elasticities are dependent on input levels, and not constant as implied in the usual Cobb-Douglas formulation of the profit function.

The elasticities of rice supply and demand for labor derived from the estimates of equation 1 are in Table 19. The demand for labor with respect to its own price (i.e., wage rate) was inelastic (-0.7) within the observed price ranges. Thus, a 10% increase in wages would reduce the demand for labor in rainfed rice production in Camarines Sur by 7%, which in turn was estimated to bring about a 2% decrease in rice supplies. A 10% increase in the real price of chemicals would decrease the labor demand 4%. A similar increase in the real price of land preparation service would increase labor demand 2%. A 10% increase in pesticide price however, would bring about a 4% increase in rice supply or a 2% increase in land preparation cost.

Table 19. Derived own and cross-price elasticity estimates of rice supply and labor demand[a], Camarines Sur, Philippines, 1982.

Price of, quantity of	Rice supply	Labor demand
Labor	-0.21	-0.68
	(5.40)	(5.96)
Pesticides	-0.41	-0.37
	(4.28)	(5.23)
Machineries	-0.18	-0.21
	(4.73)	(4.92)
Land	0.78	0.84
	(8.12)	(8.70)
Capital flow	0.23	0.12
	(5.20)	(4.93)
Paddy	0.82	1.21
	(6.23)	(9.20)

[a] Figures in parentheses are the asymptotic F values, as the elasticity estimates are linear transformations of the parameter estimates of the translog profit function.

The rice supply and labor demand elasticities with respect to farm size were both less than 1.0. As farm size increased the demand for labor decreased (elasticity of 0.8) — thus labor-land ratios decreased as farm size increased. Also, larger farms tended to have lower output per unit area than did smaller farms; a 10% increase in farm size was associated with an 8% increase in rice supplies. Rice supply was sensitive to rough rice prices. A 10% increase in rough rice price was estimated to increase supply by 8%, but to increase the labor demand by more than 12%. Therefore, even in these adverse rainfed environments, rice price policies may have a significant impact on rice supply. Of equal interest, increases in the real price of rice may have a significant impact on the demand for labor in rainfed rice production.

Consequences of new rice technology

Agricultural Economics Department

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Farmers who do not adopt new technology will not benefit from it. Because production increases brought about by new technology may result in lower prices, farmers who do not adopt the new technology will fall behind. Whole classes of farmers not adopting the new technology may contribute to widening income disparities. Tenant farmers may be a class of nonadopters. Economists studying the consequences of new rice technology and rice-based cropping systems collaborated with colleagues in Thailand, Bangladesh, and Nepal to determine to what extent they differed from farmer-owners in adopting new technology.

Locations where modern rice varieties (MVs) and fertilizer have been adopted to a moderate level were needed so that new and old technology could be observed within a compact research area. Sites in Thailand, Bangladesh, and Nepal fit this situation. Because factors affecting production and the use of new technology varied across countries, each study was somewhat different.

Yield and input use in Bangladesh. Four villages were selected from Joydebpur subdivision of Dhaka District. One hundred and thirty households were selected at random from all the village households. Twenty households headed by landless laborers or absentee workers were excluded from the farm survey. Data were collected through direct farmer interviews during several visits in the 1981 aus season. All rice was rainfed.

A complete survey identified owned, rented (in and out), and mortgaged (in and out) types of tenure. Different leasing arrangements were identified and defined on the basis of the terms and conditions of output and input sharing.

Because many farmers owned and rented land, the parcels operated were categorized under different tenure systems and the differences among categories of parcels, rather than farms, determined.

All parcels were classed into four tenure categories. Because the mortgaged and leasehold parcels were very few, the analysis was focused on owner-operated parcels and share-tenant parcels. Data from all parcels in the two categories were compared. In addition, 30 owner-tenant farms were selected. From these farms, 30 owned parcels (OPs) and 30 share-rented parcels (SRPs) producing MVs were compared for yield, input use, MV adoption, cropping pattern, and cropping intensity.

OPs had significantly higher yields than SRPs, for both the paired parcels and all parcels. The difference was 0.53-0.64 t/ha. OPs yielded 15-20% higher than SRPs. MVs yielded significantly higher than the local varieties (LVs).

Preharvest animal power inputs, preharvest labor, seeds, manure, and fertilizers were compared (Table 1). Farmers used significantly higher amounts of manure on OPs than on SRPs. Animal labor, human labor, seeds, and fertilizer did not differ significantly between OPs and SRPs.

Only 43 of 110 farmers used credit; only seven obtained credit from formal sources. The banks give no credit to farmers who do not own their land. The credit source of 89% of the borrowers was moneylenders charging a 33% interest rate. There were no differences in credit source by tenure group.

The parcels were arranged by cropping pattern. A LV - fallow - MV pattern was used on 65-85% of the land. Tenure made no difference, for either the

Table 1. Average input use on OPs and SRPs producing MVs, four villages, Dhaka District, Bangladesh, 1981 aus season.

Land	Preharvest labor (d/ha)		Seed (kg/ha)	Manure (t/ha)	Fertilizer (kg/ha)
	Animal[a]	Human[b]			
			60 parcels on 30 farms		
OP	36.2	110.1	62.2	3.3	213.3
SRP	37.5	104.3	54.0	1.3**	213.7
			144 parcels		
OP	36.6	110.7	60.6	3.0	270.0
SRP	35.1	95.4	52.8	1.0*	197.9

[a]Preharvest animal labor. [b]Preharvest human labor.

entire sample or the paired parcels (Table 2). A slightly greater proportion of the SRPs followed a three-rice cropping pattern, but the difference in cropping intensity between OPs and SRPs was not significant.

MV adoption was significantly higher on OPs for the paired parcels during the boro season and aus season. Comparison of all parcels showed a significantly higher adoption of MVs in the boro season only.

A detailed analysis was made of the income and productivity for the aus season crop. Value of rice production in the aus season was 50-75% higher on parcels growing MVs than on those growing LVs (Table 3). Yields reported by owners were higher for MVs, but were not associated with differences in paid-out costs of inputs such as fertilizer, power, and labor. For example, owners and share-tenants growing MVs spent the same amount on inputs, but owners had 16% higher yields. Although output was the same, share-tenants spent 30% more than fixed-rent tenants growing MVs. Individual input levels of the three tenure categories, both purchased and family-supplied, were similar (Table 4).

Returns above paid-out costs represent the income earned by resources committed to production by the farm family. This shows the largest impact of differences in tenure arrangements. OPs returned much greater earnings to farm families than SRPs simply because owners pay no rent. The returns above paid-out costs were substantially higher for MVs than for LVs.

The possible reasons for the productivity differences were analyzed using estimates of a Cobb-Douglas production function (Table 5). The esti-

Table 2. Cropping pattern of OPs and SRPs of the same farms, four villages, Dhaka District, Bangladesh, 1980-81.

Cropping pattern (aman-boro-aus)	30 parcels				144 parcels			
	OP		SRP		OP		SRP	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
MV - MV - MV	0.00	0	0.00	0	0.00	0.0	0.00	0
LV - MV - MV	0.51	4	0.92	8	4.55	10.0	1.03	6
LV - LV - MV	0.00	0	0.40	3	2.09	4.0	0.51	3
LV - MV - LV	0.00	0	0.35	3	1.65	4.0	0.35	2
LV - LV - LV	0.57	4	0.20	2	0.70	2.0	0.20	1
MV - fallow - MV	0.00	0	0.00	0	0.10	0.0	0.02	–
LV - fallow - MV	10.82	84	7.84	66	34.97	74.0	11.72	70
LV - fallow - LV	1.03	8	2.20	18	3.19	7.0	2.89	17
Total	12.93	100	11.91	100	47.25	100	16.72	100

Table 3. Farm income obtained on land operated under three types of tenure by 130 sample farmers, Dhaka district, Bangladesh, 1981 aus season.

Tenure type	Income[a] ($/ha)				
	Output value	Paid-out input costs	Land rent	Return above paid-out costs	Family-supplied resources[b]
			MV		
Owner	647	130	0	517	499
Share-tenant	556	129	278	149	165
Fixed-rent	554	99	212	242	193
			LV		
Owner	370	77	0	293	465
Share-tenant	353	90	177	86	190
Fixed-rent	353	79	244	30	172

[a]US$1 = TK16. [b]Inputed value of family-supplied land, labor, and capital.

Table 4. Paid-out and farm-supplied inputs on land operated under three tenure categories, 130 sample farmers, Bangladesh, 1981 aus season.

Tenure type	Variety	Input value[a] ($/ha)					
		Fertilizer	Manure	Animal power	Labor	Land	Total[b]
				Paid-out costs			
Owner	MV	35	0	11	84	10	130
Share-tenant	MV	35	0	12	79	278	407
Fixed-rent	MV	36	0	8	56	212	311
Owner	LV	20	0	8	49	0	77
Share-tenant	LV	25	0	13	49	177	267
Fixed-rent	LV	24	0	7	48	244	323
				Family-supplied inputs			
Owner	MV	0	20	50	103	308	499
Share-tenant	MV	0	7	47	97	0	165
Fixed-rent	MV	0	0	59	97	0	193
Owner	LV	0	10	51	138	247	465
Share-tenant	LV	0	0	54	115	0	190
Fixed-rent	LV	0	9	59	84	0	172

[a]$1 = TK16. [b]Includes some minor costs in addition to those listed.

Table 5. Estimated coefficients and *t* values of the Cobb-Douglas production function for rice output per parcel, sample farms, Dhaka district, Bangladesh, 1981 aus season.

Independent variable	All farms		30 farms 60 parcels MVs
	158 parcels MVs	39 parcels LVs	
Land	0.51	0.69	0.51
	(8.5)	(3.8)	(4.2)
Animal power	0.29	–0.14	0.08
	(4.4)	(0.6)	(0.9)
Labor	0.03	0.23	0.21
	(0.6)	(1.6)	(2.3)
Manure	0.01	0.01	0.01
	(2.0)	(0.2)	(2.1)
Fertilizer	0.15	0.13	0.17
	(3.5)	(0.9)	(4.0)
Share-rent dummy	–0.13	–0.03	–0.15
	(2.9)	(0.2)	(2.0)
Fixed-rent dummy	0.01	0.01	
	(0.1)	(0.1)	
Constant	6.17	6.25	5.38
	(22.7)	(7.8)	(12.4)
R^2	0.94	0.74	0.92
F value	367.0	12.5	97.0
n	158	39	60

mates are statistically satisfactory, with acceptable R^2 values and with most coefficients significantly different from zero, judged by their *t* values.

The significant, negative value of the dummy variable for share tenancy suggests that resources used on SRPs had a lower over-all productivity than those used on OPs. The fixed-rent dummy variable was not significantly different from zero. Resource productivity was more satisfactorily estimated for the MV parcels.

The only measured difference between OPs and SRPs was in the level of applied organic matter (OM). Farmers apparently apply their farmyard OM on owned fields rather than on rented fields, probably recognizing that the long-term effects of OM may outlast their rental rights. The higher OM levels seem to increase the productivity of other inputs.

Yields were 15% higher on owner-operated land than on share-tenant land because of a combination of small differences rather than a single major difference. There were no large differences in use of modern inputs by tenure category although there was slightly lower MV use on share-tenant land. Only OM was applied at significantly different rates — owned land, 3 t/ha; share-tenant land, 1 t/ha — and could be the reason for the higher productivity of OPs.

The mean reported yield of all parcels was 3.1 t/ha. If all share-tenant parcels had the same yield as OPs, the mean yield would have been 3.3 t/ha; if all the land had been planted to MVs, the mean yield would have been 3.6 t/ha. These differences suggest the magnitude of yield losses that may be associated with share-tenant land. While not

representative of the situation in Bangladesh as a whole, they indicate that share-tenant land was associated with slightly reduced yields. Thus, changing tenure arrangements would be expected to have a relatively modest impact on production although it would have a major income-transfer effect.

Tenancy and land quality in Thailand. In 1981, a survey of 83 farmers was conducted in four irrigated rice-growing villages in Chainat province. Two districts with different levels of market access — Sanphaya, 13 km from Chainat town, and Sankhaburi, 99 km from Chainat town — were selected. Two villages in Sanphaya were classified as having good market access (GMA) and two in Sankhaburi as having poor market access (PMA). The farmers in each village were classified as tenants or owners based on tenure status data obtained from the village headman. Eleven farmers in each group were randomly chosen and interviewed. After incomplete questionnaires had been eliminated, the final sample size was 83.

Farm size did not differ significantly across tenancy groups, but the average farm in PMA villages was 20% larger. On the average, more than 90% of all land was irrigated wetland rice.

About 66% of the tenants paid a fixed amount of product (usually rice), 20% paid a fixed amount of cash, and a few paid with a combination of these (five tenants paid a share of the first crop and a fixed amount from the second).

Owners had an average cropping intensity of 1.97; tenants, 1.92. About 80% of the owners and 92% of the tenants used a rice - rice cropping pattern. Some owners in the GMA villages practiced triple cropping, growing an additional crop of groundnut or soybean.

Farm income provided 86% of total family income; nonfarm employment, 9%; and working for other farmers, the balance. Rice dominated farm revenues, except for GMA owners who had significantly higher total farm revenue, because of nonrice contributions (Table 6). In PMA villages, owners had significantly higher revenue from rice and farm costs were lower.

The impact of differences in costs and revenues on net cash incomes was startling. GMA owners had incomes three times greater than GMA tenants; PMA owners, 65% higher than PMA tenants.

There were no significant differences in use of farm inputs by owners and tenants in villages with the same market access. Owners did not monopolize technology in this study. The income differences were largely traceable to revenue differences in the GMA villages and to differences in both costs and revenue in the PMA villages.

Table 7 compares the economic performance of the two most important cropping patterns. Owners' yields were 10% higher but cost differences were much less. Owners had higher yields and a higher rate of return on variable costs, even though their use of variable inputs was similar to that of tenants.

Table 6. Farm incomes[a] obtained by four farm groups, Chainat, Thailand, 1980-81.

Group		Revenue ($/ha)		Cash costs ($/ha)	Net cash income ($/ha)
Market access	Tenure	From rice	Total		
Good	Owner	592 ab	822 a	365 a	457 ab
Good	Tenant	470 b	475 c	353 a	122 c
Poor	Owner	655 a	678 ab	186 b	492 a
Poor	Tenant	460 b	504 bc	206 b	298 bc

[a]US$1 = ฿20.

Table 7. Profitability analysis of crop production among tenant groups, Chainat, Thailand, 1980-81.

Item	Rice-fallow		Rice-rice	
	Owner	Tenant	Owner	Tenant
Yield (t/ha)	3.06	2.77	6.98	6.21
Gross returns ($/ha)	553	486	1256	1807
Total labor and power costs ($/ha)	226	220	451	426
Total material cost ($/ha)	85	87	164	176
Total variable cost (TVC) ($/ha)	311	307	614	602
Net return above TVC ($/ha)	238	178	642	485
Rate of return to variable cost	1.77	1.58	2.04	1.81

Owners had higher rice output even after correcting for land, labor, and fertilizer differences. Production was significantly higher in the DS. This suggests a factor associated with tenure affecting output different from those usually considered.

To explain the inferior productivity of tenants, it was hypothesized that land-quality differences may exist between tenants and owners. Because the farms were all irrigated, two factors related to irrigation — the distance to the irrigation canal and the number of months fields were irrigated during the DS — were likely to influence crop performance. Owners tended to operate plots closer to the irrigation canal that had irrigation water longer.

Because owners operated better irrigated plots, they had a distinct productivity advantage. Particularly in GMA villages, they planted their rice crops 3-4 wk earlier than the tenants probably because irrigation was available earlier. Plots with three crops were significantly closer to irrigation and had water a significantly longer time during the DS. They were all owner-operated and planted to soybean or groundnut after the two rice crops.

It appears that land ownership gives advantages to the owner-operators, enabling them to monopolize better quality land. Where market access widened the economic opportunities, differences in control over good-quality land resources tended to increase income inequalities.

Factors affecting adoption in Nepal. A random sample of 146 farmers was selected from lists of owners and tenants in 24 villages of 11 towns in Kapilvastu district. The nearness of some villages to the Indian border, had no effect on technology use. Only 17% of the sample used MVs and fertilizer. Because farmers had many parcels of rice land and grew many different varieties, the detailed data were collected from one parcel of each farmer.

Parcels where MVs and fertilizer were used had the highest yields although all yields were quite low (Table 8).

At the same technology level, tenants had substantially lower paid-out costs for inputs and labor. This is consistent with some theories on the behavior of share-tenants, but is different from what was observed in Bangladesh. The higher paid-out costs of owners can be traced to their substantially higher use of hired labor. Owners growing MVs with fertilizer applied substantially more fertilizer than their share-tenant counterparts. Owners growing LVs with fertilizer used substantially more purchased power and other inputs than their share-tenant counterparts.

The combination of higher output value, lower paid-out costs, and no paid-out land rent made the returns above paid-out costs of owners with MVs nearly three times as great as that of their share-tenant counterparts. The return above paid-out costs of farmers growing MVs was higher than that of farmers growing LVs.

There was a substantial difference in the use of modern technology among owners and tenants. The chi-square contingency test was used to test

Table 8. Farm incomes compared for two tenure types and four technology levels, Kapilvastu district, Nepal, 1980.

Tenure type	Fertilizer category	Parcels (no.)	Yield (t/ha)	Costs and returns[a] ($/ha)				
				Output value	Paid-out input costs	Land rent paid	Return above paid-out costs	Family supplied resources[b]
				MV				
Owned	User	22	1.8	229	97	0	132	248
Share-tenant	User	4	1.6	196	48	88	60	152
Owned	Nonuser	20	1.5	197	52	0	145	190
Share-tenant	Nonuser	23	1.2	142	23	64	55	131
				LV				
Owned	User	12	1.2	127	131	0	–4	218
Share-tenant	User	4	1.3	145	47	65	33	149
Owned	Nonuser	32	1.1	120	41	0	79	157
Share-tenant	Nonuser	29	1.0	123	15	56	52	157

[a]US$1 = Rs12. [b]Imputed value of family-supplied land, labor, and capital.

whether irrigation and tenure were associated with the use of modern technology. The hypothesis of independence of irrigation and variety used could not be rejected at the 10% level of probability. Likewise, the hypothesis of independence between tenure status and use of MVs could not be rejected: half of the owners grew MVs and half did not. Among share-tenants, the proportion was nearly the same; however while most were paying 50% of their output as rent, some were paying 40%. Tenants paying 40% were more likely to be growing MVs.

Among MV users, fertilizer use was not independent of irrigation — a much higher proportion of farmers with irrigation used MVs. However, among LV growers, irrigation was independent of fertilizer use; most did not use fertilizer. Tenure status was not independent of fertilizer use — a much smaller proportion of tenants applied fertilizer.

In Nepal, where fertilizer use is a relatively new technology, farmers had different perceptions of its value. More farmers with experience in fertilizer use believed that the application of 40-8.8 kg (N,P)/ha would give a higher yield than farmers who had never used fertilizer (Table 9).

NEW RICE TECHNOLOGY AND LABOR ABSORPTION

To assess the impact of new rice technology on the labor absorbing capacity of agriculture, economists studying the consequences of rice technology and rice-based cropping systems compared the histories of two different rice-growing villages in the Philippines.

Study sites and data collection. One village (called Laguna village in the study) is located in the wetland rice belt of Laguna Province, which is one of the most productive rice-growing areas in the Philippines. The other village (Iloilo village) is at the northwestern edge of the rainfed-wetland dominating rice plain in Iloilo Province.

The data used in this study were collected as a part of larger research projects involving field surveys in 1980-82 for Laguna Village and in 1979-82 for Iloilo village. Information for this study was obtained gradually during the course of the surveys through interviews with all existing households and aged villagers.

Historical changes in agriculture. Laguna village began in the 1880s and Iloilo village in the 1850s. Although Iloilo village had a higher population than Laguna village in 1920 (Table 10), the land-man ratios of the two villages were comparable, suggesting their similar initial conditions as rainfed, wetland-based rice villages. Major agricultural changes since settlement are in Table 11. Early settlement at both sites was unorganized as people from adjacent areas came in gradually when new rice fields were opened. In both villages, there was extensive rainfed rice farming based on the open-land frontier, which ended by the late 1940s. Since then, agriculture evolution in the two villages has diverged sharply.

Laguna village. Extension of a national irrigation system to the village suddenly changed the rainfed rice farming. Irrigation made double cropping possible for all rice fields, establishing a complete rice monoculture pattern.

Another major technological change was introduction of MVs and associated technologies in the

Table 9. Yields that farmers at different technology levels perceived they could obtain using two fertilizer rates, Kapilvastu District, Nepal, 1980.

Farmer's technology		Perceived yield (t/ha)		Calculated added net return over zero fertilizer ($/ha)
Variety	Fertilizer	No fertilizer	Fertilizer[a]	
MV	User	0.9 a	2.3 a	165
MV	Nonuser	1.0 a	1.8 ab	100
LV	User	1.0 a	2.3 a	161
LV	Nonuser	0.8 a	1.7 b	105

[a]Fertilizer rate = 40-8.8-0 kg (N, P, K)/ha.

Table 10. Selected statistics of the two study villages, Laguna, and Iloilo provinces, Philippines, 1920, 1950, and 1980.

		Laguna village			Iloilo village		
		1920	1950	1980	1920	1950	1980
Population		51	204	706	125[a]	337	616
Household:	Farmer	9	37	46	25	58	96
	Landless farm worker	—	7	71	—	n.a.	11
	Others[b]	—	—	9	—	n.a.	12
	Total	9	44	126	25	58	119
Farm land (ha):[c]	Wetland; irrigated	—	—	85	—	—	—
	rainfed	36[a]	89[a]	—	88[a]	130[a]	130
	Dryland	—	—	—	n.a.	n.a.	16
	Total	36	89	85	88	130	146
	(per farm)	4.0	2.4	1.8	3.5	2.2	1.5
	(per capita)	0.7	0.4	0.1	0.7	0.4	0.2
Farm land tenanted (%)		n.a.	98	98	n.a.	n.a.	90
Multiple cropping ratio		1.0	1.0[a]	2.0	1.0	1.0[a]	1.9
Rice yield (t/ha per crop)		n.a.	2.2	4.0	n.a.	n.a.	2.9
Land productivity (t/ha per year)[d]		n.a.	2.2	8.0	n.a.	n.a.	3.2
Household income (t/year):[d]	Farmer	n.a.	n.a.	11.9	n.a.	n.a.	5.3
	Landless	n.a.	n.a.	5.0	n.a.	n.a.	1.6
	Av	n.a.	n.a.	7.6	n.a.	n.a.	5.1
Gini-ratio:	Size distribution of farm land[e]	n.a.	0.46[f]	0.77	n.a.	n.a.	0.31
	Size distribution of household income	n.a.	n.a.	0.42			0.31

[a]Rough estimates. n.a. = data not available, (—) = none. [b]Retired and nonfarm households. [c]The area cultivated by village farmers. [d]Value terms converted into rice equivalent using farm-gate rice price. [e]Size distribution of operational holdings. [f]As of 1960.

Table 11. Major technological and institutional changes in agriculture in the two Philippine villages since their settlement.

Time period	Laguna village	Iloilo village
19th century	Settlement began (1880s) with extensive rainfed rice farming	Settlement began (1850s) with extensive rainfed rice farming
Late 1940s	Land frontier closed	Lowland land frontier closed Upland cultivation began
1950s		Mindanao resettlement project
1958	Irrigation system constructed (complete rice double cropping)	
Early 1960s	Hand tractor Improved cultural practices (fertilizer, chemical, rotary weeder, dry seedbed)	Improved local rice varieties Land-use intensification (multiple cropping of dryland crops on wetland)
	Gama system	Improved cultural practices (fertilizer, chemical, hand weeding)
Late 1960s	MV, with further improvements in cultural practices Land reform (Operation leasehold)	
1973	Credit program (M-99)	Land reform (Operation leasehold)
		M-99
Late 1970s	Herbicide	MV, direct seeding, partial double cropping of rice
	Mechanical thresher	Mechanical thresher

late 1960s. By the early 1970s, the MV diffusion virtually reached 100%. As a result of the changes, the average annual rice yield increased from 2.2 t/ha in 1950 to 8.0 t/ha in 1980 (Table 10).

During the period of MV introduction, a land reform program was implemented and share-tenants became leaseholders. With a fixed rent, a significant portion of the increasing income resulting from MV technology stayed with the leaseholders.

A labor-hiring arrangement for harvesting was another important institutional change. The traditional open harvesting system in which everyone helped with the harvest for a certain share of the output was replaced by a system called *gama* which allowed only those who did weeding without receiving wages to join the harvest.

Iloilo village. After the land frontier closed in the late 1940s, rice farming remained rainfed. There were only small improvements such as a gradual replacement of wooden plows with steel plows. Farmers gradually started to cultivate hilly upland areas that had been left to grazing water buffaloes.

As farm size rapidly decreased because of population pressure, land-use intensification through multiple cropping became necessary. With the introduction of improved LVs around 1960, farmers started to grow dryland crops, particularly the maize - rice - mungbean pattern. Fertilizers and chemicals were introduced. Taro and squash were added to the list of crops planted in the dryland areas, exhausting the limited dryland available by the end of the 1960s.

In 1973, land reform was implemented through a government rice production-credit program (M-99). Land reform effectively restored the share-rent to the old one-third level or established leaseholders with lower levels of fixed rent. For most participating farmers, the M-99 credit resulted in a one-time injection of cash that was mainly used for converting existing local debts into bank debts.

As a component of the M-99 program, MVs were introduced. However, MVs performed under rainfed conditions no better than the existing improved LVs. Farmers started to adopt MVs partially in well watered wetland areas after 1975, when very early-maturing MVs were introduced. By the late 1970s, rice double cropping was practiced in about one-third of the wetland areas. The adoption of direct-seeding and the mechanical thresher helped double cropping adoption by reducing timing conflicts that arose from the addition of a second rice crop to the existing multiple cropping system.

Changes in labor use in agriculture. Reflections of changes in agriculture, just described, are found in the changes in labor requirements (Table 12).

In Laguna village, the irrigation improvement and the adoption of MV technology resulted in a tremendous increase in labor employment capacity. Labor reduction attributed to labor-saving technology, such as the hand tractor and the dry

Table 12. Changes in labor use for crop production in two study villages, Philippines, 1953-1980.

Labor function	Labor use for rice production (man-days/ha per crop)							
	Laguna village				Iloilo village			
	1956[a]	1966[b]	1976	1980	1953[c]	1970	1978	1980
Land preparation	20	19	11	11	15	25	24	25
Crop establishment[d]	17	12	12	12	28	24	14	7
Weeding[e]	5	14	32	18	9	8	8	9
Harvesting and threshing	25	32	38	21	31	37	2	21
Others	4	12	12	12	–	2	2	2
Total	71	88	105	74	83	96	82	84
(% hired)	(58)	(58)	(71)	(81)	(65)	(56)	(45)	(38)
Total village labor use for crop production (1,000 man-days/yr)	9	21	25	18	9	15	16	15

[a]Based on 20 rainfed farmers in Laguna. [b]Based on 62 irrigated farmers in Laguna. [c]Based on a survey in a village 20 km from the study village. [d]Seedbed preparation/seeding, pulling seedlings, and transplanting. [e]Weeding and replanting.

seedbed method, was more than compensated for by the increased labor needs for intensive crop care, especially weeding. The total labor requirement per year was more than doubled between 1950 and 1960; it increased another 20% by the mid-1970s. However, labor demand started to decline in the late 1970s because of herbicide and mechanical thresher adoption.

In Iloilo village, the total labor requirement also increased significantly between 1950 and 1970. However, because labor demand increased mainly through gradual increases in multiple cropping, the rate of increase was much lower than that in Laguna village. In the late 1970s, the labor requirement in Iloilo village was reduced by direct seeding and mechanical thresher adoption, but labor demand was maintained, as in 1970, by a further increase in multiple cropping with a second rice crop.

Another sharp contrast between the two villages was in the changes in the amount of hired labor used. In both villages, hired labor has traditionally done the transplanting and harvesting. Therefore, the amount of hired labor used was high in the 1950s.

In Laguna village, hired labor increased to more than 80% of the total labor toward the late 1970s. Between 1966 and 1976, the increase in man-days of hired labor was higher than the increase in the total labor requirement, indicating a substitution of hired labor for family labor. This substitution occurred because of improved farmer incomes attributed to land reform and MV technology. A bulk of the hired labor went into weeding as part of the new labor-hiring arrangement for weeding and harvesting.

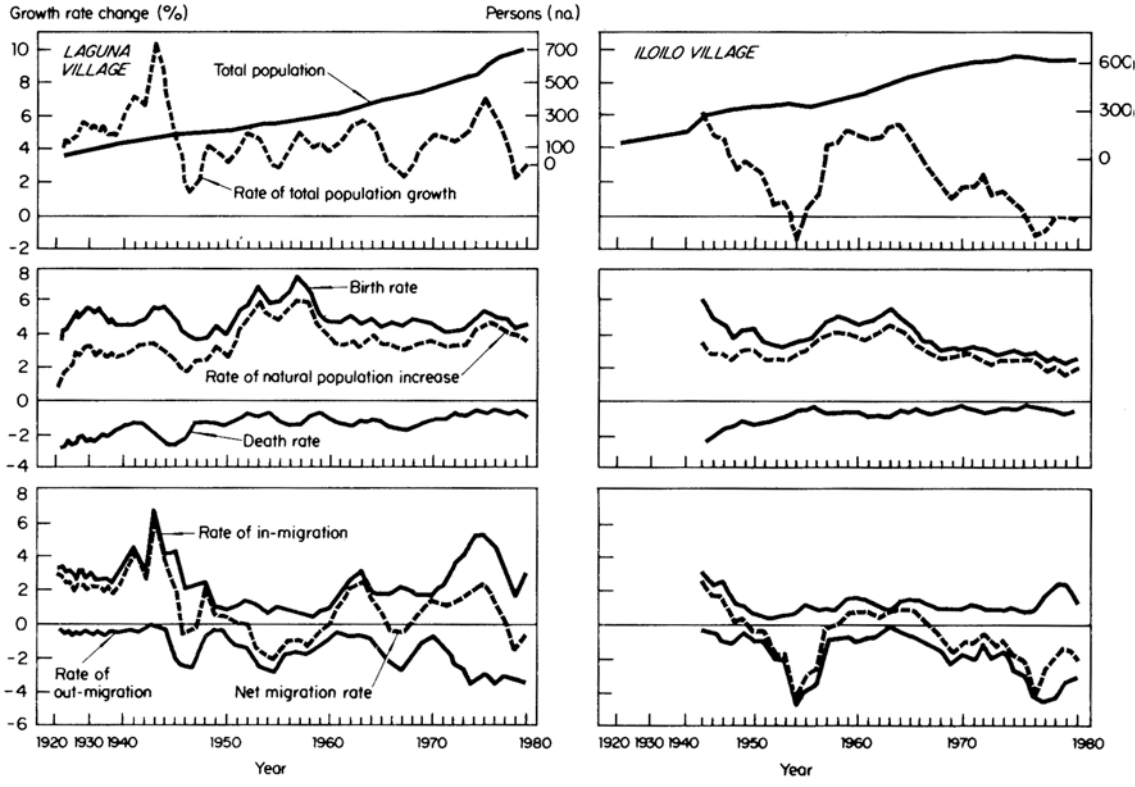
In Iloilo village, the hired labor declined continuously from the 1950s to 1980 as family labor was substituted for it. The nature of labor operations in the complex multiple cropping systems made it difficult for hired laborers to do them. Moreover, the income effect, which worked in Laguna village, was hardly in existence.

Changes in village population. The average population growth rate per annum from 1920 to 1980 was 4.5% in Laguna village and 2.7% in Iloilo village; the national average for the same period was 2.6%. However, the rates went through large cyclical fluctuations over time, depending on rate increase of natural and social population (Fig. 1). Although natural population increases affect the total population growth, migration largely determines the patterns of cyclical movements.

Although absolute levels of in-, out-, and net-migration rates differ very much, six phases of migration chronologies were identified by cyclical movements of the net-migration rate in the two villages: phase 1, before 1950; phase 2, 1950-59; phase 3, 1960-64; phase 4, 1965-69; phase 5, 1970-74; and phase 6, 1975-79. There was an abnormal period during the mid-1940s when the in- and out-migration rates jumped because of a huge inflow of evacuees during World War II and their outflow after the war.

In Laguna village, phases 1 and 2 were characterized by rural-rural migration with a large net population inflow. The majority of in-migrants came from surrounding upland areas to the village as members of farmer households. This rural-rural migration pattern still prevailed throughout phases 3 and 4. A few migration flows were distinguished in phase 5. First, the rural-rural migration flow was dichotomized into an outflow from the village farmer class to the outside and a large inflow from the outside rural areas, especially from the upland area, to the village landless worker class. Second, the urban-rural migration flow became substantial with a considerable net inflow to the village landless class. Phase 6 was characterized by a dual migration pattern. On one hand, the rural-rural migration continued with a large net inflow from the upland area to the bottom of the village strata. This large inflow in the 1970s resulted in landless workers making up a majority of the village households in 1980 (Table 10). On the other hand, the rural-urban migration flow increased sharply, with a majority of the out-migrants from the upper farmer class in the village. Many out-migrants were wealthy farmers' children who had higher educational levels and found jobs in factories and offices in urban centers. However, the number of circular migrants, who found temporary jobs in the cities typically as construction workers, also increased significantly.

In Iloilo village, the migration pattern was the same as that in Laguna village until 1950. In phase 2, a large outflow of population was recorded. Most of the out-migrants went to Mindanao,



1. Changes in population growth rates and total population in the study villages, Laguna and Iloilo provinces, Philippines, 1920-80.

located some 500 km south, as part of a government resettlement project. However, many out-migrants were not satisfied in Mindanao and returned to the village in the early 1960s. These returning migrants characterized phase 3. The migration pattern from phases 4 through 6 was characterized by one-sided rural-to-urban migration of village youths who sought employment in the city.

Inducements to population adjustment. Two contrasting processes of population adjustment were discerned by combining the historical reviews on agriculture and population in the two villages.

Technology-induced population change in Laguna village. In Laguna village, the marginal changes in population corresponded to the major events in the local agriculture. The large influx of in-migrants in phase 1 was induced by the availability of rice land. As the land frontier was exhausted, the rate of in-migration declined and finally became negative in phase 2. Extensive rainfed rice farming with a stagnant technology failed to absorb the rapidly increasing population because of the high number of births after the war.

After completion of the irrigation system in 1958, a new wave of in-migrants arrived during phase 3. The labor-absorption potential created by irrigation improvement was the major inducement. In phase 4, the net-migration rate became negative again, coinciding with no dynamic change in rice farming.

The drastic demographic changes in phase 5 coincided with the dynamic changes in rice farming after MV introduction. Most of the huge wave of in-migrants came from the dryland areas where there had been no significant technology changes. They joined the village landless worker class. Along with the introduction of the MV technology came an increase in labor demand, especially for weeding. At the same time, land reform was implemented. It improved the economic and social positions of the farmers, inducing them to sub-

stitute family labor with hired labor. The closed harvesting system replaced open harvesting. These changes appeared to absorb the landless worker migrants. The urban sector showed a rapid growth from the early 1970s onward and the increasing employment opportunities in this sector facilitated the out-migration of farmer-class family members, consequently establishing a two-way migration pattern.

The two-way migration pattern was strengthened in phase 6. Although the flow of in-migrants from the dryland areas to the village landless worker class continued, more people, not only from the farmer class but also from the landless worker class, moved to the cities.

All this shows a unique process of technology-induced population adjustments. Most likely, the marginal changes in population were induced by changes in employment opportunities, which were in turn determined by the technological changes in agriculture and the growth of the nonfarm sector.

Population-induced technological change in Iloilo village. Population adjustments in phase 1 were essentially the same as those in Laguna village. The extensive rainfed rice farming with an open land frontier attracted people from the surrounding dryland areas up to 1950. The population inflow declined as the land frontier was used up; many villagers left as participants in government resettlement programs during phase 2.

Starting with phase 3, the process diverged sharply from that of Laguna village. Iloilo village remained a rainfed rice area. Nevertheless, the possibility of increasing labor absorption did exist. During phase 3, rice farming intensification with the improved LVs and crop diversification on the limited land resources corresponded to the rapid population growth attributed to a high birth rate and the net population inflow. The net population inflow resulted from two waves of migrants returning from the unsuccessful resettlement site in Mindanao. Agricultural intensification was the result, not the cause, of the population inflow. In phase 4, the exodus of village youths seeking jobs in the city began.

During the early part of phase 5 the halt to increasing out-migration coincided with land reform and the government credit program. However, the out-migration remained high and began to increase again rapidly despite the further increase in multiple cropping. MVs did not perform well under rainfed conditions and it was only after the mid-1970s that the farmers started to realize an increasing multiple cropping ratio with MVs. The introduction of a second rice crop into the multiple cropping system was made possible by the adoption of labor-saving techniques and the substitution of family labor with hired labor. As a result, the overall labor demand showed little increase in phase 6 when the out-migration flow was substantially larger than in the previous phase.

The six migration phases in Iloilo village revealed that the changes in village agriculture were induced by population increase.

Migration functions. An estimation of migration functions relating the migration rates to explanatory variables provided a partial support to the above hypotheses (Table 13). The estimated regression equations explain well the large migration rate fluctuations.

For Laguna village, three equations were estimated separately for in-, out-, and net (in minus out)-migration rates. The regression coefficients of the man-land ratio indicated that an increase in population pressure on the limited land resource decelerated in-migration and accelerated out-migration. Irrigation development had a highly significant impact on the migration rates opposite to those of the man-land ratio. The variable constructed by multiplying the ratio of land area planted with MVs and the ratio of land area under leasehold tenancy had significant coefficients in the in- and net-migration equations. This suggested that large in-migration flow was induced by land reform implementation and MV introduction. The coefficient of *gama* (Table 13) in the in-migration equation was not significant at conventional significance levels, but it was at least larger than its standard error, suggesting that the new labor-hiring practice worked as an inducement to the population inflow. The development in the nonfarm sectors showed a two-way impact on migration flow; on one hand, it reduced the population inflow, on the other hand, it facilitated the population outflow.

For Iloilo village, only the net migration equation with a limited number of explanatory variables was estimated. The result, however, seemed to

Table 13. Migration regressions with migration rates as dependent variables, Laguna and Iloilo provinces, Philippines.

Variable[a]	Regression coefficient[b] (%)			
	Laguna village			Iloilo village
	In	Out	Net	Net
MANLAND	−1.11	0.25	−1.62	−1.96
	(0.20)	(0.17)	(0.29)	(0.66)
IRRIGATION	2.11	−1.38	3.45	
	(0.48)	(0.40)	(0.62)	
MV·LANDREF	7.84	−1.51	10.38	
	(1.84)	(1.06)	(2.32)	
GAMA	2.47		0.04	
	(1.68)		(2.20)	
NONFARM	−2.90	3.26	−3.92	−0.82
	(1.31)	(1.05)	(2.01)	(0.95)
DWAR 1	2.14		2.74	
	(0.39)		(0.50)	
DWAR 2		1.96	−1.50	
		(0.41)	(0.60)	
DGOVSETP				−2.64
				(0.40)
DLV				1.61
				(0.46)
Intercept	5.39	−0.82	5.88	5.96
R^2	0.80	0.73	0.81	0.81
D-Wd stat.	2.17	0.80	1.68	1.61
F stat.	31.3	25.9	28.2	32.6
D.F.	48	49	47	31

[a]MANLAND = man-land ratio (persons per hectare); IRRIGATION = the ratio of irrigated land area to the total planted area) and LANDREF (ratio of farm land under leasehold tenancy to the total farm land); GAMA = ratio of farmers adopting the *gama* system to all farmers; NONFARM = NNP at the 1972 prices, sum of the industry and service sectors (index, 1972 = 1.0); DWAR 1 = 1 for 1941-44; DWAR 2 = 1 for 1945-47; DGOVSETP = 1 for 1951-56 during which the government recruited applicants for the resettlement programs in Mindanao; DLV = 1 for the years after 1960 when improved LVs were introduced. [b]Figures in parentheses are standard errors.

support the hypothesis. In addition to the simple dummy variables for the government resettlement program and the improved LVs, two independent variables were included, of which only one, the man-land ratio, was significant. This suggested that the increasing population pressure against the land was the major factor underlying the population adjustments. As the population increased, the marginal part of the population was pushed out regardless of outside employment situations.

The comparative study of the two villages clearly indicated that technological advances in agriculture could successfully increase rural employment. In Laguna village, the intrarural migration generated by changes in the rice farming area contributed not only to reducing the interregional income disparity created by the technological developments in the rice production, but also to mitigating the urban poverty problem. Had there been no technological development in the rice farming areas, large migration flows from both the dryland areas and the rice farming areas would have rushed into the urban centers.

However, with the extremely high birth rate, the technology-induced population adjustment of Laguna village may easily have been switched to the population-driven model of rural adjustment, if the nonfarm sector had failed to provide increasing employment and if a new technological change in agriculture had failed to come about after exhausting the potential of existing MV technology. Further technology development in agriculture and employment development in nonfarm sectors are both necessary to avoid rural impoverishment when population is the major force inducing change in the rural sector.

MIGRATION, WAGE DIFFERENTIALS, AND SEGMENTED LABOR MARKETS

During 1980-82, migration and wage surveys were conducted in rural villages and urban centers of Laguna Province, Philippines. The purpose was to identify the extent and directions of drastic migration movements around a rice-growing area that were triggered partly by introduction of new rice technology.

Migration structure in a wetland rice village in Laguna. Table 14 summarizes the migration flow in and out of a small rice village in Laguna Province from 1966 to 1980. The village had a population of 385 at the end of 1965. Hence, nearly 65% of the 1965 population migrated into and 55% migrated out of the village during the 15-yr period.

The village is located in the Laguna wetland rice belt along the southeastern coast of Laguna de Bay. A strip of well-irrigated wetland along Laguna de Bay runs into dryland areas in Laguna and surrounding mountainous provinces of Rizal, Quezon, and Batangas. Road and highway networks provide relatively easy access to urban centers from most of the Laguna villages. The

urban influence was less on the southeastern coast than on the southwestern coast of the lake where a large number of factories have been built recently. However, the travel time from the village to Manila was reduced from more than 3 h to less than 2 h by highway improvements during the late 1970s and increased the village's exposure to urban influences. The village, however, continued to have pure rural rice monoculture.

There were several migration flows to and from the village, all, except one, having a considerable number of migrants (Table 14). Migration incidences around the village were not one-sided rural-to-urban movements. In fact, the largest migration flow ran from the dryland areas, where there were no significant technology changes, to the village, where the demand for agricultural labor had been significantly increased by MV introduction since the late 1960s. These rural-to-rural migration flows resulted in a large net migrant inflow for the 15-yr period. Rural-to-urban and urban-to-rural migration flows also existed. The rural-to-urban migration flows between the village and the modern urban sectors were larger than the flows between the village and the informal urban sector. Although in the former, the rural-to-urban migrations outnumbered the urban-to-rural migrations, resulting in net outflows from the village during the period, in the latter, there was a net inflow from the informal urban sector to the village. The migration flow from the village to the informal urban sector was exceptional in that there were only a few migrants for the 15-yr period.

Another point noted in Table 14 is a class differential structure of migration flows. Incidences of migration around the village again were not simple, as envisioned in naive migration models where rural poor are pushed out to or pulled out by the urban sectors. Instead, the migration flows were characterized by a distinct dualistic class structure. Although the overwhelming majority of the in-migrants from the outside dryland areas joined the village landless worker class, the majority of the out-migrants to the modern urban sectors was from the village farmer class. The out-migrants to the high-modern sector were almost exclusively from the farmer class. By contrast, in addition to those coming from the dryland areas, the landless workers received a considerable number of in-migrants from the low-modern and the informal urban sectors.

Although many family migrations were found in the in-migration flows, regardless of origin, most out-migrants to the urban sectors were single. The

Table 14. Migration flow around a wetland rice village in Laguna Province, Philippines, 1966-80.

Status in village	Migrants[a] (no.)					
	Rural		Urban			Total
	Wetland rice area[b]	Dryland area[c]	Modern		Informal[f]	
			High[d]	Low[e]		
Farmers[g]						
In-migration	26 (11)	21 (10)	24 (5)[h]	5 (3)	6 (0)	82 (29)
Out-migration	54 (25)	27 (13)	38 (28)	24 (20)		143 (86)
Net in-flow	-28 (-14)	-6 (-3)	-14 (-23)	-19 (-17)	6 (0)	-61 (-57)
Landless workers[i]						
In-migration	29 (13)	97 (17)		32 (10)	10 (2)	168 (42)
Out-migration	13 (10)	22 (5)	1 (1)	27 (10)	3 (3)	66 (41)
Net in-flow	16 (3)	75 (12)	-1 (-1)	5 (-12)	7 (-1)	102 (1)
Total:						
In-migration	55 (24)	118 (27)	24 (5)	37 (13)	16 (2)	250 (71)
Out-migration	67 (35)	49 (18)	39 (29)	51 (42)	3 (3)	209 (127)
Net in-flow	-12 (-11)	69 (9)	-15 (-24)	-14 (-29)	13 (-1)	41 (-56)

[a]Figures within parentheses refer to the number of single-person migrants. [b]Rural occupations in the wetland rice belt in Laguna. [c]Rural occupations outside the wetland rice belt in Laguna. [d]Office workers, permanent factory workers, and big self-employed businesses. [e]Casual workers in construction, service, and manufacturing sectors. [f]Street vendors and house helpers. [g]Those with paddy fields to cultivate. [h]Includes 10 persons who migrated into the village to live in while having urban jobs. [i]Farm landless workers.

migrants' age structure reflected this trend (Table 15).

The majority of the migrants to and from the village moved around within the southern Tagalog region. However, there were some in-migrants from such remote regions as Bicol and Visayas. Some arrived from the low-modern or informal urban sectors. Metro Manila emerged as a major destination of the out-migrants. Many recent out-migrants whose original destinations were the southern Tagalog region ended up migrating to the outskirts of Metro Manila and finding jobs in the urban sectors.

Table 15. Number of migrants, by sex and age class, in the rice village, Laguna Province, Philippines, 1960-80.

	Migrants (no.)			Total
	Below 15	15-29	30 and above	
Male				
In-migrant	42	50	28	120
Out-migrant	31	47	24	102
Net inflow	11	3	4	18
Female				
In-migrant	53	56	21	130
Out-migrant	16	80	11	107
Net inflow	37	–24	10	23
Total				
In-migrant	95	106	49	250
Out-migrant	47	127	35	209
Net inflow	48	–21	14	41

More than 90% of the out-migrants found their jobs in the modern urban sector. Nearly 70% of the out-migrants from the village farmer class got jobs in factories or offices. Salaried jobs almost exclusively went to farmer-class migrants. In contrast, jobs found by out-migrants from the landless-worker class were limited mostly to construction work. The village's class structure reflected the ultimate urban jobs of the out-migrants.

The educational level was consistently higher for migrants to and from the farmer class than for those to and from the landless worker class, except for the in-migrants from the informal urban sector to the village farmer class (Table 16). On the average, migrants found in rural-to-urban and urban-to-rural migration flows had a higher education than those in rural-rural migration flows.

Wage differentials and affinity of labor markets. Wage rates and earnings per day in different sectors and regions were compared.

The average agricultural wage rate in the dryland belt was 15% lower than that in the wetland rice belt. Because the cost of living was almost the same for the two belts and because their relative closeness made migrating between the two very inexpensive, a small wage differential was enough to induce large intra-rural migration.

The regional differentials in agricultural wage rates were large. In Bicol and Visayas, they were 35-50% lower than in the Laguna wetland rice belt.

Table 16. Average years of schooling of migrants in and out of the village, Laguna Province, Philippines, 1966-80.

Status inside and outside the village	Years of schooling[a] (no.)					
	Rural		Urban			Total
	Wetland rice area	Dryland area	Modern		Informal	
			High	Low		
Farmers						
In-migration	5.3 (12)	7.0 (13)	12.8 (9)	8.2 (5)	3.0 (2)	7.7 (41)
Out-migration	5.6 (25)	6.6 (10)	12.4 (26)	6.8 (14)		8.3 (75)
Landless workers						
In-migration	5.1 (16)	4.9 (29)		6.8 (14)	4.0 (3)	5.3 (62)
Out-migration	4.9 (7)	5.3 (7)	8.0 (1)	6.5 (18)	4.0 (3)	5.8 (36)
Total						
In-migration	5.2 (28)	5.6 (42)	12.8 (9)	7.2 (19)	3.6 (5)	6.3 (103)
Out-migration	5.4 (32)	6.1 (17)	12.3 (27)	6.6 (32)	4.0 (3)	7.5 (111)

[a] Figures in parentheses are numbers of cases. In the case of family migration, only the family head is considered. Single migrants below age 15 and above 64 are excluded. For the migration flow from village to urban sectors, only job-related out-migrants are considered.

It was not surprising to find landless farm workers who migrated from the rural areas in these regions to the wetland rice belt. They were not barred from migrating to the belt; but it was wise for a migrant to have labor market information, contacts, and enough money to pay for the move. Typically, the migrants from remote regions first migrated to urban centers and then moved to the belt after making contacts with migrants already there. However, once they were established as farm landless workers, their relatives and friends migrated directly to the rice belt from the remote regions.

The majority of the intra-rural migrants were landless farm workers with little education. The agricultural labor markets among the different areas and regions were continuously linked by the intra-rural migration flows in which the labor force moved freely from low-wage to high-wage markets. In contrast, the urban labor markets were apparently more stratified where migrants had to have specific skills and education before they could enter the labor force. Migrants could not move to the high-wage market unless they were qualified. Wage earnings in the urban sectors ranged from \$1.33 to \$41.66/d (Table 17) and it was clear that higher qualifications meant higher wages.

At the bottom of the strata was the two-segmented informal urban sector. In one segment, there were self-employed workers such as street hawkers with free territory, and employed workers, such as helpers in the city markets. Workers in this lowest strata earned no more than \$2.22/d. In the other segment, workers earned as much or more than permanent unskilled laborers in the modern sector.

Even though very low, the wage rates in the first segment of the informal sector were often higher than the agricultural wage rates in Bicol and Visayas, so many in this segment were migrants from these regions. Because the agricultural wage

Table 17. Comparison of wage rates, wage earnings per 8-h day, and qualifications in different labor markets, Laguna Province, Philippines, 1982.

	\$/day[a]	Qualification[b]
Rural sector		
Laguna wetland rice belt[c]	2.22	None
Laguna dryland belt[d]	1.88	None
Central Luzon[e]	1.88	None
Bicol[e]	1.44	None
Visayas[e]	1.11	None
Urban sector (Metro Manila)[f]		
Informal		
Street hawker: Free territory	1.33	None
With territory	3.66	Territory entry right
Casual laborer[g]	2.22	None
Modern		
Low: Construction laborer (unskilled)	2.55	None
Casual laborer[h]	3.55	High school education or higher
High: Permanent laborer (unskilled)	4.11	High school education or higher
Permanent laborer (skilled)	5.66	Skill or college (or vocational)
Construction laborer (skilled)	5.55	Skill
Office worker (new recruit)	5.55	College education or higher
Factory supervisor	14.44	College and/or experience
Factory department head	21.66	College and experience
Factory manager	41.66	College and experience

[a]\$1 = ₱9. [b]Qualification necessary to enter the labor market. [c]Based on the farm wage survey in the Laguna wetland rice belt. Weighted average of daily wage rates for land preparation (\$3.33), transplanting (\$2), and weeding (\$2) using hired labor days per hectare as weights. \$1 = ₱9. [d]Based on the farm wage survey in the Laguna coconut belt. Weighted average of wage per day for harvesting (\$2.22/1,000 nuts), piling (\$1.22/1,000 nuts), husking (\$1.88/1,000 nuts) of coconuts using hired labor days per hectare as weights. [e]Estimated by multiplying the rate of wage differential between the region and southern Tagalog of rice farm workers in 1981 to the average wage rate of Laguna wetland rice belt in 1982. [f]Based on the nonfarm wage survey. [g]For nonfarm firms with less than 20 employees. [h]Average for nonfarm firms with 20 employees or more.

rate in the Laguna wetland rice belt was not less than the wage rate in the informal sector, there was a negligible migration flow from the rice belt to the informal sector and a larger flow in the opposite direction.

The wage rate of unskilled construction laborers in the modern sector was often as low as that of casual laborers in the informal sector because skills or education are usually not required for either. However, once migrants acquire construction worker skills, they may be paid as much as college graduates hired as office workers. The wage rate of this construction sector might be high enough to attract permanent migrants from regions with low agricultural wage rates, but probably not enough to attract migrants from the Laguna rice belt, especially if there is a large difference in living costs. Because no qualifications were required for entering this labor market, farmers and landless farm workers were found in this large circular migration flow. In all of the free-entry labor markets in the urban sectors, migrants from remote regions made contacts with those in the rice belt and often moved to the rice belt.

Other labor markets in the modern sector mostly required more than an elementary school education for newcomers. The wage differentials between these modern sectors and the Laguna rice belt appeared large enough to induce permanent migration. A large rural-to-urban migration flow was found, but the overwhelming majority of the migrants was from the village farm class who could afford to pay for their children's education. The segmented labor markets in the modern sector acted as a screening mechanism of migrants from rural areas.

Cropping systems program

Physical and biological environment

Multiple Cropping Department

RICE LAND CLASSIFICATION IN THE CENTRAL CAGAYAN VALLEY **362**
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RICE LAND CLASSIFICATION IN THE CENTRAL CAGAYAN VALLEY

Cropping systems research should be conducted at sites representative of the areas where the technology is to be implemented. However, because land qualities are often heterogenous within an area that is climatologically homogenous, one site can not be representative, so technology should be tested over a range of land types at different sites. In the Philippines, cropping systems research is conducted at Solana in the Cagayan River Basin (CRB) to identify alternative rainfed rice-based cropping patterns that fit farm and community resources and are more productive than the traditional patterns commonly grown on old alluvial terraces of the central part of the river basin. To test cropping patterns and component technology beyond the original site, sites with similar field conditions must be identified.

The alluvial and the plain land systems of the CRB cover about 300,000 ha of level land where field crops are grown. A rapid and efficient land mapping system has been used to identify land with similar characteristics. To represent the alluvial land system, landform units (LU) on which rice is grown were identified on alluvial terraces, third recent river terraces, and alluvial fans. To represent the plainland system, LUs on lower interfluves were selected. LUs are at the third level of a hierarchal land classification of the CRB landform. Thirty sites were selected in seven Cagayan municipalities — Faire, Piat, Tuao, Solana, Tuguegarao, Iguig, and Amulung. The soil profiles on the selected LUs where rice production dominated were described and sampled for chemical and physical properties.

Principal component analysis was applied to the following soil surface and subsurface attributes: bulk density, color value, color chroma, sand, clay, silt, moisture content (5 bar), moisture content (10 bar), organic C, total N, free Fe, pH (water), pH (KCl), Na, K, Mg, Ca, total exchangeable bases, cation exchange capacity, total P, and total K. Determinations were also made for the number of horizons, thickness of the plow layer, surface Olsen P, and Olsen Mn. Nine principal components extracted from the data were interpreted as specific surface, organic matter and P, water retention, soil reaction, alkalinity, soil genesis, redox state of the surface, redox state of the subsurface, and tilth. These components explained 86% of the total variance. Specific surface alone explained 45% and organic matter and P, 12%. Specific surface is strongly associated with many soil attributes important to soil productivity such as the base status-related attributes of both surface and subsurface horizons, the moisture-related attributes of the surface and total N, sand, and total K of the surface.

Separate analyses of principal components were made on the 28 soil chemical attributes and the 18 soil physical attributes. Six components of the chemical attributes corresponding to eigenvalues greater than 1 accounted for 85% of the total variance. Soil fertility alone accounted for 55%. The other five components were subsurface organic matter-P, soil reaction, surface alkalinity, subsurface alkalinity, and Mn availability. As was the case when all 46 attributes were analyzed, the first component of the chemical subset was orthogonal to the organic matter-P component. Six components of the physical properties corresponding to eigenvalues greater than 1 accounted for 77% of the total variation. These components were surface horizon water retention, redox regimes, soil color value, subsurface water retention, soil genesis, and soil tilth.

To classify the sites according to their attributes, principal component scores were computed for each site. These scores, computed to obtain data compression, were used in a cluster analysis of the sites. The clustering statistics indicated that five groups could be separated from 29 sites. One site did not conform to any group. The dendogram from the cluster analysis is in Figure 1.

The salient features of each group were:

Group 1. High inherent production potential, slightly acid, marginal P status.

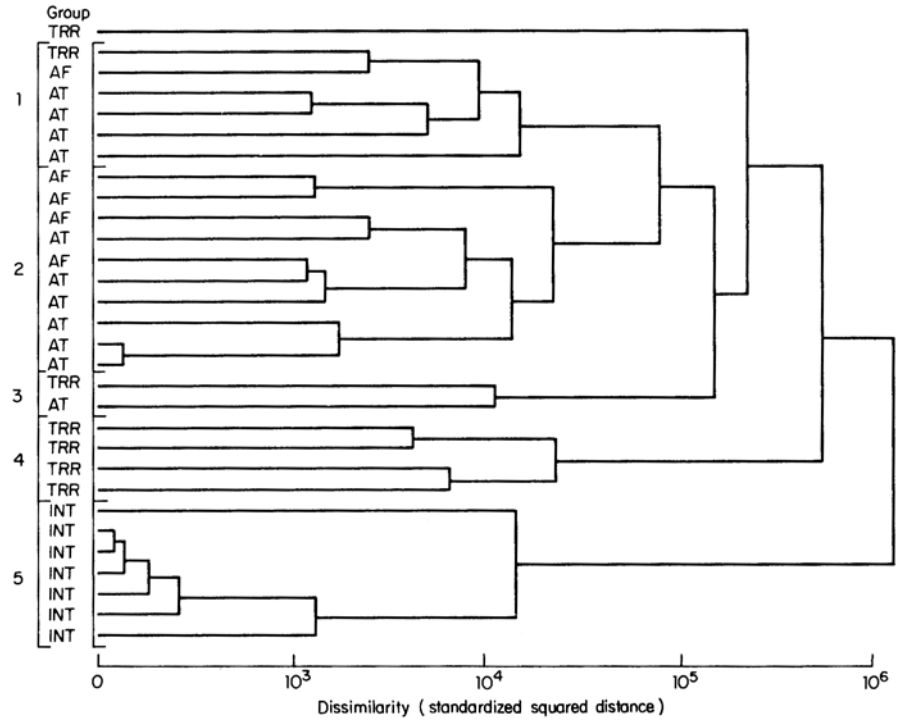
Group 2. High inherent production potential, moderately acid, marginal P status.

Group 3. Intermediate inherent production potential, moderately acid, adequate P status.

Group 4. High inherent production potential, slightly acid, adequate P status.

Group 5. Low inherent production potential, moderately acid, deficient P status.

A cross classification of groups and LUs for the



1. Dendogram showing clustering pattern of 30 LU samples, CRB, Philippines, 1981. TRR = third recent river terrace, AF = alluvial fan, AT = alluvial terrace, INT = lower interfluve.

30 sites is in Table 1. Group 5, which was most distinct, included only lower interfluve LUs. Group 4 contained four third recent river terrace LUs, but two more of these LUs were mixed with groups 1 and 3. The five alluvial fan sites were contained in groups 1 and 2, which were dominated by alluvial terrace sites. It was concluded that when LUs are differentiated, soil differences will also be separated when contrasts are great, as in the case of soils in the lower interfluves versus others in this study. Where the soil differences are not pronounced, as in the case of soils on alluvial fans and some alluvial terrace soils, landform differentiation may not yield satisfactory soil differentiation.

RICE COMPUTER MODEL

A rice crop simulation model, RICEMOD, developed by IRRI scientists, is driven by the daily climatic variables of rainfall, pan evaporation (E_{pan}), solar radiation, maximum and minimum temperature, and day length. In this model, the soil hydraulic relationships are functions of soil water diffusivity and volumetric soil water content, soil water matric suction and volumetric soil water content, and soil hydraulic conductivity and soil water matric suction.

The model has undergone various refinements and the RICE300 version was tested for use in the Cropping Systems Program. The objectives were to determine 1) the realism embodied in the model, and, therefore, its usefulness in evaluating the production potential of rice in future environmental studies, and 2) the sensitivity of the model to changes in the values of selected parameters or

Table 1. Cross-classification of 30 LU samples and groups separated by cluster analysis. CRB, Philippines, 1981.

LU	Group					
	5	2	1	3	4	Non-conforming
Third recent terrace			1	1	4	1
Alluvial fan		4	1			
Alluvial terrace			4	1		
Lower interfluve	7					

driving variables. Parameters or variables to which the model exhibits sensitivity are the ones that must be accurately determined if the model is to be useful as a predictor of mean rice yield and yield stability when the crop is planted in a new location or at an earlier or later date.

In eastern Philippines, the start of a new cropping season begins in April; in western and central Philippines, in late June. In all simulations, 1 Apr and 25 Jun 1980, were arbitrarily chosen as the transplanting dates for 25-d-old IR36 seedlings. The soil profile was recharged on both transplanting dates. An extended dry period occurred after the 1-Apr transplanting. The simulation was run for approximately 122 d of plant age. In the model, plant age at harvest was a function of stress days, with increasing stress extending the time for which the crop would mature.

Sensitivity to environmental changes. For the 1 Apr-started simulation, sensitivity tests were made on environmental variables and parameters. Climatic variables and soil hydraulic parameters were changed ± 10% and ± 50%. In some cases, a 50% change was too severe and caused a computer termination of the run; a smaller change was then tried and reported. Combinations of changes were made to represent changing climatic variables, such as an increase or decrease in latitude or a wetter or drier year, and changing soil variables, such as variations in clay content or aggregation. For the 25 Jun-started test, parameters or variables usually changed by ± 50%.

RICEMOD can calculate many plant and soil properties, but only panicle weight (PW) and root-shoot ratio (R:S) were used to illustrate model sensitivity. The results are shown as percentage changes from the standard simulation in which the original parameter values or driving variables were used. Table 2 shows the absolute values simulated for the different variables in the standard case.

Climatic variable values for the test period are summarized in Figure 2. Percentage changes in PW from the standard simulation for the various climatic variables are in Table 3. For the 1-Apr start, increases in rainfall had little effect on simulated yield but decreases had a very noticeable effect. Because 1 Apr precedes the normal start of the WS by 4-6 wk, this was expected because the early WS had little rainfall and even large percentage increases would not appreciably increase rainfall during the vegetative growth phases. Limited early growth was made mainly from stored soil moisture. During the reproductive phases, rainfall appeared adequate for a modest yield. For the 25-Jun start, neither an increase nor a decrease in rainfall had an appreciable effect on PW.

For the 1-Apr start, the model was very sensitive to E_{pan}. A 10% increase or decrease equally reduced the simulated yield. The slight decreases were caused by changes in photosynthate partitioning between other plant parts and panicles. A 50% increase in E_{pan} further decreased PW; a 50% decrease increased the simulated PW. For the 25-Jun start, a 50% increase in E_{pan} decreased PW by only 10%; a 50% decrease had no effect on PW.

Following both starts, major radiation changes had similar effects on PW. A modest increase occurred when radiation was increased 50%, but a major decrease occurred when the radiation was decreased 50%.

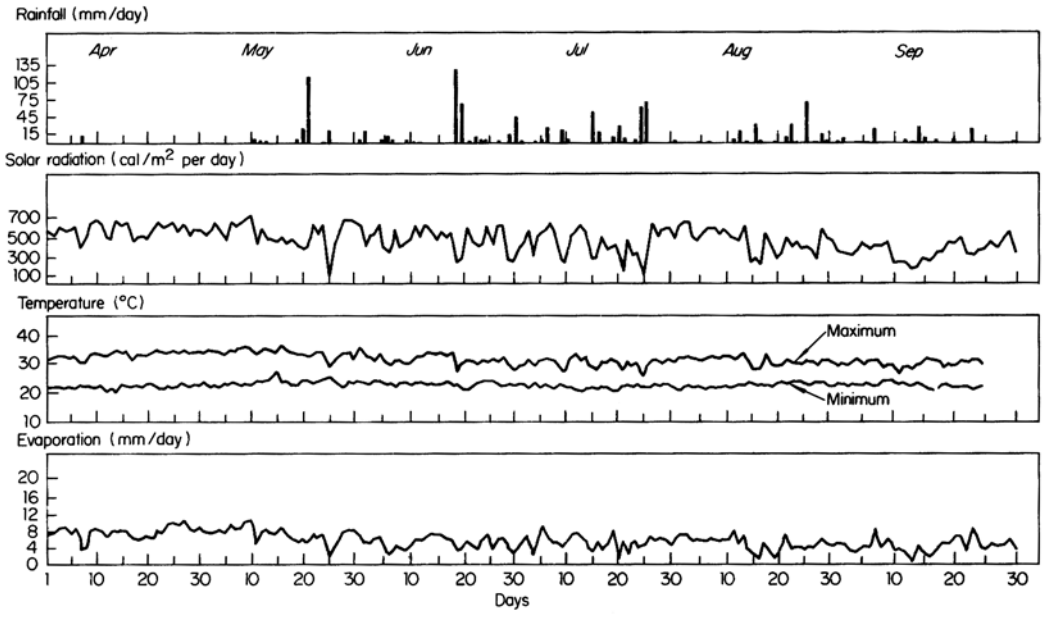
Day length was the most sensitive climatic variable in the model. It is used in several of the model's equations, in particular for the calculations of leaf water potential (LWP) and photosynthetic radiation received. A 50% change in this variable caused more than a 50% change in the simulated PWs. The extreme sensitivity to day-length changes suggested that additional experimental data be sought to validate the day length-dependent physiological relationships used in the model.

The model was only moderately sensitive to changes in maximum and minimum temperatures; PW changes were inverse to temperature changes. The model was more responsive to minimum temperature changes.

Table 2. Simulated values of plant parts at harvest for the standard cases.[a]

Variable	Weight (g/m^2)	
	1 Apr	25 Jun
Leaf	25	96
Stem	403	577
Root	310	334
Panicle	362	528
	R:S	
	0.39	0.28

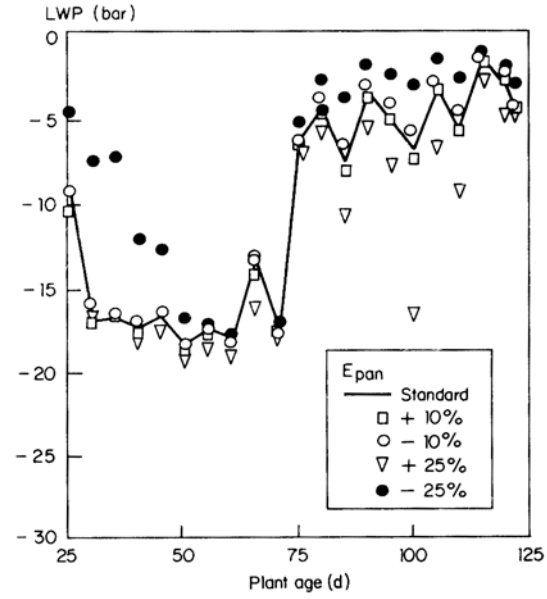
[a]Simulation used 1980 IRRI weather data.



2. Daily rainfall, solar radiation, maximum and minimum temperatures, and E_{pan}. IRRI upland weather station, April-September, 1980.

One often-used physiological indicator of plant growth is mid-day LWP. The value of this indicator during plant development, especially the reproductive stage, has been shown to be a good yield predictor. Figure 3 shows E_{pan} changes of the simulated mid-day LWP for every fifth day after the 1-Apr transplanting until harvest. The solid line is the value for the standard case. Comparison of Figure 3 and Table 3 shows that the high yielding simulations had higher (less negative) values of mid-day LWP, especially during seed filling (day 80 onward) than did the standard case.

Table 4 shows the change from the standard simulation of the R:S caused by the changes in the environmental variables. The R:S was the ratio of the root weight to the total above-ground weight at harvest. For the 1-Apr start, the pattern of changes was similar to that of PW changes. The R:S was most sensitive to day length, E_{pan} and radiation, and least sensitive to temperature and rainfall. The percentage changes, however, were much lower and their increase or decrease was not always the same as that of PW. For example, a slight decrease in E_{pan} produced a decrease in simulated PW, but an increase in R:S. Large changes in radiation, temperature, and day length produced sizeable PW changes for the 1-Apr start and minor changes for the 25-Jun start.



3. Simulated midday LWPs vs plant age as a function of changes in E_{pan} amounts, 1 Apr simulation, IRRI, 1980.

The effects of changing the magnitudes of the soil hydraulic variables upon simulated PW and

Table 3. Simulated effects of changing weather variables on PW at harvest.[a]

Start of simulation	Increase (+) or decrease (–) (%)	Change (%) in PW caused by change in					
		Rainfall	E_{pan}	Rad[b]	Temperature		Day length
					Max	Min	
1 Apr	+10	1	–9	–1	–4	–8	9
	–10	–4	–8	–12	4	6	–19
	+50	0	–27	10	–16	–28	80
	–50	–27	31	–41	9	16	–73
25 Jun	+50	0	–10	16	–11	–18	–
	–50	–1	0	–44	7	14	69

[a]Simulation used 1980 IRRI weather data. [b]Solar radiation.

Table 4. Simulated effects of changing weather variables on R:S at harvest.[a]

Start of simulation	Increase (+) or decrease (–) (%)	Change (%) in R:S caused by change in					
		Rainfall	E_{pan}	Rad[b]	Temperature		Day length
					Max	Min	
1 Apr	+10	0	8	5	3	3	8
	–10	5	5	8	0	3	8
	+50	0	–3	8	3	0	3
	–50	5	8	3	3	5	3
25 Jun	+50	0	0	0	0	0	–
	–50	0	0	–4	0	4	14

[a]Simulation used 1980 IRRI weather data. [b]Solar radiation.

R:S are in Tables 5 and 6. The hydraulic variables that were changed were soil water diffusivity (D), soil matric suction (M), and soil hydraulic conductivity (K). In the model, D has the log exponential form, $a\ exp\ [b(\theta\text{-}0.18)]$, M has the inverse log exponential form $c\ exp\ (-d\theta)$, and K has the inverse power form eM^{-f}. θ is volumetric water content; a, c, and e are linear coefficients; b and d are exponential coefficients; and f is an inverse power coefficient.

With one exception, the model was not as sensitive to changes in soil properties as it was to changes in climatic variables. Matrix suction for the 1-Apr simulation was the one exception. The coefficient d is an exponent, and therefore a change in it will make a relatively large change in M. In fact a -50% change in d caused the model to fail after day 40 of the simulation. Model output suggested that the calculated root resistances in the top 25-cm layer became too large and caused the LWP to become very small (a large negative number). For the 1-Apr start, the model was least sensitive to the soil water diffusivity parameters, somewhat more sensitive to the soil hydraulic conductivity parameters, and most sensitive to the soil water content-matric suction parameters. For the 25-Jun start, when rainfall was more favorable, the model was very insensitive to soil hydraulic variables.

The simulated mid-day LWPs are shown in Figure 4 for different values of the exponential matric suction coefficient, d, after the 1-Apr start. The simulated values for -10 and -25% changes in the coefficient gave very low LWP values both early in the season and during seed filling compared with the standard curve, subsequently predicting lower yields. As in the earlier discussion, these are the extreme cases.

When moving from one climatic pattern to another or one soil to another, variables change simultaneously. Several such patterns were examined to see what simulation differences would be generated. A climate wetter, cloudier and cooler than that at IRRI was simulated by increasing rainfall 50%, decreasing E_{pan} 50%, decreasing

Table 5. Simulated effects of changing soil hydraulic variables on PW at harvest.[a]

Start of simulation	Increase (+) or decrease (−) (%)	Change (%) in PW caused by change in					
		Soil water diffusivity		Matric suction		Hydraulic conductivity	
		Linear *a*	Expon. *b*	Linear *c*	Expon. *d*	Linear *e*	Inverse power *f*
1 Apr	+10	0	−3	−13	−2	2	1
	−10	3	2	1	−23	−13	−5
	+50	1	−16	−21	5	1	3
	−50	3	−3	2	—	17	−13
	+25				4		
	−25				−31		
25 Jun	+50	0	0	0	0	0	0
	−50	0	0	0	—	0	0
	+25				0		
	−25				−2		

[a]Simulation used 1980 IRRI weather data.

Table 6. Simulated effects of changing soil hydraulic variables on R:S.[a]

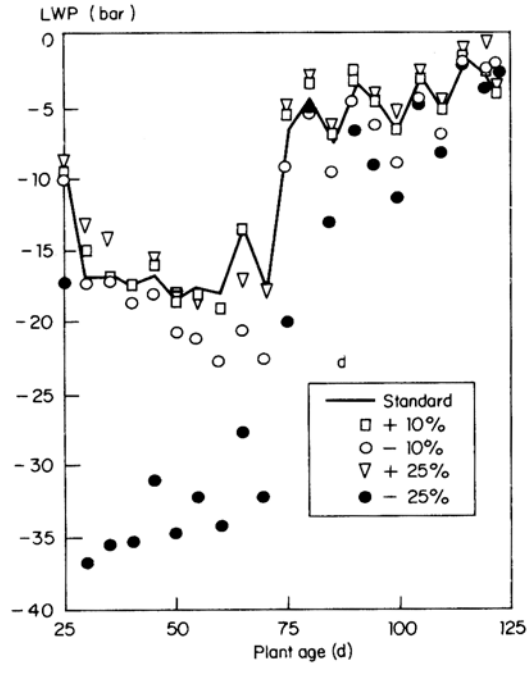
Start of simulation	Increase (+) or decrease (−) (%)	Change (%) in R:S caused by change in					
		Soil water diffusivity		Matric suction		Hydraulic conductivity	
		Linear *a*	Expon. *b*	Linear *c*	Expon. *d*	Linear *e*	Inverse power *f*
1 Apr	+10	0	5	13	5	3	0
	−10	0	−5	−3	−5	13	3
	+50	3	13	15	18	−5	−8
	−50	−5	15	−5	—	10	−5
	+25				8		
	−25				−51		
25 Jun	+50	0	0	0	0	0	0
	−50	0	0	0	—	0	0
	+25				0		
	−25				−4		

[a]Simulation used 1980 IRRI weather data.

radiation 50%, and decreasing maximum temperature 50%. To simulate a climate drier, clearer, and warmer than at IRRI, changes of the opposite magnitudes were made.

A more northern latitude was simulated by increasing E_{pan} 6%, radiation 11%, maximum temperature 4%, minimum temperature 1%, and day length 5%. A more southern latitude was simulated by decreasing E_{pan} 14%, decreasing radiation 13%, decreasing maximum temperature 8%, increasing minimum temperature 4%, and decreasing day length by 5%.

The results of these studies are in Table 7. Because moisture stress did not delay growth in the 25-Jun plantings, it took plants 7-14 fewer days to mature. Rainfall changes either increased or decreased days to harvest, but consistently decreased simulated PW. For both starting dates, R:S increased in both simulated climates. Latitude changes had less effect than rainfall changes. For the 1-Apr start, a move toward a more northern latitude showed a slight simulated increase in PW and R:S; a move toward a more equatorial latitude showed a definite simulated decrease in PW and a



4. Simulated mid-day LWPs vs plant age as a function of changes in the exponential coefficient, *d*, in the matric suction equation, 1 Apr simulation. IRRI, 1980.

slight increase in R:S.

As soil aggregation increases, total porosity, the slope of the moisture characteristic curve and saturated hydraulic conductivity may increase. The reverse happens with compaction or decreased aggregation. The first condition was simulated by decreasing *a*, *c*, and *d* 10% and increasing *e* 50%; the second by increasing *a*, *c*, and *d* 10% and decreasing *e* 50%.

As clay content of soil increases, total porosity increases, but saturated hydraulic conductivity decreases. The reverse happens as clay content decreases and sand content increases. Increased clay content was simulated by increasing *a* and *c* 10% and decreasing *d* 10% and *e* 50%. The reverse was done to simulate an increased sand content. These changes were applied only to the 1-Apr start, where the model was sensitive to hydraulic parameter changes. The aggregation increase changed simulated PW only slightly, but showed a 5% decrease in R:S. An aggregation decrease or compaction increase was much more noticeable in a depressed simulated PW. A decrease in soil clay content caused only a slight increase in simulated PW. As the soil clay content increased, however, there was a 27% decrease in simulated PW with the standard case and an 11% decrease in R:S. This demonstrates the usefulness of even simple crop growth simulation models. These changes in soil properties affect the water flow calculations in the soil from the bulk soil to the root and from one soil layer to another. These in turn affect the calculated root resistances and LWPs, which in turn affect the calculations of the photosynthesis partitioning. In the case of increased clay content, compared with the standard case, water flowed less readily from bulk soil to the plant roots and from one soil layer to another. This increased root resistance and decreased (more negative) LWP. Over-all photosynthate production decreased because of increased stress. Less photosynthate was supplied to the roots which left proportionally more photosynthate for grain production.

Sensitivity to crop parameter changes. In sensitivity tests, six crop parameters were changed independently ± 10 or ± 50% for the 1 Apr-started test and ± 50% for the 25 Jun-started test.

Table 7. Effect of interactive changes of climatic variables on crop indices as a percentage change from the standard.[a]

Start of simulation	Higher latitude	Plant age (d)	PW	R:S
1 Apr	Standard	122	0	0
	Tropical, wet	117	–12	13
	Tropical, dry	128	–54	41
	Higher latitude	122	2	10
	Lower latitude	121	–15	3
25 Jun	Standard	110	0	0
	Tropical, wet	110	–24	4
	Tropical, dry	114	–29	25
	Higher latitude	110	5	0
	Lower latitude	110	–12	0

[a]Simulation used 1980 IRRI weather data.

Light received at each canopy layer was a function of an attenuation equation parameter (AF) and photosynthetically active radiation. The leaf N was calculated as a function of a N percent equation parameter (AN) and crop age. A growth respiration equation parameter (RG) was multiplied by the amount of gross photosynthate produced per day to calculate the respiration loss due to growth. Maintenance respiration was a function of an equation parameter (RM) and a temperature coefficient and day length. A parameter for axial hydraulic root resistance (RP) was used with root length density and soil resistance to calculate total hydraulic resistance in a soil layer. The parameter (XW) was the initial rice seedling weight at transplanting.

The percentage changes from the standard simulation, corresponding to each parameter change, are in Table 8 for simulated PW and Table 9 for simulated R:S. It is immediately apparent that planting date made a major difference in the responses. The response of some were orderly. A small increase in *AN* increased the predicted yield; a larger increase in *AN* increased the yield more, and reversing the sign and magnitude of the change had the opposite effect.

For other parameters, such as *AF*, the model response was not as orderly. An *AF* increase, which is like making a canopy of broader leaves, caused a pronounced decrease in PW. In terms of light interception, decreasing *AF* is like making a canopy of narrower leaves. Decreasing *AF* 10% caused a slight PW increase. For the early planting, however, decreasing *AF* 50% resulted in a 50% PW decrease. For the 25-Jun planting, the opposite was true. A PW increase was predicted for a 50% decrease in *AF*. In the early planting, a large *AF* decrease produced a smaller leaf weight and leaf area. With low rainfall and high radiation, however, this resulted in strong negative LWPs and moisture stress of the crop. The stress effects reduced yield. For the 25-Jun planting, which had more frequent rainfall and lower radiation, the plants were not stressed; the lower leaves remained active longer, producing more photosynthate and eventually a higher than standard or earlier planting PW.

The R:S of the earlier planting had a small response to an *AF* change, but the R:S of the later planting responded more. However, responses

Table 8. Simulated PW, as a percentage change from the standard for a given percentage change in the crop parameter.[a]

Start of simulation	Increase (+) or decrease (–) (%)	Change (%) in PW caused by change in parameter					
		AF	AN	RG	RM	RP	XW
1 Apr	+10	–6	6	–5	–4	–8	1
	–10	2	–8	4	4	3	–2
	+50	–29	18	–28	–14	–37	1
	–50	–50	–50	14	14	3	–6
25 Jun	+50	–31	17	–19	–14	–12	–1
	–50	15	–34	15	14	0	0

[a]Simulation used 1980 IRRI weather data.

Table 9. Simulated R:S, as a percentage change from the standard for a given percentage change in the crop parameter.[a]

Start of simulation	Parameter change (%)	Change (%) in R:S caused by change in					
		AF	AN	RG	RM	RP	XW
1 Apr	+10	0	0	0	0	0	0
	–10	–4	0	0	0	–8	0
	+50	4	–8	0	4	8	0
	–50	0	8	–8	–8	–8	–8
25 Jun	+50	11	4	4	0	–4	4
	–50	–18	0	4	4	0	–4

[a]Simulation used 1980 IRRI weather data.

were opposite in sign and smaller in magnitude to the PW changes. Increasing *AF* increased the root mass relative to the shoot mass. Conversely, with an *AF* decrease, the higher PW was at the expense of root weight in the more weather-favorable June planting.

PW responses to *AN* changes were orderly but not symmetrical. A 50% increase increased yield only 18%; a 50% decrease decreased yield 50%.

The effects of *AN* changes and the other crop parameters (*RG, RM, RP,* and *XW*) on R:S were very slight. Only 50% changes produced appreciable changes in the predicted ratios. Model responses to *RG, RM,* and *RP* changes were generally similar in predicted PW. The responses were monotonic, but not symmetrical about zero changes. Planting date had some effect, in general decreasing the magnitude of the predicted change. If model responses are correct, they seem to suggest that decreasing the respiration loss of an MV such as IR36 would have only an appreciable effect if the respiration reduction were large.

The model responded least to *XW* changes. A 50% *XW* decrease caused the only appreciable PW decrease (5.5% for the 1-Apr planting). The initial weight of 15 to 25 d-old seedlings appeared not to appreciably affect the final crop yield. With much older seedlings, large changes would be expected.

Cropping systems program

Analysis of the social and economic environment

Agricultural Economics Department

IMPACT OF NEW CROPPING SYSTEMS IN ILOILO, 1975-80 **372**
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IMPACT OF NEW CROPPING SYSTEMS IN ILOILO, 1975-80

Completion of 6 yr of research in Iloilo Province, Philippines, provided an opportunity to make an overall assessment of IRRI's activity there.

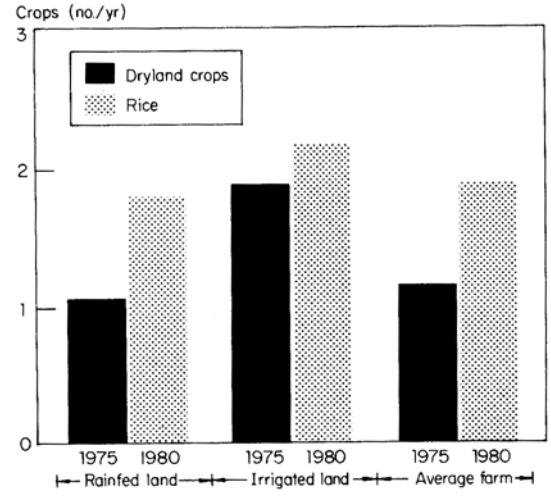
In 1975, cropping systems research was begun on rainfed farms in Iloilo to identify cultural techniques that would increase the number of sequential crops that farmers can grow each year. Although the original plan was to dry-seed early-maturing rice varieties, early rains during the first year of experiments forced researchers to broadcast seed onto wet, puddled soils. The improvisation proved popular with farmers and the wet-seeding method of rice planting was launched in Iloilo.

Coupled with the use of newly released, early-maturing MVs IR28 and IR30 (and later IR36), the new technology made it possible to grow more rice and dryland crops on rainfed and partially irrigated lands. Irrigation facilities in the area were improved by national authorities, extending the growing season by about 6 wk on 25% of the land area.

Forty-five farms were closely watched from the beginning of research in 1975 through 1980. The changes reflected the general trends observed throughout the region as the new technology spread through the Philippine government's KABSAKA extension program.

An increase in cropping intensity between 1975 and 1980 on rainfed and irrigated land was made possible by direct-seeding of early-maturing MVs (Fig. 1). On an average farm (comprising both irrigated and rainfed land), the number of crops grown each year increased from 1.1 to 1.9. On rainfed land alone, cropping increased from about 1.1 to 1.8 crops/yr. These changes resulted solely from sample farmers' casual observation of experimental plots on other farms. No formal extension of technology or other action to encourage adoption was done.

Besides growing more crops per year, farmers increased fertilizer use from about 20 to 40 kg N/ha. These and other measures increased rice yield (Fig. 2). No improvements were observed in dryland crop yields. The combined effects of higher yields and cropping intensity (Fig. 3) resulted in a 140% increase in the value of crops on farms. The mean size of sample farms declined from 2.1 to 2.0 ha during the period, such that crop value per farm in 1980 was about $1,490. Crop prices changed little over the period.

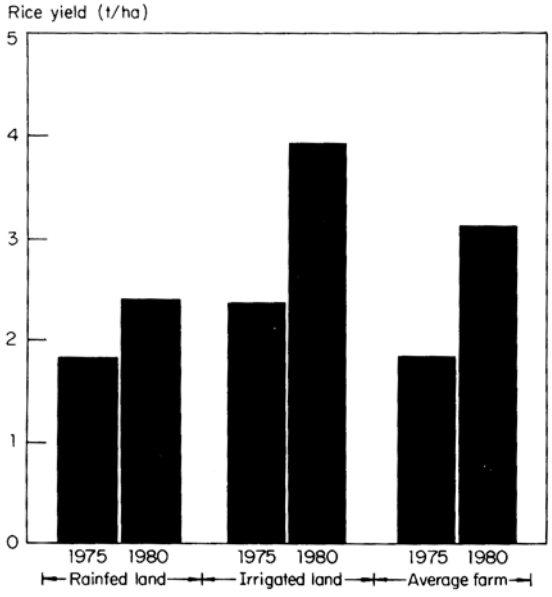


1. By adopting early-maturing MVs and early-seeding techniques, Iloilo farmers grew more crops each year on both rainfed and irrigated land. Cropping intensity rose 72% on the average farm because of the combined effect of multiple cropping technology and increased irrigation. Iloilo, Philippines, 1975-80.

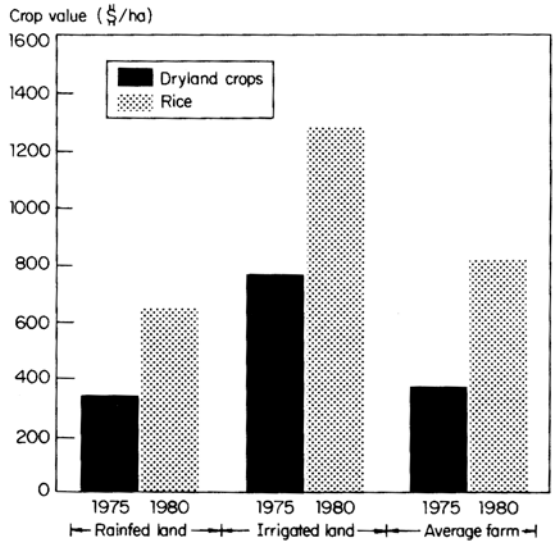
Income and its stability. Records of 1,380 rice plots were kept by the 45 sample farmers between 1975 and 1980. As expected, the returns and net returns above variable costs were higher for MVs than for LVs (Table 1). Returns were also higher for irrigated plots than for rainfed plots. What was more striking is that these returns from improved technology were more stable relative to their mean level than returns to traditional technology. This is reflected by the lower CVs for improved technology. By this measure, new technology is less risky than traditional technology.

Table 2 shows the composition of variable costs and the returns-to-cost ratio, a form of the B:C ratio. Three conclusions were evident; they ran counter to views often expressed in the popular press.

- Cash costs for fertilizer and other materials used by farmers were a small fraction of total crop production costs, and not markedly higher on MVs than on LVs.
- Total variable costs for producing the lowest technology crop (transplanted, rainfed LV) were not markedly less than those for pro-



2. Rice yields increased on farms when farmers adopted improved cropping practices. Iloilo, Philippines, 1975-80.



3. A 72% increase in cropping intensity and 42% increase in crop yields per farm resulted in a 140% increase in the value of crops on farms. Iloilo, Philippines, 1975-80.

Table 1. Returns and variability of returns from new rice technology on 45 farms in Iloilo, Philippines, 1975-1980.

Management	Plots (no.)	Total return ($/ha)	Net return ($/ha)	CV of net return[a]
Transplanted				
Rainfed				
LV	207	371	148	145
MV	84	486	259	95
Irrigated				
LV	42	387	174	107
MV	102	686	418	68
Direct-seeded				
Rainfed				
LV	106	356	176	100
MV	335	452	239	98
Irrigated				
LV	39	479	255	89
MV	475	715	436	67

[a]Coefficient of variation, computed by dividing the standard deviation by the mean.

Table 2. Costs of production and rate of returns on costs of new rice technology on 45 farms in Iloilo, Philippines, 1975-1980.

Management	Costs ($/ha)			Returns: cost
	Labor	Material	Variable	
Transplanted				
Rainfed				
LV	194	29	223	1.7
MV	191	36	227	2.1
Irrigated				
LV	172	41	213	1.8
MV	212	56	268	2.6
Direct-seeded				
Rainfed				
LV	134	36	170	2.0
MV	151	62	213	2.1
Irrigated				
LV	155	69	224	2.1
MV	178	101	279	2.6

ducing the highest technology crop (direct-seeded, irrigated MV).

- The rate of return on investment in labor and materials was uniformly higher for improved technology.

These results contrast with the popular view that modern technology displaces labor and, compared with traditional technology, requires a much higher cash investment, offers lower rates of return on investment, and subjects farmers to greater risk.

Regarding the separate issue of what rate of return a farmer expects, the data support the view of cropping systems researchers that a new technology should offer a 2-to-1 rate of return on current costs to be minimally attractive to farmers.

Employment and wages. During the 5 cropping seasons, the average employment time was higher for irrigated rice than for rainfed, and higher for MVs than for LVs (Table 3). However, the shift to wet seeding was the factor that dominated labor employment. Early in the adoption of the new cropping practices, it appeared that labor savings from direct seeding would be more than offset by increased cropping intensity. Also, higher yields were expected to increase the incomes of harvesters. However, the new technology invited other labor savings in land preparation and, eventually, in insect and weed control. More importantly, the initially higher labor requirements, coupled with higher farm incomes, set the stage for mechanization, which proceeded rapidly after the 1976-77 crop year (Table 3). By 1979-80 the time worked per farm by hired laborers was reduced more than 50% from the 1975-76 level.

The workers who remained in the labor force likely benefited from the changes because they became more efficient. Clearly in the case of harvesting, higher productivity resulted in higher earnings. Harvesters working with a mechanical thresher received one-twelfth the yield of a crop, or half the share they received using manual threshing techniques. However, mechanical threshing, being faster, enabled workers to harvest more than twice as much in a day and actually earn higher wages. The effects of the new technologies on wage rates were examined by estimating wage rates from hired-labor transactions.

Between crop years 1975-76 and 1979-80, approximately 7,500 hired-labor transactions involving 186,000 man-h were observed on the 45 farms. More than 100 different jobs were recorded and grouped into the major classes discussed. Worker compensation in cash and the value of meals, snacks, cigarettes, liquor, and produce were recorded. Weekly and annual summaries of the compensation value per hour worked were computed. Table 4 shows the nominal annual imputed wages paid for major operations and the imputed wages deflated by the consumer price index. Although annual real wages for land preparation and harvesting increased, the wages for transplanting declined throughout the period. Wages for weeding first increased then declined.

Input use. The records of sample farms provide helpful insight into farmers' use of purchased inputs and raise questions about the efficiency of those inputs. N fertilizer is the largest, often the only, cash expenditure in a farmer's crop budget. To obtain the highest yield response to N, researchers recommend incorporating it into the soil at planting, possibly with additional applications at no later than panicle initiation (PI) 10-11 wk before harvest.

On the sample Iloilo farms, only 17% of the fertilizer was applied at planting time, up to PI. Another 23% was applied in the 2 wk around PI,

Table 3. Labor use for rice production on 45 farms, Iloilo, Philippines, 1979-80.

Crop year	Labor use (man-h)					
	Per farm			Per hectare		
	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	618
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 4. Wage rates imputed from hiring transactions on 45 farms. Iloilo, Philippines, 1975-80.

Cropping season	Wage rate ($/d)								Consumer price index
	Nominal				Real				
	Land preparation	Trans-planting	Weeding	Harvesting	Land preparation	Trans-planting	Weeding	Harvesting	
1975-76	1.25	1.25	0.59	1.27	1.24	1.25	0.59	1.27	100
1976-77	1.17	1.10	1.10	1.89	1.10	1.04	1.04	1.78	106
1977-78	1.21	0.97	0.80	1.94	1.05	0.84	0.70	1.69	115
1978-79	2.21	0.85	0.71	1.99	1.80	0.69	0.58	1.62	123
1979-80	2.05	0.77	0.69	2.18	1.40	0.53	0.47	1.49	146

and the remaining 60% afterward, when the plants used less of the N.

Farmers commented that the delays in N application were caused by late availability of funds and a desire to observe crop progress before investing in it.

The changes in labor and material input use and crop production have brought major changes in the farm household, labor force structure, and farm capital. General findings in other studies show that children and farm operators now work less on farms, both being replaced by hired labor. All rice is now mechanically threshed when previously none was. By 1982, tractors had replaced carabao on 33% of the rice land.

Adjustments are still in progress and more distant effects are now only hinted. Weeds appear to be on the increase and farmers speculate they may need to return periodically to transplanting. Changes on the 45 farms continue to be monitored as the need occurs.

By the 1982-83 crop year, 13,500 ha in Iloilo and surrounding provinces were part of the government's KABSAKA program and direct-seeded with early-maturing rice varieties. Higher cropping intensity has resulted in the mechanization of plowing and harvesting and a consequent decline in draft animal ownership. More than 50 firms in the area manufacture small threshers, where before 1975 there were none.

Cropping systems program

Pest control

Plant Pathology, Entomology, and Agronomy Departments

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DISEASES

Plant Pathology Department

Surveys. *Wetland rice-based cropping systems.* In Barangay Iraga, Philippines, during the 1982 rice-growing season, leaf blast (*Piricularia oryza* Cav.), became an important disease causing severe damage to most of the IR52 seedlings in seedbeds. The disease had not been observed previously. Dry-seeded and wet-seeded IR52 in six cropping patterns and research-managed fields also suffered from blast with 1980 SES severity ratings of 4-7. Blast aggravated an already poor crop stand because of drought; most of the lower leaves became dry. Mild cases of the disease occurred in Barangays Bauan and Bangag, except in a few fields with very green plants where the severity rating reached 7. Light, intermittent showers, which kept leaves wet for long periods, greatly contributed to the blast severity.

Light grain discoloration and light infections of sheath blight (*Thanatephorus cucumeris* [Frank] Donk), brown spot (*Helminthosporium oryzae* van Breda de Haan), and narrow brown spot (*Cercospora oryzae* Miy.) were also observed at the site.

On mungbean after rice, *Rhizoctonia solani* Kuhn in damped-off seedlings was found in isolation plates where 2% of the infected seedlings collected from cropping patterns and research-managed fields yielded *Rhizoctonia. Sclerotium rolfsii* Sacc. was common, as was powdery mildew (*Erysiphe polygoni* D.C.)

On mungbean before rice, Cercospora leaf spot (*Cercospora* sp.), was less severe than during the previous year, with ratings only 0-3 (<5% leaf area affected) probably because of no rain at the late growth stage.

Farmers and plant diseases. A survey of 30 farmers' concepts of and responses to plant diseases was conducted in three barangays of Solana, Cagayan, Philippines. Interviewed farmers, shown color photos of common local crop diseases, recognized only RTV. The solution of 10% of the farmers was to either rogue or bury the infected plants. Ninety-seven percent observed false smut, not as a disease, but as a sign of good harvest. Most of the farmers attributed postemergence damping-off to excessive water in the soil. Farmers attributed Cercospora leaf spot, powdery mildew, and rust of grain legumes and sheath blight of rice and maize to insects. Most of the farmers' local names for such diseases were associated with insects. Seventeen percent associated downy mildew of maize with late planting; only 10% said black spot of peanut occurred at crop maturity. Forty percent of the farmers sprayed their crops but none used fungicides.

Chemical control. *Damping-off in legumes.* Fungicides have been identified for seed treatments to control damping-off caused by *Sclerotium rolfsii, Rhizoctonia solani,* and *Pythium debaryanum,* singly and in combination. A trial was conducted to determine interactions among soil-borne pathogens by observing the incidence of preemergence damping-off as influenced by the seed treatment (Table 1). Mancozeb + benomyl effectively controlled *Rhizoctonia* damping-off, but the control was nullified in the presence of *Sclerotium*. *Sclerotium* appeared to be more aggressive than *Rhizoctonia* because isolates from infected seeds sown in soil infected with both *Rhizoctonia* and *Sclerotium* yielded only *Sclerotium*. With thiophanate methyl the results were similar. However, orthocide RE-26745 had less effect on *Rhizoctonia* and isolation from infected seeds sown in *Rhizoctonia*- and *Sclerotium*-infested soil yielded only *Sclerotium*. It appeared that, with orthocide, *Rhizoctonia* enhanced the pathogenic ability of *Sclerotium*, thereby significantly increasing the infection from 42.9%, with *Sclerotium* alone, to 59.2%, with *Sclerotium* and *Rhizoctonia* together.

Metalaxyl was excellent against *Pythium* damping-off (Table 1), but was inactive against *Rhizoctonia*, suggesting that *Rhizoctonia* is tolerant of metalaxyl. On the other hand, PCNB + thiadiazole was effective against *Rhizoctonia* damping-off, but did not work in the presence of *Pythium*. Seventy percent of the infected seeds from *Rhizoctonia* + *Pythium*-infested soil was attacked by *Pythium*. With carboxin + captan, it appeared that *Rhizoctonia* increased the infectivity of *Pythium*; disease incidence increased significantly from 53.8 to 69.6%.

Treating mungbean seeds with orthocide RE-26745 might cause synergism between *Pythium* and *Sclerotium* because the infection by the com-

Table 1. Selected treatments with possible interaction among soil-borne pathogens in seed-treatment experiment.[a] IRRI, 1982.

Rhizoctonia (R) and Sclerotium (S)

Fungicide (g ai/kg seed)	Infection[a] (%)			Pathogen involved in R + S
	R	S	R + S	
Mancozeb + benomyl (4.4)	31.7 b	71.6 a	77.8 a	100% S
Thiophanate methyl (0.7)	49.5 b	77.0 a	80.1 a	100% S
Orthocide RE-26745 (3.0)	63.1 a	42.9 b	59.2 a	100% S

R and Pythium (P)

Fungicide (g ai/kg seed)	Infection (%)			Pathogen involved in R + P
	R	P	R + P	
Metalaxyl (0.7)	80.5 a	12.0 b	80.1 a	100% R
PCNB + thiadiazole (0.9)	15.1 b	73.1 a	81.3 a	70% P
Carboxin + captan (1.4)	32.9 c	53.8 b	69.6 a	60% P

S and P

Fungicide (g ai/kg seed)	Infection (%)			Pathogen involved in S + P
	S	P	S + P	
Orthocide RE-26745 (3.0)	42.9 b	17.0 c	59.6 a	100% S 100% P
Metalaxyl (0.7)	79.7 a	12.0 b	80.5 a	100% S 60% P
PCNB + thiadiazole (0.9)	25.2 c	73.1 a	60.7 b	90% P
Carboxin + captan (1.4)	19.7 b	53.8 a	53.0 a	75% P

[a]Potato dextrose agar (PDA) with carboxin + captan at 0.125 g/liter was used to detect Pythium in association with Rhizoctonia and with Sclerotium; PDA with mancozeb at 0.94 g/liter + metalaxyl at 0.54 g/liter for Rhizoctonia; and PDA with benomyl at 0.56/gliter + metalaxyl at 0.54 g/liter for Sclerotium. In a row, separation of means by Duncan's multiple range test at the 5% level.

bination was significantly higher than that caused by either pathogen alone. Both *Sclerotium* and *Pythium* were present in equal proportion isolated from infected seeds. With metalaxyl, *Sclerotium* was more active than *Pythium*, as shown by higher colonization percentage of infected seeds by *Sclerotium*; with carboxin + captan, *Pythium* was more aggressive than *Sclerotium*. With PCNB + thiadiazole, infection level in soil infested with both *Sclerotium* and *Pythium* was significantly lower than in soil infested with *Pythium* alone, but significantly higher than in soil infested with *Sclerotium* alone. Because 90% of the infected seed was colonized by *Pythium*, the presence of *Sclerotium* could therefore have adversely affected *Pythium*, causing the reduction in infection.

Cercospora leaf spot in mungbean before rice. It was previously observed that Cercospora leaf spot in mungbean was controlled well by spraying mancozeb + benomyl even at a low rate of 0.44 g ai/liter and that two sprayings (35 and 45 DE) were as effective as three sprayings (25, 35, and 45 DE). Further trials were conducted to confirm these findings and to determine the proper timing and

the most effective minimum spray frequency. In trial 1, where the initial infection rating was only 0.3-0.5, the effect of spraying was already statistically detected at 19 DE (Table 2). At 29 DE, the disease was controlled only by the 20-DE treatment in the three-spray regimens, suggesting that the 10-DE spray was no longer effective after 19 d. However, the 20-DE spraying proved to be still effective at 39 DE. Statistically, the efficacy of the 30-DE spraying was more pronounced during the first priming (51 DE), implying that the control derived from the third spraying was too late as far as the first harvest was concerned. Based on disease ratings at 39 DE, spraying once at 20 DE had the best performance among single-spray applications; as expected, three sprayings provided the best disease control. Disease ratings were also taken at 51 DE to obtain a correlation between the disease rating at first priming and yield. However, the effect of treatments could not be correlated with yield probably because of a low infection despite providing an inoculum source in the vicinity of the experimental field.

In trial 2, the disease did not increase substantially, as shown at the 51-DE observation, where the highest mean disease rating was only 6.2. Yield was much lower because of profuse vegetative growth commonly observed on the variety during the rainy season and was inconsistent with treatments.

From these two trials, it appeared that the best time to spray to control Cercospora leaf spot is 20 DE. The minimum effective spray frequency could not yet be identified because sufficient data on yield with cost-and-return analysis were not available.

At the Solana site, an experiment was conducted in a farmer's field using an LV (Table 3). Even though the infection was low (the highest mean disease rating was only 1.6), the treatment effects could still be determined. Copper oxychloride and thiophanate methyl provided similar control.

Table 2. Effect of time and frequency of fungicide spraying on the Cercospora leaf spot severity and yield of mungbean before rice (trial 1). IRRI, 1982.

Spraying time (DE)	Disease rating[a]/leaf				Yield (t/ha)
	19 DE	29 DE	39 DE	51 DE (at 1st priming)	
10 + 20 + 30	0.7 b	0.6 b	2.0 d	4.0 b	1.04
10 + 20	0.6 b	0.6 b	2.9 abc	6.6 a	1.08
20 + 30	1.4 a	0.5 b	2.3 cd	4.4 b	1.17
10 + 30	0.7 b	1.6 a	2.6 bcd	4.3 b	0.97
10	0.7 b	1.5 a	3.3 ab	6.4 a	0.75
20	1.5 a	0.7 b	2.8 abcd	6.0 a	0.92
30	1.6 a	1.7 a	3.0 abc	4.6 b	1.04
No spraying	1.5 a	1.7 a	3.6 a	6.8 a	0.91

[a]1-9 scale: 1 = <1% leaf area affected, 9 = >50% infection. Av of four replications.

Table 3. Effect of treatments on severity of Cercospora leaf spot on mungbean before rice in four farmers' fields. Solana, Cagayan, Philippines, 1982.

Fungicide[a]	Rate (g ai/liter H_2O)	Disease rating[b]/leaf				
		Field 1	Field 2	Field 3	Field 4	Mean
Copper oxychloride	2.68	0.05	0.04	0.04	0.19	0.08
58%	1.34	0.27	0.09	0.07	0.38	0.20
Thiophanate methyl	0.44	0.06	0.10	0.02	0.13	0.08
70%	0.22	0.11	0.12	0.06	0.30	0.15
	0.11	0.03	0.29	0.09	0.37	0.20
Untreated	–	0.51	0.47	0.33	1.58	0.72

[a]Applied as foliar spray at bud to flowering stage. [b]At 19 DAT on 1-9 scale: 1 = <1% leaf area affected, 9 = >50% infection.

Generally, the degree of control was reflected by application rates.

Blast in rice. Because leaf blast has become important in Barangay Bauan, an experiment on chemical control of the disease was conducted in the seedbed and the field. Three locally available fungicides were sprayed at the recommended and half the recommended rate. In the seedbed, pretreatment observation on seedlings at the one- to two-leaf stage revealed a mean blast lesion count of 1.1 to 2.0/leaf. At 15 DAT, benomyl at 1 g/liter provided the best protection for newly formed leaves. Edifenphos and copper oxychloride provided no control.

Powdery mildew in mungbean after rice. Reduced application rates of mancozeb + benomyl (1.40 g ai/liter) and chlorothalonil (0.95 g ai/liter) have already been found effective against powdery mildew in mungbean after rice. In 1982, an experiment was conducted to determine the proper time of spraying and the most effective minimum spray frequency.

The field trial used three planting dates so control at varying degrees of infection could be observed. Pretreatment observation at 9 DE revealed that all the plants, even in the third planting, were healthy. In the first planting, the infection was so slow that, even at 29 DE, the first spraying was still effective (Table 4). At 39 DE, the control offered by all treatments, except at 30 DE, did not differ significantly. In the second planting, which had higher infection, the effect of the first and second sprayings was reflected statistically on infection at 19 and 29 DE, respectively. So, 10-DE spraying was no longer effective at 29 DE. Much higher infection in the third planting revealed that among single sprayings, the 20-DE treatment was best; the 20- + 30-DE sprayings were superior to the 10- + 20-DE.

Because of insufficient levels of powdery mildew infection in the field, the test was repeated in the greenhouse. The effectiveness of spraying once at 20 DE was consistent with that in the field trials.

Cropping systems and soil-borne diseases. *Soil-borne diseases in dryland fields.* It has been observed that continuous cropping of cowpea results in the prevalence of *Fusarium* infection, severe stunting, and reduced yield. In the sixth cropping (not counting the repeated 1981 plantings), the infection was higher in cowpea - cowpea - cowpea and dryland rice - cowpea - cowpea patterns than in the pattern with green maize, where infection was substantially low (Table 5). It appeared that the infection was favored by at least two successive croppings of cowpea, as observed during the third cropping. Furthermore, the plants from such two-cropping patterns were stunted and had a lower stand count because of the higher infection. Regardless of the cropping sequence, *Fusarium* was the prevailing pathogen isolated from infected plants.

Based on sclerotia count, the population of *Rhizoctonia* in the soil was consistently higher than that of *Sclerotium* in the dryland rice - green maize - cowpea sequence; that of *Sclerotium* was higher in the continuous cropping of cowpea (Fig. 1). The *Fusarium* population was not correlated with percentage of infection observed on 21 Jul and 18

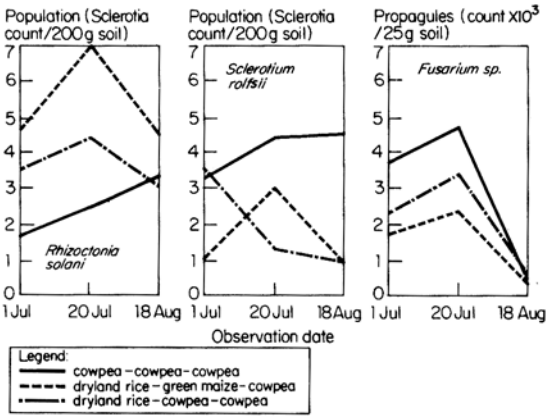
Table 4. Severity of powdery mildew on mungbean after rice as affected by time and frequency of spraying and by planting date. IRRI, 1982.

Spraying time (DE)	Disease rating[a]/leaf								
	First planting			Second planting			Third planting		
	19 DE	29 DE	39 DE	19 DE	29 DE	39 DE	19 DE	29 DE	39 DE
10 + 20 + 30	0.0 c	0.0 b	0.0 c	0.0 b	0.0 c	0.0 c	0.0 b	0.0 b	0.0 d
10 + 20	0.0 c	0.0 b	0.1 c	0.0 b	0.0 c	0.1 c	0.0 b	0.0 b	1.0 c
20 + 30	0.1 bc	0.0 b	0.1 c	0.2 a	0.0 c	0.0 c	0.4 a	0.2 b	0.3 d
10	0.0 c	0.0 b	0.1 c	0.0 b	0.3 b	2.1 b	0.0 b	0.5 b	3.4 b
20	0.1 a	0.0 b	0.1 c	0.2 a	0.0 c	0.1 c	0.4 a	0.4 b	1.1 c
30	0.0 bc	0.7 a	0.4 b	0.2 a	1.0 a	0.3 c	0.4 a	2.2 a	1.3 c
No spraying	0.1 b	0.7 a	1.8 a	0.3 a	1.0 a	2.6 a	0.4 a	2.1 a	4.0 a

[a]1-9 scale: 1 = 1-5% leaf area affected, 9 = >75% infection; 13 randomly selected plants considered per plot.

Aug, although the highest proportion of infection was attributed to *Fusarium*. Generally, the population of the three pathogens in the soil decreased over time (Fig. 1) and the decrease was correlated with the reduction in the incidence of soil-borne diseases (Table 5).

Saprophytic survival of three soil-borne pathogens. Damping-off caused by *Sclerotium rolfsii* has been common on mungbean grown after wetland rice. Damping-off caused by *Rhizoctonia solani* and root rot caused by *Fusarium* sp. has been common on grain legume crops grown in strictly dryland fields (Annual reports for 1978 and 1979).



1. Population of three soil-borne pathogens in a dryland field planted to cowpea as a third crop in three cropping patterns. IRRI, 1982.

It appeared that *Sclerotium* survived better than *Rhizoctonia* and *Fusarium* when submerged during the growing of wetland rice. Studies on the survival of the three pathogens in dryland and wetland rice fields suggested that *Fusarium* could remain highly viable in dryland fields for months. However, the recovery of mycelia of *Sclerotium* and *Rhizoctonia* dropped from 100 to 0% (Fig. 2). All three pathogens had poor saprophytic survival in wetland rice fields.

In the wetland fields, the *Fusarium* population, determined using a PCNB agar medium and the sclerotia count of *Rhizoctonia*, did not increase substantially compared with that of *Sclerotium*, which reached as high as 104 sclerotia/200 g of soil. The density of the three pathogens was consistently higher in dryland than in wetland fields.

Subsequent percentage recovery from a zero reading and increase in population were due to the natural occurrence of the pathogens, as revealed in the study of competitive saprophytic ability in healthy legume stalks (Table 6). *Fusarium* was most efficient in colonizing the legume stalks in both wetland and dryland fields. *Rhizoctonia* colonized more stalks than *Sclerotium* in the dryland field, but both pathogens had poor competitive saprophytic ability in the wetland field. A very minimal colonization percentage by the three pathogens in subsequent months suggested that their mycelia in the stalks had died. Inconsistent results for *Fusarium* could be attributed to the

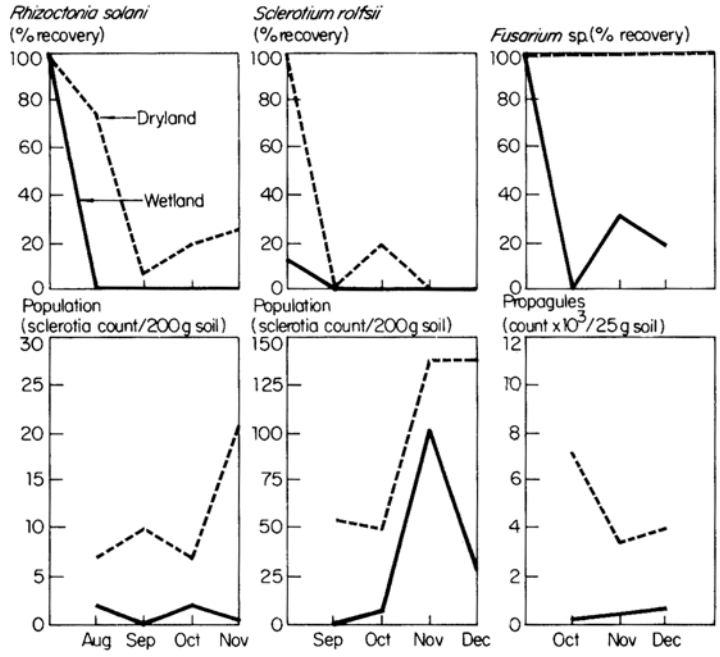
Table 5. Incidence[a] of soil-borne diseases and pathogens involved at three observation dates in sixth[b] cropping in a dryland field with three cropping patterns.[c] IRRI, 1982.

Cropping pattern	21 Jul		4 Aug		18 Aug	
	Infection	Pathogen	Infection	Pathogen	Infection	Pathogen
Cowpea - cowpea - cowpea	Damping-off	7.9% R	Stem and	0.2% R	Stem and	7.9% R
	12.6%	1.2 S	root rot	96.2 F	root rot	1.2 S
		64.5 F	20.1%	1.1 P	3.9%	64.5 F
		8.6 P				8.6 P
Dryland rice - green maize - cowpea	Damping-off	14.1 R	Stem and	84.4 F	Stem and	14.2 R
	3.6%	0.8 S	root rot	5.5 P	root rot	0.8 S
		55.4 F	3.7%		2.1%	55.4 F
		4.3 P				4.3 P
Dryland rice - cowpea - cowpea	Damping-off	9.5 R	Stem and	0.2 R	Stem and	9.5 R
	23.9%	1.1 S	root rot	95.8 F	root rot	1.1 S
		68.4 F	16.7%	1.3 P	2.9%	68.4 F
		5.1 P				5.1 P

[a]Infection figures followed by % indicate incidence, based on the ratio of infected plants to the total population X 100. R = *Rhizoctonia*, S = *Sclerotium*, F = *Fusarium*, P = *Phythium*. [b]Repeated planting in 1981 was not considered. [c]Each figure represents a mean of four replications.

presence of other species in the field.

Although the colonization percentage of the stalk by *Sclerotium* was less than that by *Rhizoctonia*, *Sclerotium* produced more sclerotia, as in the saprophytic survival study, suggesting that it survives better saprophytically by forming numerous sclerotia. Likewise, *Fusarium* was no longer recovered from stalks in subsequent months, but its density in the soil markedly increased in dryland fields.



2. Saprophytic survival and population of three soil-borne pathogens in dryland and wetland rice fields. IRRI, 1982.

Table 6. Competitive saprophytic ability and population of three soil-borne pathogens in dryland and wetland rice fields. IRRI, 1982.

Month	*R. solani*		*S. rolfsii*		*Fusarium* sp.	
	Dryland	Wetland	Dryland	Wetland	Dryland	Wetland
			Colonization[a]			
0[b]	87.5	12.5	37.5	0.0	100.0	100.0
1	37.5	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	12.5	12.5
3	18.8	0.0	18.0	0.0	0.0	0.5
4	0.0	0.0	0.0	0.0	–	–
			Population[c]			
1	0.0	0.0	14.0	0.0	4.0×10^2	4.5×10^2
2	0.0	0.0	13.0	37.5	6.5×10^2	2.0×10^2
3	3.0	1.0	160.0	29.0	1.7×10^3	9.0×10^2
4	3.5	2.0	121.5	13.5	–	–

[a]Determined by planting the harvested stalks on 2% water agar. [b]At 5 d after burying the stalk, which coincided with the period from land preparation to planting. [c]Sclerotia count from 200-g soil for *Rhizoctonia, Sclerotium,* and *Fusarium* propagules from 25-g soil, on over-dry weight basis.

Entomology Department

Mungbean insects. *Yearly and monthly variations.* Developing an insect control recommendation for a site takes a minimum of 3 yr because potential practices must be tested at the existing levels of pest presence over years. Planting dates, climatic factors, and yield potential must also be considered. The results of trials on mungbean planted after rainfed rice in Pangasinan, Philippines, support this point.

From 1977 to 1980, the yearly and monthly variations in insect abundance and yield loss were compared (Table 7). The rice stubble was plowed under and insect counts were taken in plots without insecticide treatment. Because of the spread in planting dates of the single rice crop, mungbean was planted from October through December.

Beanfly *Ophiomyia phaseoli* abundance varied greatly from year to year but not among months of planting. Thrips *Thrips palmi* was only recognized as a pest in 1979 and 1980 but showed significant variability between years and was not abundant in the November and December plantings. Flea beetle *Medythia suturalis* damage was highly consistent over the years and was least in the December plantings. Aphid *Aphis craccivora* and pod borer *Heliothis armigera* varied from year to year with no apparent pattern.

Yield varied from 0.9 to 1.4 t/ha over the 4-yr period in insecticide-protected plots. Highest yields were recorded in the November and December plantings when there was less cloud cover.

Despite the high variability in insect abundance in the unprotected plots, yield loss was consistently high over the years (69-93%) and months (63-85%).

The results showed that a minimum of two insecticide applications at 10-d intervals was necessary to protect each major growth stage (preflowering and postflowering) against the wide array of expected insect pests each month or year. The use of economic thresholds to determine timing of insecticide application was not practical because of the consistently high yield losses expected. Broad-spectrum chemicals were needed because of the large number of expected pests.

Rice stubble and control of preflowering insects. Preflowering insect pests cause one-third of the total yield loss (0.9 t/ha) on mungbean planted with high tillage after rainfed rice in Pangasinan.

Table 7. Variations in insect abundance and yield loss over years and planting months in mungbean planted after rainfed wetland rice.[a] Manaoag, Pangasinan, Philippines, 1977-80.

Character	Year				Month planted		
	1977	1978	1979	1980	Oct	Nov	Dec
Beanfly-infested plants[b] 25 DE (%)	53 c	74 d	31 b	18 a	36 a	23 a	27 a
Flea beetle[c] 14 DE (% defoliation)	24 a	18 a	13 a	20 a	20 b	17 b	11 a
Thrips[d] 25 DE (no./10 terminals)	–	–	4 a	14 b	22 b	4 a	2 a
Aphid infestation[e] (scale) 25 DE	4.3 b	3.0 a	3.0 a	3.8 b	1.9 a	4.7 c	3.8 b
Pod borer larvae[f] 45 DE (no./10 plants)	4 a	10 b	8 b	1 a	5 b	1 a	5 b
Yield (t/ha)							
Unprotected	0.1 a	0.3 a	0.2 a	0.3 a	0.1 b	0.4 a	0.5 a
Protected[g]	1.3 a	1.4 a	1.2 a	0.9 b	0.8 b	1.1 a	1.2 a
Yield loss (%)	93	77	81	69	85	63	63

[a]No. of field replications: 1977-Nov (4), Dec (7); 1978 - Dec (4); 1979-Oct (4), Nov (3), Dec (4); 1980- Oct (3), Nov (3), Dec (9). [b]25-35 plants dissected. [c]25-35 plants sampled. [d]25-35 leaf bud terminals. [e]1-9 scale on per-plant basis: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many colonies running together; 25-35 plants sampled. [f]25-35 plants sampled. [g]1977: Preflowering: 0.5 kg ai monocrotophos EC/ha 2 and 12 DE. Postflowering: 1 kg ai endosulfan EC/ha 25, 35, 45 DE. 1978: Preflowering: 1% carbofuran seed treatment. Postflowering: 0.5 kg ai decamethrin EC/ha EC/ha 25, 35, 45 DE. 1979-80: Preflowering: 0.5 kg ai monocrotophos EC/ha 2, 9, 16 DE. Postflowering: 0.03 kg ai decamethrin EC/ha 25, 35, 45 DE.

Insecticides were the only control method because no insect-resistant varieties were available.

A minimum of two applications was necessary to protect the crop against beanfly, thrips, flea beetle, and aphid, which reduce crop stand and early plant vigor, causing stunted plants that set few pods.

Minimum tillage methods have been developed to establish mungbean quickly after rice harvest when soil moisture is more favorable. Studies revealed that the presence of standing rice stubble interferes with the colonizing ability of beanfly, thrips, aphid, and leafhopper during the first 21 DE.

Trials from 1977 to 1980 compared the effect of rice stubble on preflowering insect pest abundance and yield using a split plot design. The results confirmed its suppressing effect on beanfly, thrips, aphid, and leafhopper in untreated plots (Table 8). However, in plots protected with insecticide during the postflowering period only, yields were the same with standing rice stubble (0.64 t/ha) and without (0.63 t/ha).

Leaving the rice stubble in the field apparently had no economic benefit. This was surprising considering the substantial degree of insect control provided by the rice stubble. However, insecticides provided a higher level of control than rice stubble. Rice stubble did not affect flea beetle or leaf miner *Stomopteryx subsecivella*.

Despite stubble presence, high yield losses occurred because the economic injury level of the crop was lowered by an attack of several pest species at once, even though their abundance was relatively low. This multipest yield loss phenomenon has been recently demonstrated on rice. Each preflowering mungbean insect pest caused a different kind of plant injury, which as a whole counteracted the plants' ability to recover from that damage.

If plants were attacked by only one insect pest which inflicted a specific type of damage (removing leaf tissue — flea beetle, leaf miner; tunneling the stem — beanfly; feeding on developing buds — thrips; or removing photosynthate — aphid, leafhopper), they could tolerate high numbers. Yield loss accelerated dramatically as the number of pest species increased, blocking the plants' alternative compensatory pathways. The economic injury level for each pest became progressively lower as the number of pest species increased. The high preflowering yield losses in mungbean grown after rice could be explained by the presence of pest species acting on four different plant parts.

Table 8. Effect of rice stubble on preflowering insect abundance and yield of mungbean planted after rice. Manaoag, Pangasinan, Philippines, 1977-80.

Character	Insecticide protection	Rice stubble	No rice stubble	Difference
Flea beetle[a] 14 DE (% defoliation)	Untreated	11 b	11 b	ns
	Treated	3 a	2 a	ns
Beanfly[b] 25 DE (% infested plants)	Untreated	14 b	28 b	**
	Treated	8 a	8 a	ns
Thrips 25[c] DE (no./10 terminals)	Untreated	3 a	9 b	**
	Treated	3 a	3 a	ns
Aphid infestation[d] (scale) 25 DE	Untreated	1.4 a	3.4 b	**
	Treated	1.0 a	1.0 a	ns
Leafhopper 25[a] DE (no./10 plants)	Untreated	1 b	3 b	**
	Treated	0 a	0 a	ns
Leaf miner[a] 25 DE (no./10 plants)	Untreated	6 b	5 b	ns
	Treated	1 a	2 a	ns
Yield (t/ha)	Untreated	0.36 c	0.33 c	ns
	Postflowering only	0.64 b	0.63 b	ns
	Treated	1.01 a	1.05 a	ns

[a]25-35 plants sampled. [b]25-35 plants dissected. [c]25-35 leaf bud terminals. [d]1-9 scale on per-plant basis: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many colonies running together; 25-35 plants sampled.

Farmers' control practices. The low mungbean yields of farmers in Solana, Philippines, result from waterlogging caused by heavy rains, drought, low seeding rates, and weeds. Insect and disease pressure is minimal on this early monsoon crop because it follows a 3-mo DS, during which legumes are not grown.

However, the low plant populations may be the result of heavy insect damage to seed in storage. Farmers were surveyed to learn about their stored seed pest problems and their knowledge of mungbean pests in general. All farmers interviewed grew mungbean in wetland and dryland environments. About 76% of the farmers grew the traditional Araña variety, which has been cultivated for more than 50 yr in Solana. Only 12% planted the improved Pagasa variety introduced in 1980; the remaining 12% planted either Kusapo or Mirado, both traditional varieties.

The seed for planting came from previous harvests stored in the household (59%) or from the local market (41%). Farmers purchased seed if they recently experienced crop failures or low yields. Farmers grew mungbean mainly as a subsistence crop, saving some seeds for planting and selling the surplus.

More than 90% of the farmers stored seed in quantities ranging from 8 to 13 kg for less than 5 mo. Seed was stored for short periods because two mungbean crops are generally grown each year, alternating between the wetland and dryland areas. Seeds were stored in fertilizer sacks (50%), metal biscuit tins (16%), beverage bottles (10%), plastic jerry cans (6%), or clay pots, cloth bags, and paper cement bags (3% each). One farmer believed that the cement odor controlled storage insects.

Harvesting traditional varieties required up to five primings (average of three) while the more evenly maturing Pagasa variety was primed only once or twice. About 83% of the farmers saved their seeds for storage from the first priming regardless of variety because they said seeds from later primings lost viability. Selecting the earliest maturing seeds would minimize infestation in the field by storage insects (mainly bruchid seed weevil).

Seed was stored in the corner of the living room (83%) or on the doorstep in a sack which was used as a foot mat (13%). Some farmers believed that frequent stepping on the stored seeds killed the insects.

All of the farmers dried their seeds before storage, some up to six times but most (83%) only two or three times. Each drying lasted about 5 h in the midday sun. Sun-drying would kill insects at all life stages in the seed. After storage, only 37% of the farmers dried their seeds again once or twice. The majority of the farmers believed that this additional effort was unnecessary.

Farmers were consistent with IRRI findings in ranking pod borers as their greatest insect pest problem (9.9 importance value on a scale of 0-10), followed by aphids (8.6), and defoliators (8.5). Storage weevils were not highly regarded as pests (4.6), nor were seed bugs (4.0). The only other insect pests mentioned were field crickets (0.3).

Two diseases — damping off (*Sclerotium rolfsii* Sacc., *Rhizoctonia solani* Kuhn, and *Pythium debanyanum* Hesse) and powdery mildew (*Erysiphe polygoni* D.C.) — were mentioned by less than 7% of the farmers. Rats had an importance value of only 1.0.

When shown color photographs or actual specimens, all farmers recognized pod borers; 97%, aphids and defoliators; 67%, the storage bruchid; and 47%, the green stink bug. None of the farmers could identify beanfly or flea beetle damage.

Most farmers interviewed (81%) said they used insecticide to control insect pests in the field. However, the economics farm record-keeping data showed no farmer applied any insecticide during the past 3 yr (1980-82). This was interpreted to mean that the farmers had used insecticide at some time in past years, but did not do so as a normal practice.

The most frequently mentioned insecticides, all emulsifiable concentrates, were endosulfan (38%), methyl-parathion (33%), azinphos methyl (26%), and monocrotophos (3%). The farmers indicated no other control methods. This absence of indigenous pest control technology was surprising because three Filipino cultural groups (Ilocano, Ibanag, and Itawis) have settled in Solana from other regions and mungbean is not a new crop.

Farmers ranked flooding, drought, insects, and weeds as the major constraints to high mungbean yield. Research has shown that weeds are more important than insects in reducing yield. By ranking

insects ahead of weeds, farmers may not realize the importance of weeds in reducing yield. But with such large farms and the high risk of weather-related crop failure, these farmers probably do not have the time or resources to devote to weed control.

As population increases, the farm size will decrease and the farm families will be forced to increase their level of management, which will include weed and insect control measures.

WEEDS

Agronomy Department

Tillage, fertilizer, and weed control in rice cropping systems. In 1982, studies on the long-term effects of tillage, fertilizer level, and weed control methods on weed growth and crop yield in three cropping systems were continued on the 9th and 10th crops.

Continuous transplanted irrigated rice. Evaluations were made for two levels of tillage (minimum tillage consisting of one plowing followed by one harrowing 1 wk later and conventional tillage consisting of one plowing followed by three harrowings at weekly intervals) and three N levels (0, 60, and 120 kg/ha). Six weed control treatments were tested within each N level.

On the 9th and 10th croppings, the degree of land preparation and the N rate had little effect on the weed flora at 40 DT. *Echinochloa* sp. was the dominant weed regardless of tillage level and N rate. N application resulted in a significant increase in total weed weight at harvest (Table 9). In the fertilized plots, regardless of tillage, herbicide treatments within each N level were inferior to rotary weeding followed by hand weeding. Butachlor, 2,4-D, and thiobencarb - 2,4-D performance decreased as the level of applied fertilizer increased. However, rice yield from the fertilized herbicide-treated plots was not significantly reduced despite an increase in total weed weight (Table 10).

The effect of land preparation on weed growth varied. As reflected in the yield in the unweeded plots (Table 10), rice planted from December to April (9th crop) had lower total weed weight than rice planted from April to July (10th crop).

Plots treated with 120 and 60 kg N/ha did not differ much in yield. However, both yielded significantly higher than the unfertilized plot. Yield reduction attributed to weeds was higher in the fertilized plot than in the unfertilized in both croppings. Greater yield reduction attributed to weeds was observed in crop 10 (14-100%) than in the 9th crop (13-63%).

Table 9. Effect of degree of tillage, N level, and weed control treatment on total weed weight at harvest of the 9th and 10th crops of TPR. IRRI, 1982 DS.

Weed control method	Weed wt (g/m^2)					
	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
			9th crop			
Rotary weeding fb hand weeding	7 c	7 d	20 c	16 b	6 c	27 c
2,4-D (0.8 kg ai/ha)	14 b	60 b	223 a	16 b	29 b	235 a
Thiobencarb (1 kg ai/ha) – 2,4-D (0.5 kg ai/ha)	27 b	34 c	105 b	3 d	35 b	127 b
Butachlor (1 kg ai/ha)	21 b	22 c	157 ab	3 d	21 b	137 b
Butachlor (1 kg ai/ha) fb 2,4-D (0.8 kg ai/ha)	4 c	23 c	145 ab	6 c	34 b	117 b
No weeding	44 a	146 a	225 a	98 a	113 a	232 a
			10th crop			
Rotary weeding fb hand weeding	9 c	63 c	41 c	13 d	37 b	25 c
2,4-D (0.8 kg ai/ha)	210 a	210 ab	194 b	19 bcd	59 b	158 b
Thiobencarb (1 kg ai/ha) – 2,4-D (0.5 kg ai/ha)	43 bc	127 b	240 ab	16 cd	13 c	182 b
Butachlor (1 kg ai/ha)	46 b	43 c	237 ab	36 abc	17 c	200 b
Butachlor (1 kg ai/ha) fb 2,4-D (0.8 kg ai/ha)	88 ab	65 c	254 ab	49 a	17 c	161 b
No weeding	45 bc	505 a	442 a	51 a	467 a	540 a

The weed control treatments resulted in significant yield increases within each N level. In general, yields obtained with thiobencarb - 2,4-D, butachlor, and butachlor fb 2,4-D were comparable to those with rotary weeding followed by one hand weeding. Yields were significantly lower with 2,4-D than with hand weeding in the fertilized minimum- and conventional-tillage plots in the 9th crop (Table 10).

One crop of rainfed transplanted rice. Plots were kept weed-free with tillage during the DS (WFT) or were prepared as soon as there was enough water for puddling (PWP). N levels were 0, 40, and 80 kg/ha.

The composition of the weed flora was affected by tillage method, but not by fertilizer level. *Monochoria vaginalis*, *Echinochloa glabrescens*, and *Paspalum* sp. (in order of dominance) dominated the WFT plots. *Fimbristylis littoralis*, *M. vaginalis*, and *Cynodon dactylon* dominated the PWP plots.

Butachlor application, either alone or in combination with hand weeding, resulted in better weed control in WFT plots than in PWP plots (Table 11).

In WFT plots, yields were significantly lower

Table 10. Effect of degree of tillage, N level, and weed control treatment on grain yield of the 9th and 10th crops of TPR.[a] IRRI, 1982 DS.

Weed control method	Yield (t/ha)					
	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
			9th crop			
Rotary weeding fb hand weeding	3.0 a	3.5 a	4.1 a	2.3 abc	3.5 ab	4.3 a
2,4-D (0.8 kg ai/ha)	2.3 a	2.7 b	2.7 c	1.8 c	3.0 b	1.8 b
Thiobencarb (1 kg ai/ha) – 2,4-D (0.5 kg ai/ha)	2.6 a	3.5 a	4.1 a	2.1 bc	3.8 a	4.2 a
Butachlor (1 kg ai/ha)	2.7 a	3.7 a	3.4 b	2.7 ab	3.8 a	4.1 a
Butachlor (1 kg ai/ha) fb 2,4-D (0.8 kg ai/ha)	2.6 a	3.6 a	4.2 a	2.8 a	3.7 a	3.8 a
No weeding	1.7 b	1.5 c	2.2 c	2.0 c	1.3 c	1.8 b
			10th crop			
Rotary weeding fb hand weeding	2.1 a	3.1 a	3.6 a	2.0 ab	3.3 a	3.0 a
2,4-D (0.8 kg ai/ha)	1.8 a	2.8 a	3.6 a	2.1 ab	2.9 a	3.1 a
Thiobencarb (1 kg ai/ha) – 2,4-D (0.5 kg ai/ha)	2.3 a	3.1 a	3.1 ab	2.1 ab	2.8 a	4.0 a
Butachlor (1 kg ai/ha)	1.8 a	3.1 a	3.1 ab	2.4 ab	3.2 a	3.6 a
Butahclor (1 kg ai/ha) fb 2,4-D (0.8 kg ai/ha)	2.4 a	2.6 a	2.8 b	2.6 a	2.6 a	3.6 a
No weeding	1.8 a	0 b	0 c	1.7 b	0 b	0 b

[a]LSD = 0.6 (5%) for two N levels.

Table 11. Effect of land preparation time and weed control method on weed weight and TPR yield.[a] IRRI, 1982 WS.

Weed control method	Time of application (DT)	WFT[b]		PWP[c]	
		Weed wt (g/m^2)	Yield (t/ha)	Weed wt (g/m^2)	Yield (t/ha)
1 HW	21	5 c	2.4 b	34 b	2.5 b
Butachlor (2 kg ai/ha) fb 1 HW	1 fb 35	14 b	3.0 a	65 a	3.3 a
1 HW fb 2,4-D (0.8 kg ai/ha)	14 fb 35	43 a	2.4 a	149 a	2.1 bc
Butachlor (2 kg ai/ha)	1	16 bc	2.7 ab	81 a	2.7 b
One rotary weeding	21	26 ab	2.4 b	98 a	1.7 cd
No weeding	–	42 a	2.7 ab	137 a	1.6 d

[a]Av of three replications and three N levels. [b]WFT = plots kept weed-free with tillage during the DS. [c]PWP = plots prepared as soon as there was enough water for puddling.

with hand weeding alone or followed by 2,4-D and rotary weeding than with butachlor application followed by hand weeding. This was attributed to some mechanical damage combined with difficulty in removing weeds because of limited soil moisture. In the other land preparation method, herbicide application and hand weeding resulted in significant yield increases over the no-weeding check. The weed weights did not differ significantly. The damaged crop in the rotary-weeded plots yielded similarly to the no-weeding check (Table 11).

Dry-seeded rainfed bunded rice followed by transplanted rice. Land preparation consisted of WFT or preparing the land after the onset of the monsoon rains (OMR). The three N levels used in both crops were 0, 60, and 120 kg/ha. Six weed control treatments were tested at each N level.

Melochia concatenata and *Echinochloa colona* were the major weeds. The time of land preparation and N level had little effect on the weed flora at 45 DE.

The N rate did not significantly affect the weight of weeds growing in association with rice 45 DE in the unweeded WFT and OMR plots. In general, OMR plots had a higher total weed weight than WFT plots.

Significant effects attributed to applied N were observed in some herbicide-treated plots. Butachlor when applied alone failed to control weeds in fertilized plots, but controlled weeds effectively in the unfertilized ones (Table 12). When followed by hand weeding or propanil, either tank-mixed or sequentially applied, butachlor controlled weeds as effectively as two hand weedings.

Weed control treatment significantly affected dry-seeded rice yield (Table 13). The plots with butachlor followed by hand weeding had yields comparable to the yields of the twice-weeded plots. Plots where butachlor was applied alone had no yields except in the unfertilized plot tilled during the DS. In WFT plots, those treated with butachlor combined with propanil, either tank mixed or sequentially applied, had yields not significantly different from those of the twice-weeded plots. In the OMR plots, those treated with butachlor yielded lower than the twice-weeded plots.

E. colona, E. glabrescens, and *Echinochloa crus-galli* ssp. *hispidula* were the major weeds in transplanted rice and were not affected by N level or tillage method for the previous seeded rice. However, in the WFT plots, weed weights appeared higher for *E. colona* and lower for *E. crus-galli* at lower N rates. Total weed weight was higher when 120 kg N/ha was applied.

Total weed weight was not significantly affected by the fertilizer level, except in the butachlor-treated plot. Weed control was better when butachlor or 2,4-D was followed by one hand weeding.

Transplanted rice yield was low because of low rainfall late in the season. Significant yield reduction attributed to weeds was observed in OMR plots, but not in WFT plots (except in the unfertilized plot). In general, plots treated with butachlor and 2,4-D followed by one hand weeding had

Table 12. Weed weight 45 DE in rainfed, bunded DSR as affected by tillage and weed control treatment, IRRI, 1981 WS.

Weed control method	Weed wt (g/m^2)					
	WFT[a]			OMR[b]		
	0 kg N/ha	60 kg N/ha	120 kg N/ha	0 kg N/ha	60 kg N/ha	120 kg N/ha
2 HW 14 & 35 DE	13 d	13 c	7 c	24 d	28 c	21 c
Butachlor (2 kg ai/ha) PE	118 b	427 a	525 a	205 b	326 a	494 a
Butachlor (2 kg ai/ha) PE fb 1HW, 30 DE	16 d	15 d	38 b	28 d	25 c	32 c
Butachlor (2 kg ai/ha) + propanil (3 kg ai/ha), 7 DE	21 d	82 b	50 b	42 cd	62 c	102 b
Butachlor (2 kg ai/ha) PE fb propanil (3 kg ai/ha), 7 DE	54 c	96 b	40 b	78 c	112 b	134 b
No weeding	332 a	560 a	580 a	531 a	626 a	725 a

[a]WFT = plots kept weed-free with tillage during the DS. [b]OMR = land prepared after the onset of monsoon rains.

Table 13. Yield of dry-seeded rainfed, WS bunded IR36 as affected by tillage, N level, and weed control treatment. IRRI, 1982 WS.

Weed control method	Yield (t/ha)					
	WFT[a]			OMR[b]		
	0 kg N/ha	60 kg N/ha	120 kg N/ha	0 kg N/ha	60 kg N/ha	120 kg N/ha
2 HW 14 & 35 DE	3.9 a	4.1 a	4.2 ab	3.2 a	3.5 a	4.0 a
Butachlor (2 kg ai/ha) PE	1.6 c	0 d	0 c	0 d	0 c	0 c
Butachlor (2 kg ai/ha) PE fb 1 HW, 30 DE	3.4 b	3.5 c	3.9 b	3.2 a	3.5 a	3.8 a
Butachlor (2 kg ai/ha) + propanil (3 kg ai/ha), 7 DE	3.3 b	3.6 bc	4.1 ab	1.7 b	1.6 b	1.5 b
Butachlor (2 kg ai/ha) PE fb propanil (3 kg ai/ha), 7 DE	3.6 ab	3.9 ab	4.3 a	1.4 c	1.6 b	1.5 b
No weeding	0 d	0 d	0 c	0 d	0 c	0 c

[a]WFT = plots kept weed-free with tillage during DS. [b]OMR = land prepared after the onset of monsoon rains.

Table 14. Effect of weed control method on weed weight 50 DE and yield of dry-seeded rainfed bunded IR36. IRRI, 1981 WS.

Weed control method	Weed wt (g/m^2)	Yield (t/ha)
No weeding (check)	614 a	0.0 b
1 HW (21 DE)	97 c	1.5 a
2 HW (14 and 35 DE)	38 d	1.5 a
Butachlor + propanil	362 ab	0.4 b
Pendimethalin fb 2,4-D	284 b	0.3 b

similar yields to plots weeded twice.

Dry-seeded rainfed bunded rice - transplanted rice. Five weed control methods were tested in the 1981 WS:

- one hand weeding (1 HW), 21 DE;
- two hand weedings (2 HW), 14 and 35 DE;
- butachlor + propanil (1.5 kg + 1.5 kg ai/ha tank-mixed, applied 7-10 DE);
- pendimethalin fb 2,4-D (2.0 kg PE fb 0.5 kg 18-20 DE); and
- unweeded check.

In dry-seeded rice (DSR), twenty 5- × 8-m plots laid out in a randomized complete block design with four replications were used. In transplanted rice (TPR), the same plots were halved — one half was left unweeded or untreated; the other was treated with the same weed control methods used in the DSR. Land preparation (one plowing + two harrowings) and fertilizer application 100-18-33 kg (N, P, K)/ha were the same for both crops.

The four major weed species in DSR and their dominance varied with weed control method used. *E. colona* dominated all plots except the pendimethalin fb 2,4-D plots. *E. colona* was more dominant in the hand-weeded plots than in the unweeded or herbicide-treated plots. *Rottboellia exaltata* dominated in the herbicide-treated plots and the unweeded check. *Cyperus rotundus* predominated in the pendimethalin fb 2,4-D and 2 HW plots. There were more weed species in the hand-weeded plots.

Two hand weedings significantly reduced weed weight at 50 DE compared with the other treatments. Pendimethalin fb 2,4-D controlled weeds better than butachlor + propanil (Table 14). Rice yields were significantly higher in the hand-weeded plots.

When no weed control was done in the TPR, *Ludwigia octovalvis* dominated the plots that were either left unweeded or treated with butachlor + propanil. It was the least important weed in the DSR. In both crops, *E. colona* was the second most dominant in the unweeded plots, but the most dominant in the previously hand-weeded plots. *F. littoralis* dominated only in plots previously treated with pendimethalin fb 2,4-D. *Lindernia* sp. tended to increase in plots previously treated with butachlor + propanil (Table 15).

When the same weed control as that in the preceding crop was used in the TPR, *E. colona* still dominated in the hand-weeded plots. *Cyperus difformis* infestation was high in pendimethalin fb 2,4-D plots whereas, *Lindernia* sp. dominated in 2 HW and butachlor +propanil plots.

At 50 DT, plots given the same treatments as in

Table 15. Importance value of weed species composing the weed flora in TPR 50 DT as affected by weed control methods in the preceding rainfed, bunded DSR and weed control method in TPR. IRRI, 1981 late WS.

Weed species	Importance value (%) when preceding crop received				
	No weeding (check)	1 HW (21 DE)	2 HW (14 & 35 DE)	Butachlor + propanil	Pendimethalin fb 2,4-D
No weeding in transplanted rice					
Ludwigia octovalvis	29.5	10.0	15.5	22.5	18.4
Echinochloa colona	24.6	27.7	42.0	12.9	10.4
Fimbristylis littoralis	12.6	16.0	13.6	9.2	26.7
Echinochloa glabrescens	3.7	20.2	8.4	16.1	3.8
Lindernia sp.	1.5	2.0	0	15.0	7.6
Others[a]	28.1 (12)	23.9 (11)	20.5 (12)	24.3 (12)	33.1 (10)
			Total no. of species		
	17	16	16	17	15
Weed control same as in preceding crop					
Ludwigia octovalvis	29.5	18.4	15.5	0.3	4.3
Echinochloa colona	24.6	27.7	25.3	14.2	5.3
Fimbristylis littoralis	12.6	17.7	7.2	3.6	9.6
Eclipta alba	5.7	1.8	3.9	17.5	6.1
Cyperus difformis	3.3	0.3	0	9.5	29.2
Lindernia sp.	1.6	13.5	32.3	34.0	16.3
Others[a]	22.7 (11)	20.6 (7)	15.8 (8)	21.1 (6)	29.2 (9)
			Total no. of species		
	17	13	13	12	15

[a]Values in parentheses are the number of species composing less than 10% of the weed flora.

Table 16. Weed weight 50 DT and yield of rainfed transplanted IR50 as affected by weed control in the previous dry-seeded crop and weed control method in transplanted rice. IRRI, 1981 late WS.

Weed control in previous dry-seeded rice	No weed control in transplanted rice[a]	Same weed control as in dry-seeded rice[a]	Mean[b]
		Weed wt (g/m^2)	
No weeding	156	156	156 a
1 HW (21 DE)	162 a	68 a	115 ab
2 HW (14 and 35 DE)	211 a	26 b	118 bc
Butachlor + propanil	150 a	54 a	102 bc
Pendimethalin fb 2,4-D	114 a	47 b	81 c
		Yield (t/ha)	
No weeding	0.1	0.1	0.1 b
1 HW (21 DE)	0.3 a	0.4 a	0.3 ab
2 HW (14 and 35 DE)	0.5 b	1.0 a	0.8 a
Butachlor + propanil	0.2 b	0.8 a	0.5 ab
Pendimethalin fb 2,4-D	0.4 a	0.8 a	0.6 ab

[a]Separation of means in a row by Duncan's Multiple Range Test at the 5% level. [b]Separation of means in a column by Duncan's Multiple Range Test at the 5% level.

DSR had significantly lower weed weights than the unweeded plots. Pendimethalin fb 2,4-D suppressed weeds in TPR better than butachlor + propanil and hand weeding, but it did not result in a significant yield increase. Generally, yields in treated plots were significantly higher. Only 2 HWs resulted in a significantly higher yield than the unweeded check (Table 16).

Major weeds in the DSR such as *R. exaltata, C. rotundus,* and *Cleome rutidosperma* were the least important weeds in TPR. The least important weeds in DSR such as *L. octovalvis, F. littoralis, Eclipta alba, C. difformis,* and *Lindernia* sp. became the major weeds in TPR. The weed control method affected their dominance. *E. colona* was the only weed that predominated in both crops and

Table 17. Effect of weeding regime on the relative dry weight of two major weed species, total dry weed weight, and yield of dryland rice grown in rotation with mungbean. IRRI, 1982.

Regime	Relative dry wt (%) 2 WE		Total dry weed wt (g/m^2)		Dryland rice (yield (t/ha)
	Rottboellia exaltata	*Cyperus rotundus*	2 WE	11 WE	
		1980			
Weedy fallow	26	63	95	508	–
Weed free[a]	38	53	165	7	2.4
1 HW	14	70	113	214	1.6
2 HW	17	67	162	45	0.8
Pendimethalin fb 2,4-D	–	91	50	220	0.7
		1981			
Weedy fallow	93	7	312	1252	–
Weed free[a]	30	58	60	4	0.2
1 HW	74	24	163	344	0.2
2 HW	41	46	93	38	0
Pendimethalin fb 2,4-D	–	99	100	221	0.1
		1982			
Weedy fallow	82	17	28	1135	–
Weed free[a]	4	82	5	17	1.8
1 HW	45	50	16	755	0
2 HW	9	81	7	346	0
Pendimethalin fb 2,4-D	27	67	18	950	0

[a]Three hand weedings in rice, two hand weedings in mungbean.

became a major component of the weed flora in the hand-weeded plots. However, it was suppressed by herbicide application.

The shift in weed dominance in the DSR - TPR cropping sequence was greatly influenced by the weed control method, puddling, and moisture condition after planting and throughout crop growth.

Rice-based cropping systems. *Continuous use of same weed control practice.* During the 1980 WS at IRRI, a study was initiated to determine the effect of the continuous use of the same weed control practice on the weed population in a dryland rice - mungbean pattern. Five weeding treatments (Table 17) were maintained in each plot until the 1982-83 cropping season.

The weed flora changed. In dryland rice, the annual grass *R. exaltata* dominated the weedy fallow plot during the second and third years (Table 17). When the plot was kept weed free by three hand weedings in rice and two hand weedings in mungbean, the *R. exaltata* population was almost eliminated during the third year. However, *C. rotundus, Ipomoea triloba, Eleusine indica, Dactyloctenium aegyptium,* and some broadleaf weeds took over, although their total weight was kept low by the hand weedings.

Two hand weedings reduced the proportion of *R. exaltata* more than one hand weeding. The change in the weed flora in the twice-hand weeded plots was similar to that in the weed-free plot. Continuous herbicide application resulted in *C. rotundus* build-up. However, in 1982, *R. exaltata* made up 27% of the weed flora later in the season because pendimethalin failed to completely control the weed because of dry soil condition.

Severe drought in 1981 caused extremely low rice yields. In 1982, occasional moisture stress and tremendous weed growth reduced yield to zero in all but one treatment.

Tillage and weeding requirement of maize and mungbean after dryland rice. The importance of the degree of weeding in the rice crop and tillage method for the establishment of maize and mungbean after rice was studied. The conventional tillage plot had significantly fewer weeds than the zero-tillage plot. Without weeding, conventionally tilled plots that were adequately weeded previously had significantly fewer weeds. No residual effect of the previous weeding regimes was observed in the

Table 18. Effect of previous weeding treatment and tillage method on maize and mungbean yield planted after dryland rice. IRRI, 1980 late WS.

Weeding treatment in rice crop	Yield (t/ha) when previous rice crop received					
	Zero tillage			Conventional tillage		
	Weeded	Unweeded	Difference	Weeded	Unweeded	Difference
			Maize			
1 HW	1.3 b	1.1 a	0.2^{ns}	1.3 a	1.1 b	0.2^{ns}
2 HW	1.4 b	1.1 a	0.3^{ns}	1.5 a	1.0 b	0.5**
No weeding	1.7 a	1.2 a	0.5**	1.5 a	1.4 a	0.1^{ns}
			Mungbean			
1 HW	1.1 a	0.4 a	0.7**	1.5 b	1.7 a	0.2^{ns}
2 HW	1.3 a	0.7 a	0.6*	1.8 a	1.4 a	0.4^{ns}
No weeding	0.6 b	0.4 a	0.2^{ns}	0.7 c	0.4 b	0.3^{ns}

Table 19. Effect of DS cultural practices and degree of tillage on weed growth and dryland rice yield. IRRI, 1982.

Dry-season cultural practice	Weed count at 14 DE (no./m^2)	Weed wt at 14 DE (g/m^2)	Weeding time (man-h/ha)	Rice yield[a] (t/ha)	
				One plowing fb one rotovation	One plowing fb three rotovations
Maize	380 c	56 b	1104 a	1.4 a	1.8 a
Mungbean	420 c	84 ab	1037 a	1.1 ab	1.4 b
Fallow with paraquat (0.75 kg ai/ha)	612 a	155 a	1381 a	0.7 bc	1.0 c
Weedy fallow	522 b	121 a	1244 a	0.4 c	1.0 c

[a]Av of three replications and six weed control treatments.

zero-tillage plot.

In general, maize planted after rice needed no weeding for optimum yield and mungbean planted in conventionally tilled plot needed no weeding when the preceding rice crop was adequately weeded (Table 18). The zero-tillage mungbean plot required weeding for optimum crop yield. When planted in a previously unweeded plot, the mungbean stand and growth were poor and yield was very low.

Dryland rice. *Dry-season management practices, tillage, and weed control.* The response of weeds and dryland rice yield to cultural management practices during the preceding DS was examined during the 1982 WS at the IRRI dryland farm. During the DS, the plots were planted to maize, planted to mungbean, left fallow with weed control (paraquat at 0.75 kg ai/ha), or left fallow without weed control. Two tillage levels and six weed control treatments were used on the dryland rice crops following the four cultural practices.

The dominant weed species were *C. rotundus, R. exaltata, E. indica,* and *Digitaria* sp.

Plots planted to maize or mungbean during the previous DS had a significantly lower weed density and biomass at 14 DE than the fallow plots (Table 19). Tillage treatments for rice after each cultural practice had no significant effect on weed growth. However, yields were better in plots rotovated three times than in those rotovated once.

With adequate weed control for the rice crop, the average yields from plots previously planted to maize or mungbean were generally higher than those from the fallow plots, indicating that DS cropping is beneficial to the succeeding WS dryland rice crop.

Time and degree of both land preparation and weed control. At the IRRI farm, the effect of time and degree of both land preparation and weed control on weed population and dryland rice yield was investigated.

DS plowing commenced after the harvest of the last crop. WS land preparation was done 1 DBS. All plots were rotovated once 1 DBS. Five weed control treatments (subplot) were applied on each of the main plots.

The relative abundance of the weed species was affected by the time and degree of land preparation. Dry-soil plowing followed by three rototillings — two dryland and one at 1 DBS — reduced the proportion of *C. rotundus* but enhanced the growth of *I. triloba* (Table 20). With only one rototilling 1 DBS following dryland plowing, the proportional change of the two species was minimal. Surprisingly, the *Digitaria* sp. population was substantially reduced by this tillage treatment. Increasing the rotovations from one to three in the WS did not alter the balance between the major weed species.

Staggered intensive rototilling from DS to WS resulted in heavier weed growth 2 WE than rototilling at one time regardless of the intensity. However, average yield across weeding treatments due to staggered rotovations was better than that of the other tillage treatments. All herbicide treatments yielded significantly more than the untreated check.

Mungbean. Several treatments involving herbicides such as PPG-844, pendimethalin, and bentazon, applied either alone or in combination using two rates, were tested for weed control in mungbean at the IRRI dryland area. Interrow cultivation followed by hand weeding and hand-weeded and untreated checks were also included.

The area was initially infested with *R. exaltata.* Major weeds appearing later were *C. rotundus, Commelina diffusa,* and *C. benghalensis.*

Both PPG-844 and pendimethalin were slightly toxic to mungbean, but the crop recovered. PPG-844 applied PE at 2.0 kg ai/ha adequately controlled weeds, except *C. rotundus*; the yields were similar to that of the hand-weeded check (Table 21). At a reduced rate (1.0 kg ai/ha), PPG-844 followed by bentazon was not effective against *R. exaltata* and resulted in lower yields.

Pendimethalin at both 1.0 and 1.5 kg ai/ha controlled *R. exaltata* effectively, but yields were low because of later infestation of broadleaf weeds (*Commelina* sp.). A significant yield increase was obtained with pendimethalin (1.0 kg ai/ha) followed by bentazon at 1.0 kg ai/ha.

Interrow cultivation followed by hand weeding resulted in significantly lower yield than the hand-weeded check because the late weeding (33 DE) damaged the mungbean plants.

The results suggest that in a diverse weed situation, effective weed control can be achieved with the proper herbicide and other weed control combinations applied at the right mungbean growth stage.

In the Solana, Cagayan trials, *C. rotundus* and *E. colona* were the predominant weed species in the rainfed wetland experimental fields.

In one experiment, there were no significant differences in mungbean yield among the different weed control treatments although there were differences in weed weights. This could be due to moisture stress that hit the crop during the vegetative stage. Dry weed weights at 30 and 75 DE indicated that hoe weeding at 14 DE followed by spot weeding 2 d later provided inadequate weed control. Hand weeding at 10 and 25 DE gave the lowest dry weights at 30 and 75 DE which the grain yield did not reflect. Butachlor applied at 1.5 kg ai/ha 1 DE with or without a follow-up hand weeding, and two hand weedings at 75 DE provided

Table 20. Effect of time and degree of land preparation in dryland rice on the relative dry weight of the three major weed species and on the total dry weed weight 2 WE. IRRI, 1982.

Tillage treatment	Relative dry wt (%)			Total dry weed wt (g/m^2)
	Cyperus rotundus	*Digitaria* sp.	*Ipomoea triloba*	
One dryland plowing fb one rotovation 1 DBS	42	14	9	28 b
One plowing + one rotovation 1 DBS	53	41	2	33 b
One dryland plowing fb two dryland rotovations fb one rotovation 1 DBS	23	37	21	53 a
One plowing + three rotovations 1 DBS	57	31	2	25 b

Table 21. Effect of different weed control treatments on weed density, weed dry matter, and mungbean yield. IRRI, 1982 WS.

Treatment[a]	Time of application	Weeds present[bc] (at flowering stage of grasses)						Yield[b] (kg/ha)
		Broadleaf weeds		Grasses		Sedges		
		Density (no./m^2)	Dry matter (g/m^2)	Density (no./m^2)	Wt (g/m^2)	Density (no./m^2)	Wt (g/m^2)	
2 HW (check)	10 + 20 DE	61 a	14 cd	16 bc	5 c	416 a	82 d	1277 a
PPG-844 (2 kg ai/ha)	PE	1 d	0 d	5 cd	15 c	405 ab	206 abc	1158 a
Pendimethalin (1 kg ai/ha) fb bentazon (1 kg ai/ha)	PE fb 10 DE	67 a	18 c	21 bc	65 bc	352 bc	78 d	617 b
IRC fb hand weeding	10 fb 33 DE	45 a	29 bc	15 c	11 c	274 ab	118 bc	378 c
Pendimethalin (1 kg ai/ha)	PE	56 a	181 a	3 d	27 c	524 a	378 a	360 cd
Pendimethalin (1 kg ai/ha) fb bentazon 0.75 kg ai/ha	PE fb 10 DE	91 a	60 ab	3 d	22 c	371 ab	174 b	320 cde
Pendimethalin (1.5 kg ai/ha)	PE	75 a	119 ab	2 d	6 c	521 a	218 ab	282 cde
PPG-844 (1 kg ai/ha) fb bentazon (0.75 kg ai/ha)	PE fb 10 DE	9 c	5 d	44 ab	318 ab	383 ab	105 cd	160 def
PPG-844 (1 kg ai/ha) fb bentazon (1 kg ai/ha)	PE fb 10 DE	7 cd	2 d	31 c	380 ab	249 ab	71 d	132 ef
Untreated check	–	21 b	10 cd	167 a	778 a	187 b	72 d	0 f

[a]IRC = interrow cultivation using hand hoe. [b]Av of three replications. [c]*Commelina benghalensis, Rottboellia exaltata,* and *Cyperus rotundus* were the dominant broadleaf weed, grass, and sedge, respectively.

comparable weed control.

In another experiment, three seeding rates and four weed control treatments were compared at two spacings. At the 50-cm spacing, interrow cultivation (using animal-driven plow) followed by hand weeding was used while at the 30-cm spacing, butachlor at 1.5 kg ai/ha was applied because at closer spacings serious crop damage results from interrow cultivation.

Weed weights at 45 DE in the unweeded plots did not differ significantly among the three seeding rates (15, 20, and 25 kg/ha) at both the 30- and 50-cm spacings (Table 22). At the 30-cm spacing with no weeding, the yield at the 25-kg/ha seeding rate was significantly higher than the yields at the other seeding rates. Dissimilar results were obtained at the 50-cm spacing. This indicates that mungbean is more competitive with weeds at higher seeding rates and at closer row spacings.

Significant differences in yields between the weeded and unweeded treatments at all seeding rates suggest that, at the 30-cm spacing and 25-kg/ha seeding rate, weeding is still necessary to avoid appreciable yield loss.

Butachlor (1.5 kg ai/ha) application at 1 DE and interrow cultivation with an ordinary plow at 14 DE followed by hand weeding at 16 DE did not consistently give good results. One hand weeding 14 DE generally provided the weed control necessary for optimum mungbean yield.

Herbicide screening in dryland crops. The effects of different PE herbicides on weed control and yield of some dryland crops were evaluated during the WS.

The major weeds were *R. exaltata, Digitaria* sp., *E. colona, Celosia argentea,* and *C. benghalensis.*

All herbicides adequately controlled *Digitaria* sp. and *E. colona* (Table 23). However, only fuazifop - butyl and PPG-844 provided acceptable *R. exaltata* control. Sethoxydim, thiobencarb, and butachlor were ineffective against this weed, which became dominant later. Consequently, yields of all crops treated with fluazifop - butyl and PPG-844 were significantly higher than yields of those treated with sethoxydim, thiobencarb, and butachlor.

The tremendous population build-up of *R. exaltata* in plots treated with sethoxydim, thiobencarb, and butachlor resulted in zero rice yield and very low mungbean and soybean yields.

Except where fluazifop - butyl was applied at 7 DE, yields of the leafy and more competitive mungbean treated with fluazipop - butyl at 14 DE and PPG-844 at PE were similar to the yield of the

Table 22. Dry weed weight and mungbean yield as affected by weed control practice and seeding rate at two spacings. Solana, Cagayan, Philippines, 1982.

Seeding rate, weed control practice	Time of application (DE)	Dry weed wt (g/m^2) 45 DE		Yield (t/ha)	
		30 cm	50 cm	30 cm	50 cm
15 kg/ha					
Weedy check	–	115 ab	93 a	1.1 d	1.0 c
1 HW	14	77 b	66 a	1.4 c	1.1 b
2 HW	10 and 25	59 b	80 a	1.4 c	1.3 a
Butachlor, 1.5 kg ai/ha	1	180 a	–	1.3 c	–
Interrow cultivation fb 1 HW	14 fb 16	–	83 a	–	1.1 b
20 kg/ha					
Weedy check	–	117 a	144 a	1.1 d	0.9 c
1 HW	14	87 ab	116 ab	1.2 cd	1.2 b
2 HW	10 and 25	47 b	53 b	1.3 c	1.2 b
Butachlor, 1.5 kg ai/ha	1	134 a	–	1.3 c	–
Interrow cultivation fb 1 HW	14 fb 16	–	96 b	–	1.0 c
25 kg/ha					
Weedy check	–	107 a	116 a	1.3 c	1.0 c
1 HW	14	109 a	66 a	1.6 ab	1.3 ab
2 HW	10 and 25	43 b	43 b	1.8 a	1.5 a
Butachlor, 1.5 kg ai/ha	1	169 a	–	1.5 bc	–
Interrow cultivation fb 1 HW	14 fb 16	–	63 ab	–	1.1 bc

Table 23. Effects of different liquid herbicides on weed control, crop tolerance, and yield of dryland crops grown under rainfed conditions. IRRI, 1982 WS.

Herbicide treatment	Time of application	Total weed weight[b] (g/m²)			Visual toxicity rating[c]			Yield[b] (t/ha)		
		Rice	Mungbean	Soybean	Rice	Mungbean	Soybean	Rice	Mungbean	Soybean
Thiobencarb (1 kg ai/ha)	PE	439 ab	217 a	250 a	0	0	0	0 d	0.1 c	0.1 d
Thiobencarb (2 kg ai/ha)	PE	396 ab	196 a	206 a	0	0	0	0 d	0.2 c	0.1 d
Sethoxydim (0.5 kg ai/ha)	PE	637 a	166 a	256 a	4	0	0	0 d	0.1 c	0.1 d
Sethoxydim (1 kg ai/ha)	PE	580 ab	173 a	201 a	10	0	1	0 d	0.2 c	0.1 d
Fluazifop - butyl[a] (0.05/0.25 kg ai/ha)	7 DE	55 d	60 b	63 b	0	0	0	0.8 b	0.6 b	0.7 c
Fluazifop - butyl[a] (0.05/0.25 kg ai/ha)	14 DE	134 c	24 c	24 b	0	0	0	0.5 c	1.1 a	1.0 b
PPG-844 (1.5 kg ai/ha)	PE	54 d	16 c	46 b	8	6	7	0.5 c	1.0 a	0.7 c
Butachlor (1.5 kg ai/ha)	PE	468 ab	200 a	319 a	4	4	1	0 d	0.1 c	0.1 d
2 HW (check)	15 + 30 DAS	7 e	4 d	3 c	0	0	0	1.7 a	1.2 a	1.4 a
Untreated check	–	303 b	352 a	261 a	0	0	0	0 d	0.1 c	0.1 d

[a]For rice, rate used was 0.05 kg ai/ha and for mungbean and soybean was 0.25 kg ai/ha. [b]Av of three replications. [c]Rated 1 wk after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

hand-weeded check. The herbicide-treated rice plots, which were reinfested with broadleaf weeds, yielded about 62% less than the hand-weeded check.

PPG-844 had a temporarily toxic effect on all crops. Sethoxydim was very toxic to rice.

Weed ecology and biology. *Flooding tolerance of two ecotypes of* Cyperus rotundus. Three greenhouse trials were conducted to determine the effects of different depths and times of submergence on growth and development of two *C. rotundus* ecotypes.

The first trial, in June and July 1980 used a split-plot design, with dryland and wetland ecotypes in the main plots and different flooding times (0, 7, and 14 DE) and flooding depths (2, 4, and 6 cm) in the subplots. Each treatment was replicated four times. Five tubers were planted in 6-liter plastic buckets two-thirds full of ground and sieved Maahas clay loam soil. Plants were measured weekly and harvested at 4 WE.

Two randomized complete block design experiments (trials 2 and 3) were conducted from November 1981 to February 1982. For trial 2, tubers of dryland ecotypes were collected from the IRRI experimental farm and tubers of wetland ecotypes from Pasig, Manila. For trial 3, tubers of both ecotypes were collected from Pasig.

The tubers were flooded at 0, 7, 14, 21, and 28 DE. A constant depth of 4 cm was maintained in both experiments. Treatments were replicated six and four times, respectively. Five tubers were planted in each bucket.

In both trials, weekly plant heights were measured for 2 mo. At 8 WE, the plants were harvested. Dry weights of shoots, roots, and tubers were measured and total number of shoots, offshoots, and tubers produced by parent tubers were counted.

Under submerged conditions, a marked difference existed between the wetland and dryland ecotypes. Established wetland ecotype plants produced taller shoots (Table 24) and accumulated higher dry matter in all their parts than established dryland ecotypes (Fig. 3). However, tubers of both ecotypes could not produce shoots once they were submerged.

Although early submergence reduced growth of dryland ecotypes, it favored growth of the wetland ecotypes (Table 24). When submergence was de-

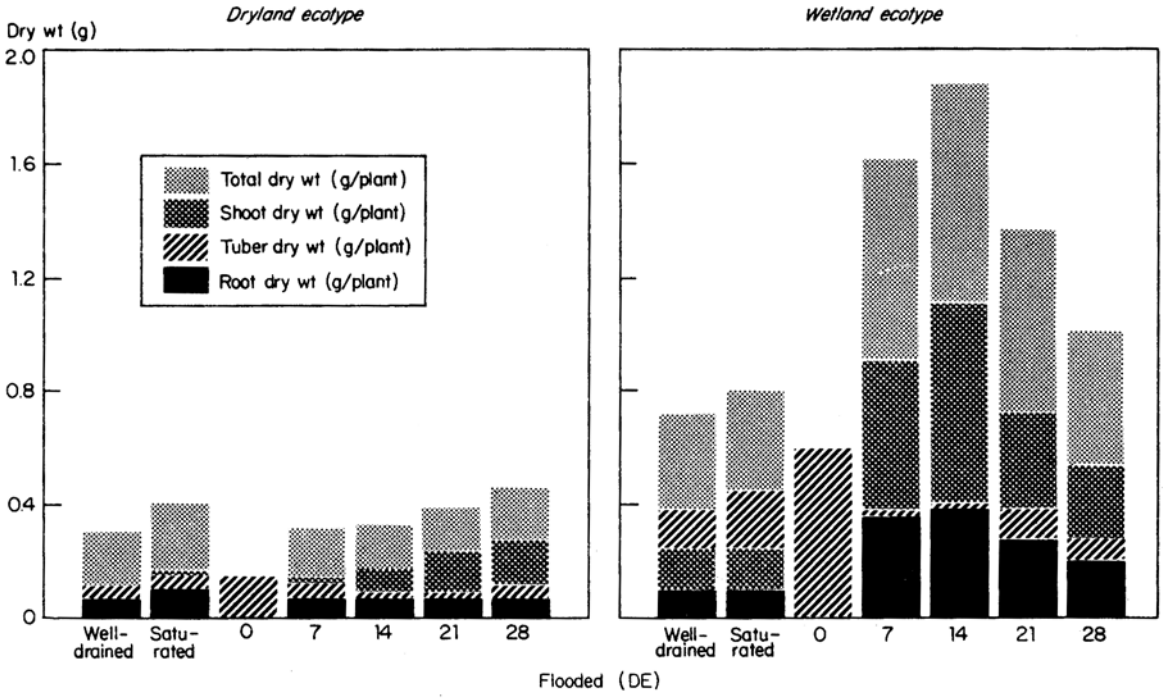
layed or deleted, vegetative and reproductive growth of the wetland ecotype plants were restricted.

Furthermore, submergence within 2 WE favored the growth and development of the wetland ecotypes; submergence 4-7 WE had little or no effect on the growth of the dryland ecotypes.

Differential competitive ability of Echinochloa colona *ecotypes and rice cultivars.* Two greenhouse experiments were conducted to determine the ecotypic differentiation of *E. colona* in competition with rice. Pangasinan (PA), Leyte (LE), and South Cotabato (SC) ecotypes were planted with rice (C171-136) at four weed:rice density combinations of 0:6, 2:4, 4:2, and 6:0.

The competitiveness of rice and *E. colona* was expressed by their relative crowding coefficients computed at each density combination with respect to rice (Kwr) or *E. colona* (Krw).

As the competition between rice and *E. colona* ecotypes continued, Krw decreased with corre-



3. Effect of time of flooding on root, tuber, shoot, and total dry weight of two ecotypes of *Cyperus rotundus.* IRRI, 1982.

Table 24. Effect of time of flooding on plant height of two ecotypes of *Cyperus rotundus* at 8 WE. IRRI, 1982.

Treatment	Plant ht[a] (cm)					
	Trial 2			Trial 3		
	Dryland	Wetland	Difference	Dryland	Wetland	Difference
Well-drained	18 a	35 c	−17*	23 ab	39 c	−15**
Saturated	20 a	34 c	−14ns	23 ab	36 c	−13*
Flooded, 7 DE	18 a	85 a	−67**	13 b	70 ab	−57**
Flooded, 14 DE	25 a	85 a	−60**	24 a	72 a	−48**
Flooded, 21 DE	24 a	72 ab	−48**	33 a	69 ab	−36**
Flooded, 28 DE	27 a	67 a	−40**	27 a	60 b	−33**
Mean	22	63		24	58	

[a]Av of four replications.

sponding increases in Kwr (Table 25). This indicated that the competitive ability of rice decreased as the competitive ability of *E. colona* increased. However, the competitiveness of each ecotype against rice varied depending on growth stage. Although the Kwr of PA was greater than 1 at all sampling times, the Kwr values of SC and LE became greater than 1 at 30 and 35 DAS, respectively.

On the other hand, higher Kwr values were obtained with SC at 60 DAS. An *E. colona* ecotype, which completes its life cycle within a short period was more competitive at the early growth stage than one with a longer vegetative growth period, and vice versa.

To evaluate the competitiveness of rice cultivars on *E. colona*, Binato and IR52 were sown with *E. colona* ecotype IG (with a green seed coat found at

Table 25. Relative crowding coefficient in interspecific competition between rice cultivars and *Echinochloa colona* ecotypes 15-60 DAS, IRRI, 1982.

Rice: weed density combination	Krw[a]				Kwr[b]			
	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Weed ecotypes[c]								
Pangasinan								
4:2	0.96	0.88	0.82	0.60	1.04	1.14	1.22	1.68
2:4	0.96	0.74	0.72	0.56	1.04	1.36	1.40	1.80
Leyte								
4:2	1.11	1.04	0.66	0.67	0.90	0.96	1.50	1.48
2:4	1.08	1.20	0.62	0.58	0.93	0.83	1.62	1.73
South Cotabato								
4:2	1.21	0.87	0.56	0.36	0.83	1.15	1.80	2.74
2:4	1.11	0.77	0.56	0.60	0.90	1.30	1.80	1.68
Rice cultivars[d]								
Binato								
4:2	0.80	1.04	1.95	0.78	0.25	0.97	0.51	0.27
2:4	0.83	1.51	1.83	0.89	1.20	0.66	0.55	1.13
IR52								
4:2	1.29	1.31	1.30	1.83	0.78	0.76	0.77	0.55
2:4	1.45	1.08	1.12	1.50	0.69	0.93	0.89	0.67

[a]Relative crowding coefficient of rice with respect to *E. colona*. [b]Relative crowding coefficient of *E. colona* with respect to rice. [c]Planted with rice cultivar C171-136. [d]Planted with an *E. colona* ecotype with a green seed coat found at IRRI.

Table 26. Effect of interspecific competition on accumulative tiller length of rice cultivars and *Echinochloa colona*, IRRI, 1982.

Rice: weed density combination	Accumulative tiller length (cm/plant)			
	Rice		*E. colona*	
	45 DAS	60 DAS	45 DAS	60 DAS
Binato				
6:0	4 b	127 a	–	–
4:2	12 a	72 b	9 b	189 a
2:4	16 a	80 b	7 b	177 a
0:6	–	–	40 a	174 a
IR52				
6:0	40 a	186 a	–	–
4:2	42 a	209 a	25 b	150 b
2:4	36 a	181 a	45 a	152 b
0:6	–	–	37 ab	181 a

Table 27. Butachlor and thiobencarb germination inhibition of *Echinochloa colona* ecotypes. IRRI, 1982.

Ecotype	Inhibition of germination (% of control)			
	Butachlor		Thiobencarb	
	1 ppm	3 ppm	1 ppm	3 ppm
Cagayan	0 c	4 bc	4 a	3 b
Pangasinan	15 b	14 ab	0 a	3 b
Nueva Ecija	0 c	0 c	0 a	0 b
IRRI (green)	2 c	7 bc	0 a	1 b
IRRI (red)	0 c	6 bc	1 a	0 b
Batangas	37 a	22 a	3 a	13 a
Camarines Sur	12 bc	12 abc	3 a	0 b
Iloilo	3 c	4 bc	3 a	0 b
Leyte	3 c	3 bc	4 a	0 b
Bukidnon	4 bc	2 bc	0 a	0 b
Zamboanga del Sur	8 bc	0 c	1 a	0 b
South Cotabato	5 bc	5 bc	1 a	1 b

IRRI) at rice:weed density combinations of 0:6, 2:4, 4:2, and 6:0.

The two cultivars had different competitive abilities against *E. colona*, which depended on the form and stage of growth. The maximum competitive ability of Binato, a taller cultivar with shorter accumulative tiller length, occurred from 30 to 45 DAS and then decreased and that of IR52, a dwarf cultivar with longer accumulative tiller length, occurred from 45 to 60 DAS (Table 25). The decrease in competitive ability of Binato was attributed to its shorter accumulative tiller length than that of *E. colona*. On the other hand, IR52's longer accumulative tiller length and its greater leaf area increased its competitive ability (Table 26). This suggested that accumulative tiller length is important in competition between rice and *E. colona*.

Response of Echinochloa colona *ecotypes to herbicides*. Responses of 12 *E. colona* ecotypes to PE (butachlor and thiobencarb) and postemergence (propanil) herbicides were determined in three greenhouse experiments. Concentrations of 1 and 3 ppm were used for the PE herbicide solutions.

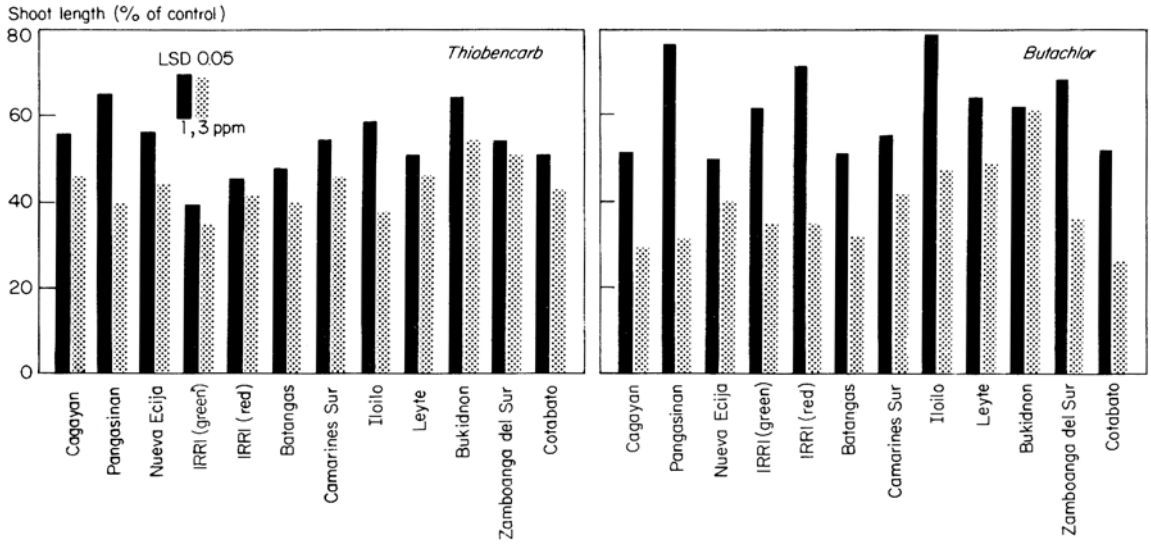
Butachlor significantly reduced germination in some ecotypes, especially BA at both concentrations (Table 27). Butachlor slightly inhibited PA and CS germination. Except for BA treated with 3 ppm, thiobencarb did not significantly inhibit germination of the ecotypes. BA appeared to be the most susceptible to both butachlor and thiobencarb; BU, was the most tolerant.

Butachlor-affected variations in shoot length of the germinating seeds were more pronounced than germination inhibition (Fig. 4). The ecotypes showed greater response variations to the 1 ppm than to the 3 ppm butachlor concentration. At 3 ppm, severe shoot length inhibition was observed on all the ecotypes, except BU. Of the ecotypes, SC was the most susceptible to 3 ppm butachlor. PA, IL, and BU appeared to tolerate 1 ppm thiobencarb; IRRI (green), was the most susceptible (Fig. 4).

To evaluate ecotype response to propanil, the second leaf of 10-d-old seedlings and the third leaf of 20-d-old seedlings of each ecotype was dipped into a 250-ppm propanil solution for 5 s. The plants were grown in nutrient solutions for 48 h, then harvested to measure the necrotic length in the

Table 28. Effect of propanil on necrotic length of *Echinochloa colona* ecotypes. IRRI, 1982.

Ecotype	Necrotic length (mm)	
	2nd leaf	3rd leaf
Cagayan	25 abc	0 b
Pangasinan	23 abc	7 b
Nueva Ecija	22 abc	2 b
IRRI (green)	26 abc	8 b
IRRI (red)	29 ab	21 a
Batangas	21 bc	0 b
Camarines Sur	31 a	28 a
Iloilo	23 abc	23 a
Leyte	20 bc	7 b
Bukidnon	24 abc	2 b
Zamboanga del Sur	20 bc	6 b
South Cotabato	19 c	24 a



4. Effect of PE-applied butachlor and thiobencarb on shoot length of *Echinochloa colona* ecotypes. IRRI, 1982.

herbicide-treated leaf.

Ecotype susceptibility to propanil was greater with the older seedlings (Table 28). With old seedlings, however, the intraspecific variation in susceptibility of the ecotypes may be more pronounced. Necrotic lengths did not differ significantly among the second leaves of 10-d-old seedlings, but differed significantly among the third leaves of 20-d-old seedlings of CS, IL, and IRRI red.

These results indicated intraspecific differences in herbicide susceptibility among ecotypes. The susceptibility may vary depending on the physical and morphological growth stages. In addition, different herbicides and concentrations may induce different ecotype responses.

Cropping systems program

Design and evaluation of cropping systems

Multiple Cropping and Entomology Departments

THE SOLANA CROPPING SYSTEMS RESEARCH PROGRAM **404**
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THE SOLANA CROPPING SYSTEMS RESEARCH PROGRAM

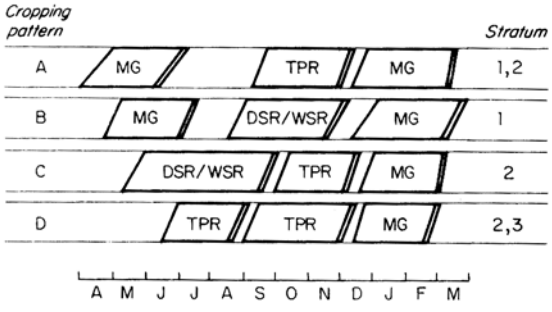
Multiple Cropping and Entomology Departments

Cropping patterns tested in 1981-82 *(Multiple Cropping).* Cropping pattern designs were based primarily on expected water regimes in three strata. The three strata were arbitrarily delineated on a broad alluvial terrace, with the delineation being determined by tendencies to drought or flooding. Stratum 1 is prone to drought, stratum 3 is prone to flooding, and stratum 2 is intermediate to these extreme conditions.

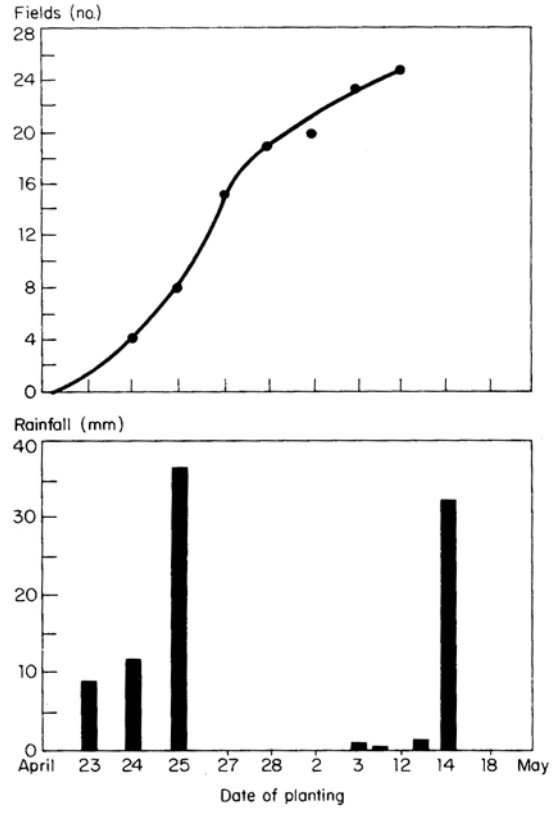
Twenty-five cooperating farmers with land in strata 1 or 2 were asked to plant pattern A (mungbean - TPR - mungbean) or pattern B (mungbean - DSR/WSR - mungbean) (Fig. 1). These patterns differed only in the planting method of the rice crop.

Twenty-three of the 25 mungbean fields were seeded within 10 d of a 58-mm rainfall during 23-25 Apr (Fig. 2). However, 5 of 11 plantings failed in stratum 1 and three of six failed in stratum 2 because flooding started 7 wk after the first planting. Mean yield from the first stratum was 0.5 t/ha. Flooding reduced second stratum mean yield by more than 50%. More intense flooding attributed to poor surface drainage caused higher yield reductions in the lower intermediate terrain (stratum 2). Regardless of field location, surface water was deeper and flood durations longer in failed fields than in harvested fields (Fig. 3).

After mungbean, rice was transplanted in 24 fields. Five fields were originally intended for wet



1. Proposed cropping patterns for different strata. Solana, Cagayan, Philippines, 1981-82. MG = mungbean, TPR = transplanted rice, DSR = dry-seeded rice, WSR = wet-seeded rice.

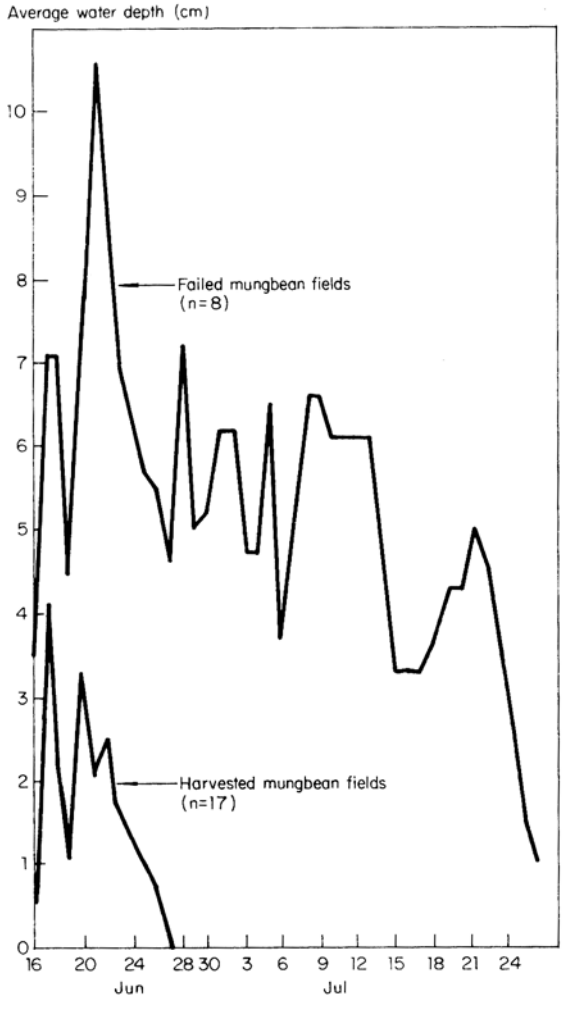


2. Daily rainfall and mungbean seeding dates. Solana, Cagayan, Philippines, 1981.

or dry direct seeding; however, standing water at planting time made transplanting the only choice. Because pattern B could not planted in 1982, the agronomic feasibility of this pattern for environments similar to Solana's is in doubt.

One of four rice varieties was planted in each of 18 fields in strata 1 and 2. The six remaining fields were divided and planted with two varieties. All fields were harvested; mean yields of varieties are given in Table 1. In stratum 1, IR46 outyielded IR52. In stratum 2, IR52 outyielded RD19, although the latter is photoperiod sensitive and known to have flood emergence ability.

The mean performance of six stratum 2 fields with DSR followed by TPR (pattern C in Fig. 1) is shown in Table 2. DSR was planted and harvested within the designed schedule. Field durations of this crop ranged from 111 to 121 d. Two fields, where emergence was poor, yielded less than 3 t/ha. Except for one field, the turnaround time



3. Average daily water depth in the harvested and failed mungbean fields during the flowering to podding stages. Solana, Cagayan, Philippines, 1981.

(TAT) for planting the next crop exceeded 3 wk because water was too deep for transplanting. Two transplanted fields were ruined by the submergence of young seedlings; they were replanted extending TAT to more than 50 d. Second-crop yields (1.5-3.6 t/ha) varied mainly because of flood-damage differences among fields. Because of the late transplanting, harvests of the second crop were delayed beyond the scheduled time.

In strata 2 and 3, transplanting of the first crop in pattern D (Fig. 1) was delayed because water was insufficient for land preparation at the scheduled planting time. First-crop yields from both strata

Table 1. Mean grain yield of rice varieties transplanted after mungbean across Strata 1 and 2, Solana, Cagayan, Philippines, 1981.

	IR52	IR46[a]	IR36[a]	RD19[b]
Mean grain yield	3.1	3.6	3.0	2.2
Cropping pattern fields	14	7	2	7

[a]Planted only in the first stratum. [b]Planted only in the second stratum.

Table 2. Mean planting dates, field durations, and grain yields of DSR and TPR (with a 39-d TAT between them) at the second stratum, mean of six fields. Solana, Cagayan, Philippines, 1981.

Crop	Planting date	Field duration (d)	Yield (t/ha)
DSR	31 May	112	3.3
TPR	2 Nov	82	2.6

Table 3. Yield of IR52 and IR36 transplanted as the first crop at strata 2 and 3, Solana, Cagayan, Philippines, 1981-82.

Stratum	Yield (t/ha)		
	IR52	IR36	Mean
2	3.1 (4)[a]	3.0 (3)	3.1
3	3.9 (9)	3.4 (8)	3.7
Mean	3.6	3.3	

[a]Numbers in parentheses are number of cropping pattern fields.

and both varieties, however, exceeded 3 t/ha (Table 3). The second crop was delayed because the first crop was transplanted late and floods destroyed seedbeds and hampered transplanting. Most of the second crops were transplanted in December; the moisture stress suffered in January and February resulted in crop failures in two fields and yield reductions in the rest.

Because of the delayed schedule in the preceding crops and excessive soil moisture after the rice crop, only 15 of 42 fields were planted with post-rice mungbean. Of the 15 fields, 13 failed because of drought. With this experience and that in the previous year, mungbean is not considered feasible under the prevailing conditions and will no longer follow rice in future cropping patterns.

Chemical insect control recommendations for Solana *(Entomology). Mungbean before rice.* DSR suffers damage from ants that remove seeds before crop emergence. To test whether stand reduction occurs on mungbean, a third growth stage was added to partition yield loss in preemergence, preflowering, and postflowering periods. Carbaryl 85% SP was chosen because it was readily available and, in earlier trials, its wettable powder formulation had given good ant control on DSR with no phytotoxic effect on mungbean.

Unfortunately, the carbaryl SP formulation at 4 g ai/kg seed (0.1 kg ai/ha) proved highly phytotoxic and depressed yields (Table 4).

However, in the bendiocarb seed treatment in potential practices 3 and 4, the plant stand was not significantly higher than that in the untreated check. Apparently ants caused no damage to mungbean seedbeds. Bendiocarb was not used as a seed treatment in the yield-loss treatments because it is systemic and controls some preflowering insect pests, which would not allow isolating the yield loss from preemergence insect damage.

A comparison of the four potential practices showed no yield increase from bendiocarb seed treatment during the preemergence and preflowering growth stages. The major pest was the bean pod borer *Maruca testulalis*. Potential practices 1 and 3 involved a single spray of permethrin at flowering; practices 2 and 4 involved one permethrin spray at flowering and one 10 d later.

Because no yield loss occurred during the preemergence growth stage, the complete protection minus the seed treatment was used. Yield loss attributed to insect pests was 0.3 t/ha (Table 4). With mungbean prices at \$0.50/kg, the economic loss became \$150/ha. Comparison of one or two permethrin sprays with the untreated check gave inconsistent results on bean pod borer control (Table 4). The greatest yield response to postflowering sprays was only 0.2 kg/ha and even though this translates into a gross benefit of \$100/ha, four replications normally are insufficient to separate means differing by 0.2-0.3 t/ha (CV = 22% with 35-m^2 yield cuts).

In 1983 trials, replications will be increased to six and will continue to compare postflowering treatments differing in number of sprays.

Dry-seeded bunded rice. The 1982 crop was destroyed by a typhoon that struck during the mid-ripening stage. However, insect numbers were monitored before the soft dough stage and no postemergence pest surpassed the economic threshold values in any field. These results have been consistent over the 3 yr of trials.

In the 1982 trials, significant stand reduction, attributed to seed removal by ants, was recorded. Aldrin WP at 4 g ai/kg seed provided a significant increase in plant stand (67 plants/m of row) over the untreated check (34 plants/m of row). At a

Table 4. Development of a chemical insect control recommendation for CES1D-21 mungbean before wetland rice, using the yield-loss method. Solana, Cagayan, Philippines, April-July 1982.

Insect control treatment	Stand (1,000 plants/ha)	Yield[a] (t/ha)
Complete protection: Seed treatment – 4 g ai carbaryl SP/kg seed; preflowering – 0.5 kg ai monocrotophos EC/ha 2, 9, 16 DE; postflowering – 0.03 kg ai decamethrin EC/ha 25, 35, 45 DE	106 b	0.51 d
Omit seed treatment	178 a	0.91 a
Omit preflowering protection	101 b	0.51 d
Omit postflowering protection	107 b	0.42 d
Potential practice 1: 0.04 kg ai permethrin EC/ha at flowering	171 a	0.61 cd
Potential practice 2: 0.04 kg ai permethrin EC/ha at flowering and 10 d later	160 a	0.83 ab
Potential practice 3: seed treatment – 4 g ai bendiocarb WP/kg seed; 0.04 kg ai permethrin EC/ha at flowering	182 a	0.79 abc
Potential practice 4: seed treatment – 4 g ai bendiocarb WP/kg seed; 0.04 kg ai permethrin EC/ha at flowering and 10 d later	158 a	0.63 bcd
Untreated check	162 a	0.61 cd

[a]Av of four replications. Carbaryl (Sevin 85 SP), monocrotophos (Azodrin 202 R 30% EC), decamethrin (Decis 2.5 EC), bendiocarb 50WP. Mungbean seeded at 25 kg/ha.

seeding rate of 100 kg seed/ha, the dosage is 0.4 kg ai/ha.

Plant stand losses attributed to ants occurred in the 1980, but not in the 1981 DSR crop. Extensive floods in early November 1980 probably severely reduced the resident ant population in stratum 1. At the height of the 1980 flood when the crop land was under at least 1 m of water, flood waters swept away ants massed together in balls to protect the queen. Nests were located in the rice bunds and it took at least 1 yr for the ant population to recover from the devastating flood.

Transplanted single rice crop. Insect populations on transplanted rice have been extremely low in each of the field trials that have been conducted. The most prevalent pests have been armyworm during the seedbed, leaf folder in the late reproductive stage, and rice bug at grain ripening. No significant yield losses have been recorded for any growth stage. In the 1981 planting of IR52 in six fields, the complete control resulted in an average of 3.6 t/ha; the untreated check, 3.1 t/ha.

The insect pest population did not reach economic threshold values in any field so no insecticide was applied. Because no significant yield losses had been registered, the threshold values are high (Table 5).

MUNGBEAN — A COMPONENT OF CROPPING PATTERNS

Multiple Cropping Department

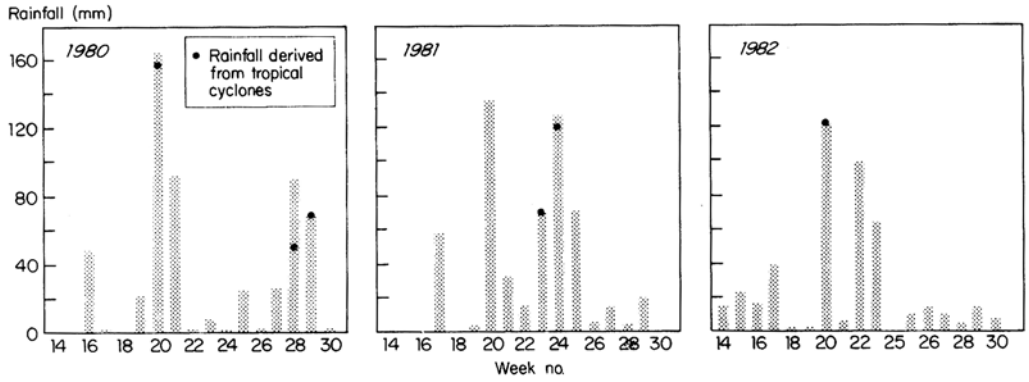
Because of its short maturity, agronomic adaptability, and market acceptance, mungbean is a common component of rainfed cropping patterns. Mungbean may be planted as the main crop under good growing conditions or grown as a marginal crop early in the WS before rice or at the end of the WS after rice. Because of the diverse environmental conditions mungbean is subjected to in different situations, management factors must be adjusted to obtain an adequate crop stand and to reduce drought and excess-water hazards.

The range of conditions and yields obtained in the Solana cropping systems project illustrates production hazards in the region. Erratic rainfall distribution within a cropping year was found to be a greater problem than total rainfall. Over 3 yr of the cropping systems project, tropical cyclones contributed 58, 40, and 48% of the rainfall in the

Table 5. The 1982 recommended insect control practice on transplanted IR52 is the use of insecticides based on economic threshold values. Solana, Philippines 1982.

Pest	Action threshold	Insecticide and dosage (kg ai/ha)
	Seedbed	
Defoliators (armyworm, cutworm, caseworm)	50% defoliation (combined for all pest species)	Monocrotophos (0.4)
	Vegetative stage	
Leaf feeders (armyworm, cutworm, whorl maggot, caseworm, leaf folder, semilooper)	25% damaged leaves (combined for all pest species)	Monocrotophos (0.4)
Stem borer	15% deadhearts	Brodan[a] (0.4)
	Reproductive stage	
Stem borer	5% deadhearts	Brodan[a] (0.4)
Leaf folder	15% damaged leaves	Monocrotophos (0.4)
	Ripening stage	
Rice bug	8/m^2	Monocrotophos (0.4)
	All stages	
Whitebacked planthopper	1/tiller	BPMC (0.4)

[a]20% chlorpyrifos + 11.5% BPMC.



4. Mungbean was planted in late April or early May (weeks 16-19) but heavy rainfall in mid-May and early June (weeks 20-23) caused flood damage. Solana, Cagayan, Philippines, 1980-82.

growing season. Weekly rainfall attributed to tropical cyclones is shown in Figure 4. In all years, mungbean planted before rice was affected directly by excess moisture and indirectly by competition from weeds that are adapted to the high soil moisture levels. Research showed it is safer and more profitable to plant mungbean on well-drained than in poorly drained terrain positions. In 1982, the mean mungbean yield from 10 farmer-cooperators' fields on well-drained land was 0.39 t/ha. From 10 fields located on poorly drained land, the mean yield was 0.24 t/ha. In mungbean adaptation tests in 12 villages outside the Solana project area but on similar terrain units, a mean yield of 0.57 t/ha was obtained from 12 well-drained fields, but only 0.12 t/ha from 11 poorly drained fields. During 1982, flooding and drought occurred (Fig. 4). Sparse rains after planting (weeks 18 and 19) caused stand reductions and slowed growth, but flood damage (week 20) was greater. Outside the project, farmers' mungbean crops were dismal. Among a control group of 43 farmers' fields, seven had no harvest at all and the remaining averaged only 0.03 t/ha.

Plant population and moisture damage. Low population densities and excess-moisture damage contribute most to low mungbean yields even in well-drained fields. Experiments were conducted to test planting methods that might increase plant population and reduce excess-moisture damage.

Solana. In an experiment during the last week of April, selected combinations of tillage levels and planting methods were tested (Table 6). A 17-mm rainfall 2 DAS eroded the ridges on treatment 5,

Table 6. Effect of tillage and sowing method on crop stand, flood damage, weeds, and mungbean yield over four repli-tions. Solana, Cagayan, Philippines, 1982 WS.

Treatment no.	Tillage level	Sowing method	Plants (no./m^2 at)		Flood[a] damage	Weed wt (g/0.5 m^2)	Yield (t/ha)
			Emergence	Harvest			
1	Zero	Drill in seed-furrow[b]	18 c	14 bc	3	154 bcd	0.16 cd
2	Zero	Roller injection planter (RIP) on flat seedbed	21 bc	7 d	1	246 a	0.06 d
3	Low[c]	Drill in seed-furrow	24 abc	24 ab	6	128 cd	0.33 ab
4	Low	RIP on flat seedbed	21 bc	18 bc	4	97 d	0.17 cd
5	Low	RIP on ridge	33 a	23 bc	7	166 b	0.27 bc
6	Low	RIP on ridge, drill in seed[d] furrow	31 ab	32 a	7	109 d	0.37 a
7	Low	Broadcast on flat seedbed	16 c	16 bc	4	109 d	0.16 cd

[a]1-9 scale where 1 = severe damage, 9 = no damage. [b]Furrows were made where seeds were sown. [c]One plowing + one harrowing. [d]Seeds were sown on ridges and in 8- to 10-cm deep furrows spaced at about 30 cm.

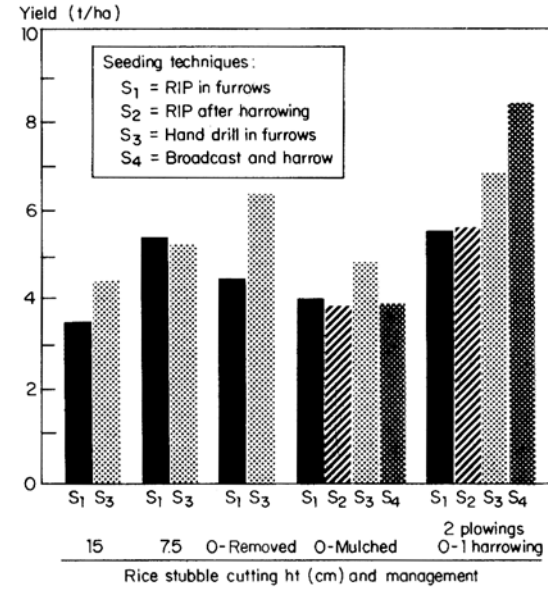
making its height similar to that of treatment 4. Plant stand and growth were severely affected by drought after emergence and by a flood 21 DAS. Flood damage ratings and weed occurrence were greatest with zero tillage, especially when sown with the rolling injector planter (RIP). Yields were low even when plant populations were 32/m^2. Poor aeration stunted the plants.

Statistical comparisons showed that emergence rates from zero and low tillage did not differ greatly. However, with zero tillage, plants were more susceptible to drought and flood hazards, weed weight was higher, and mungbean yields were lower. Although drilling in seed furrows and sowing with the RIP produced a similar number of emerged plants, crop stand reduction and weed weights were higher with the RIP. Broadcast seeding resulted in the poorest stand and yield.

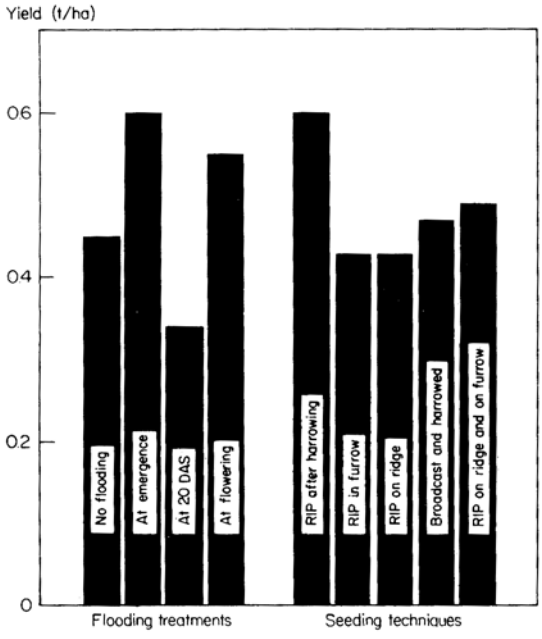
IRRI. In the first of four experiments conducted under controlled test conditions, broadcasting and row seeding were compared at population levels of 200,000 and 300,000 plants/ha under weedy and weed-free conditions. The field was prepared to a rough tilth. For the row-seed treatment, shallow furrows were opened at 75-cm centers into which seeds were hand-drilled and covered by harrowing. For the broadcast treatment, after seeds were scattered on the surface, the plots were harrowed. The desired populations were obtained by overseeding and thinning. For the weed-free treatment, plots were hand weeded at 14 and 28 DAS, and at pod-filling stage. A split-split plot design was used with planting method in main plots, plant population in subplots, and weed control factors in subsubplots. The higher population produced an average statistically insignificant yield increase of 0.08 t/ha. There was less weed competition and therefore higher yields in the weed-free treatment. Yields from unweeded treatments averaged 0.34 t/ha; from weeded treatments they averaged 0.85 t/ha. Mean total dry matter was 1.8 t/ha in the unweeded treatment and 2.9 t/ha in the weed-free treatment. Row-seeded crops showed a greater uniformity in spacing, greater ability to compete with weeds, and ease of weed control, and gave higher yields than the broadcast crops.

In the second experiment, stubble management alternatives and four planting techniques were examined. The stubble management alternatives included cutting heights of 15, 7.5, and 0 cm where stubble was removed, 0 cm where stubble was used as mulch, and 0 cm where plots were plowed twice and harrowed once. Planting techniques included broadcasting followed by harrowing, hand drilling into opened furrows, using RIP on harrowed plots, and using RIP on opened furrows. Yields from all seeding techniques at the high tillage level (two plowings, one harrowing) exceeded those from the corresponding seeding techniques where tillage was not performed (Fig. 5). Tall stubble was inferior to other stubble management regardless of seeding technique. Hand drilling tended to dominate among the seeding techniques.

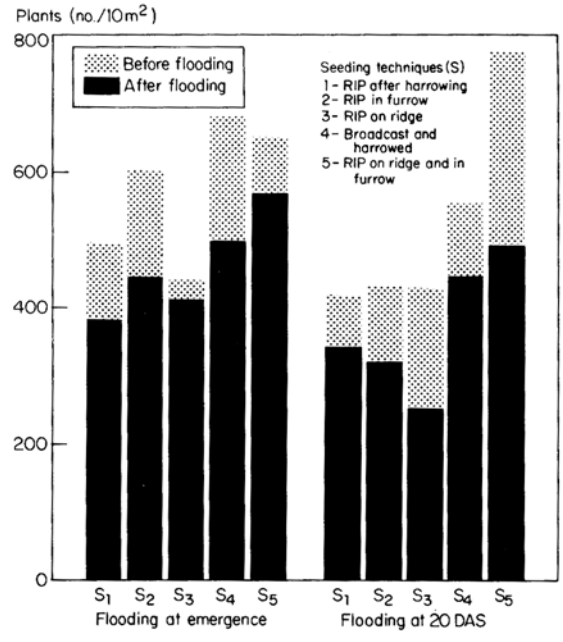
In the third experiment, broadcast seedings and RIP seedings on a flat surface, in a furrow, on a ridge, and on a ridge plus in a furrow were compared. The crop was flooded at emergence, 20 DE, and the flowering stage. A split-plot design replicated three times was used with flooding treatments in the main plots and seeding techniques in the subplots. RIP seeding was in rows at 30-cm centers. For flooding treatments, water was brought to 3-cm depth and retained for 3 consecutive days. Yield means corresponding to flooding treatments and seeding techniques are in Figure 6. The unflooded treatment gave comparatively low



5. Effect of rice stubble management and seeding technique on mungbean yield. IRRI, 1982.



6. Effect of flooding treatments and seeding techniques on mungbean yields. IRRI, 1982.



7. Stand reduction attributed to flooding at emergence and 20 DAS following different seeding methods. IRRI, 1982.

yields because of late moisture stress. Flooding at 20 DAS, when plants and roots were developing rapidly and early nodules were forming, depressed yields. RIP seeding on flat, harrowed, unfurrowed plots was superior to other seeding techniques. Broadcast seeding and RIP seeding in furrows, on ridges, or in furrows plus on ridges resulted in similar yields. An insignificant flooding-seeding interaction indicated that neither seed placement on ridges nor that in furrows produced a distinct yield advantage when water was either excessive or in short supply. Mean nodule counts from plots flooded at 20 DAS were 35% lower than those of other treatments. Stand reductions resulted from flooding at emergence and at 20 DAS were high (Fig. 7).

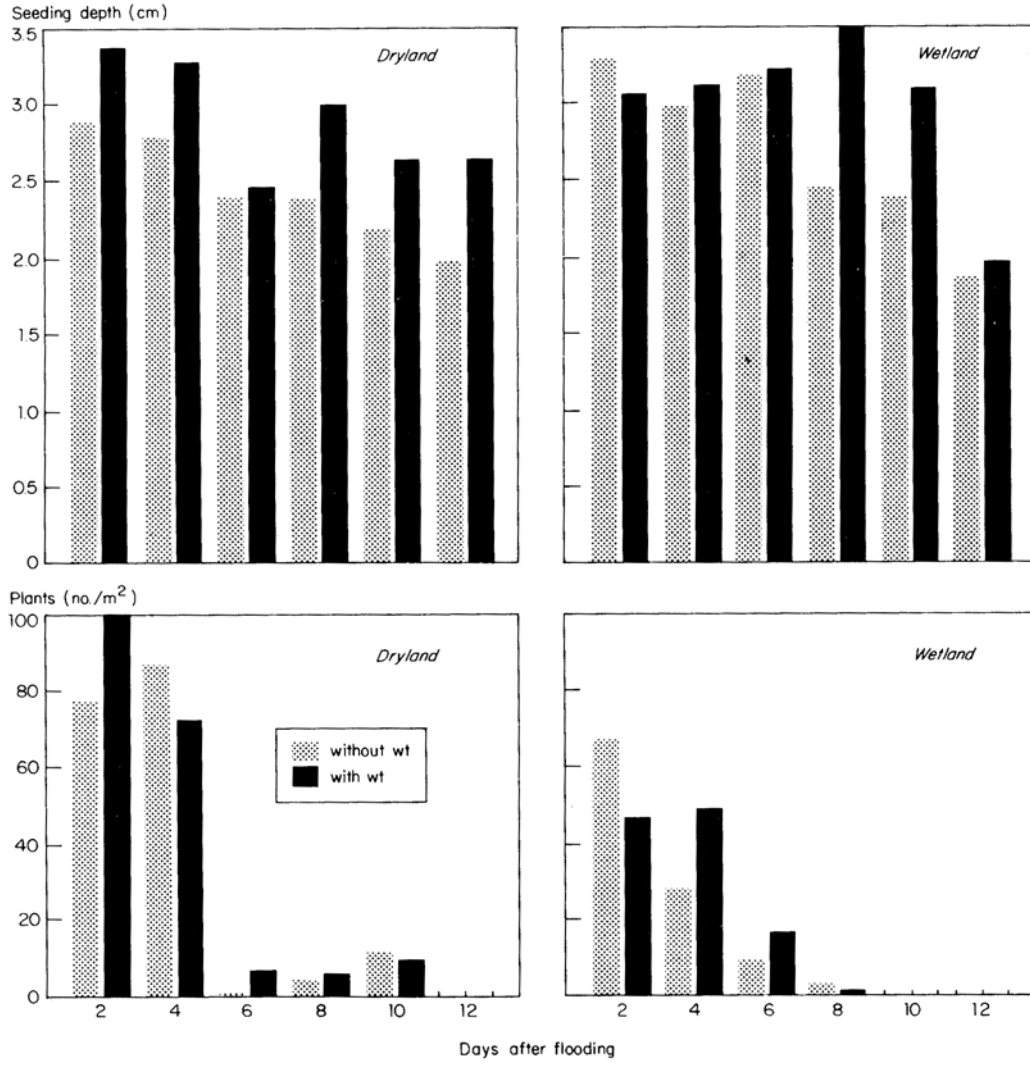
In the fourth experiment conducted in dryland and wetland fields, the effect of increasing the depth of RIP seed placement was tested by applying a 5-kg weight to the planter. To examine the effect of seed zone moisture, plantings were started on the second day after field flooding and made every 2 d up to day 12. The textural makeup of the test fields are in Table 7. Seeding depth and the number of germinated seeds were determined by excavating 5 m of randomly selected row.

Table 7. Soil texture makeup of the dryland and wetland fields in which weighted and unweighted RIP seed placements were compared. IRRI, 1982.

Texture	Dryland	Wetland
	%	
Clay	37	40
Silt	39	50
Sand	33	10

The effects of delays in seeding and additional RIP weight on seeding depth and number of germinated plants are shown in Figure 8. In the wetland soil, seeding depths from weighted and unweighted RIP were similar up to the third planting, but on the fourth and fifth plantings, seed placement was shallower with the unweighted RIP. In the wetland soil, plant germination dropped sharply after the first planting for the unweighted and after the second planting for the weighted RIP treatments. In the first planting, germination was low when seeds were placed deeper by the weighted RIP. However, the deeper placement obtained from the weighted RIP, when used after a delay of 8 and 10 d, did not increase seed emergence.

In the dryland soil, seed placement was deeper in

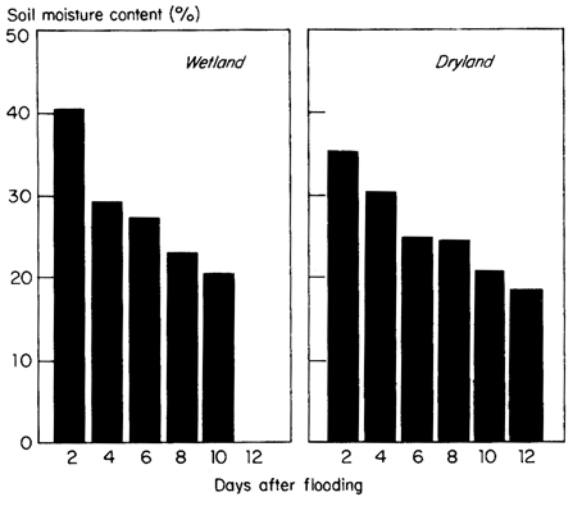


8. Seeding depth and number of germinated plants as influenced by delay in seeding and additional weight on the RIP. IRRI, 1982.

all seedings with the weighted RIP. Seed placement depth declined gradually with time for both the weighted and unweighted RIP. In both treatments, a sharp decline in germination was observed after the third planting.

As shown in Figure 9, surface soil moisture content declined gradually. In both soils, germination dropped sharply beyond a 4-d seeding delay, corresponding to moisture contents of 30% in both situations.

From the Solana and IRRI experiments, it was clear that low tillage was better than zero tillage when droughts and floods were expected. Tillage reduced weed competition and improved yield. Hand drilling in furrows resulted in better plant stand, uniformity in spacing, and ease in weed control than broadcast seeding. Except on flat-tilled unfurrowed soil, RIP seeding was inferior to hand drilling in furrows. Furthermore, RIP seeding on ridges or in furrows did not produce advantages when the crop faced either an excess or shortage of water. Flooding caused the greatest crop damage when it occurred at the emergence stage and at 20 DAS. Additional weight on the RIP increased seed



9. Surface soil (0-5 cm) moisture content at 2- and 12-d delays in mungbean seeding on wetland and dryland soils. IRRI, 1982.

placement depth, but did not produce a consistent germination increase. Germination declined sharply below a 30% soil moisture content.

RICE CROPPING INTENSITY AND INSECT ABUNDANCE

Entomology Department

Epidemics of BPH, GLH, and the virus diseases they vector have occurred in most Asian countries within the past 15 yr. The replacement of LVs with MVs has often been cited as a reason for this dramatic pest increase. However, results from Asian breeding programs have consistently shown that most LVs are highly susceptible to these pests. Clearly, another explanation must account for the increased pest problems.

The insect pests most responsible for epidemics feed almost exclusively on rice and during the period when the epidemics have occurred, dramatic changes have occurred in the resources of space, time, labor, and capital devoted to rice cultivation. These changes have been made possible by the development of photoperiod-insensitive varieties that are high tillering and respond to management.

It may not be the varieties themselves that have unleashed the reproductive powers of insect pests, but rather factors associated with crop intensification. Four salient components of this intensification are:

- Quantity-of-rice factors, which in turn may be divided into three readily measured parts: 1) the percentage of area within a given radius of a site devoted to rice cultivation (studies from several major insect pests point to a 1-km distance), 2) the cropping index (average number of rice crops per year per farm) within that area, and 3) the mean crop duration in days per farm.
- Asynchrony of cultivation within a given radius.
- Water control as measured by stress or flooded days. Field moisture status affects rice plant nutrition and insect population growth. Poor water control — too little or too much — directly or indirectly affects pest survival.
- Cultural factors. The most important from the point of view of pest abundance are: 1) amount of fertilizer, specifically N applied, and 2) insecticide usage, characterized by the number of applications per crop and dosage per application.

Establishing responsibility of individual intensity components for observed increases in pest abundance has proven difficult because historically they have tended to increase together.

From available evidence at hand, water control and cultural practices are probably of less importance because their effects are small when measured in isolation.

Insect pest epidemics arise from exponential increases in abundance. Therefore, a composite index of the quantity-of-rice factors, called hectare-days, has been created. It is equal to the product of the mean number of hectares under rice cultivation within 1 km of a site, the mean number of rice crops per year in those fields, and the mean number of days per year rice is cropped.

Hectare-days were computed from 10 sites in five Philippine provinces (Table 8) and plotted against the total insect light trap catches as a measure of abundance. The 10 sites represent three rice environments:

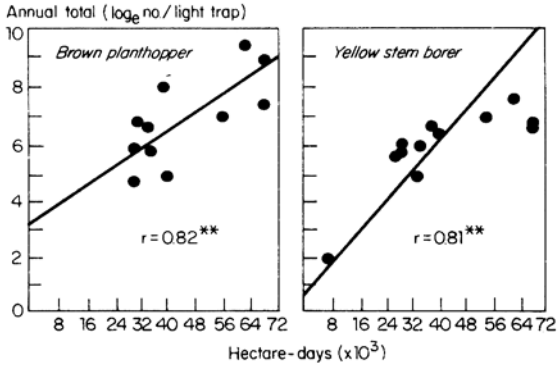
- rainfed, single crop dryland (Batangas);
- rainfed wetland, single-double crop (Cagayan, Pangasinan, Iloilo); and
- irrigated, double crop (Nueva Ecija).

BPH and YSB abundance (Fig. 10) increased exponentially with the number of hectare-days.

Table 8. Components of rice cultivation intensity affecting insect pest abundance as determined in three representative environments in five Philippine provinces, 1979-80.

Province	Site	Year	Quantity of rice factors			Cultural practices		
			Area in rice (%)	Rice cropping index	Maturation (d)	Fertilizer (kg N/ha)	Insecticide	
							Application (no./field)	Dosage (kg ai/ha)/ application
Batangas[a]	Cale	1980	20	1.0	120	66	0	0
Cagayan[a]	Iraga	1981	60	1.0	156	0	0.3	0.02
	Bangag	1981	60	1.0	174	0	0.3	0.02
Pangasinan[a]	Lipit	1979	70	1.0	134	33	0.4	0.1
	Lipit	1980	70	1.0	130	33	0.4	0.1
	Caaringayan	1979	85	1.0	129	33	0.4	0.1
	Caaringayan	1980	85	1.17	128	33	0.4	0.1
Iloilo[a]	Bunay	1979	85	1.30	110	47	1.3	0.14
	Santa Monica	1979	85	1.67	123	47	1.3	0.14
Nueva Ecija[b]	Santa Rita	1981	85	2.12	119	57	5	0.4
	Manaol	1981	85	2.12	119	57	5	0.28
	Batitang	1981	80	2.0	121	57	5	0.28

[a]Data courtesy of IRRI Economics Department, Cropping Systems Program, farm record keeping. [b]Data courtesy of the National Irrigation Administration, Cabanatuan, Nueva Ecija.



10. Relationship of two rice insect pests (measured as the total catch in a light trap per year) and rice cropping intensity (within 1 km of trap) expressed in hectare-days from five Philippine provinces. 1982.

These results confirm the hypothesis that rice quantity is a good indicator of pest abundance. N application underscored the less significant effect of cultural practices. Batangas had the highest N input, but the lowest pest numbers. An exponential equation appeared to provide a better fit of the data than a linear one, confirming the hypothesis as to the manner in which increased resources affect pest populations.

The scatter of points around the line of best fit can be accounted for by variation in the asynchrony of cultivation. The three points with the greatest hectare-days represent Nueva Ecija sites that were chosen as representing a range of degrees of asynchrony.

The significance of the exponential relationship for the design of cropping patterns must be emphasized. Increasing the mean number of rice crops from two to three is likely to lead to far more than a 50% increase in the incidence of pests per crop.

These results pertain to mean intensity over a relatively wide area (314 ha - 1 km radius). The effects may not be visible on a much smaller scale. Because a rice garden (cropping index = 4.0) covering 1 ha did not suffer significantly greater infestation than the surrounding double-cropped area does not invalidate the results. The impact of intensification is likely to be highly scale dependent, with the relevant scale given by the dispersal range of the insect concerned.

Cropping systems program

Selection and testing of cultivars for rice-based cropping systems

Multiple Cropping, Plant Breeding, and Plant Physiology Departments

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G-2261, an experimental dwarf soybean line, was studied as a possible alternative to mungbean in cropping systems. It matures early (2-8 d longer than mungbean), yields high, and has good seed quality. It was planted at selected combinations of populations and row distances because optimum plant populations or spacing geometry had not yet been determined.

Mungbean cultivars Pag-asa 1 and VC 1647B, soybean cultivar UPLSY-2, and G-2261 were planted in 50-cm-spaced rows at 300 000 plants/ha (the row spacing and population common at IRRI). G-2261 was also planted at a narrow spacing of 25 cm at 300 000 and 600 000 plants/ha. The six treatments were replicated four times in a randomized complete block design.

In all treatments, excess seeds were drilled in furrows and thinned to the desired population before the first trifoliate leaf stage. A 30:1 sand-inoculant mixture (ratio by weight) was drilled in the rows before seeding. Fertilizer was applied at 10-18-33 kg (N,P,K)/ha at planting. The DS experiment was planted on 23 Feb; the WS experiment, on 7 Jul.

Mean yield and other agronomic traits for both seasons are in Table 1. Single degree of freedom contrasts showed that, in both seasons, soybean significantly outyielded mungbean. A contrast among the three treatments containing G-2261 and UPLSY-2 indicated that G-2261 was the superior yielder. In both seasons, the narrow-row plantings did not yield significantly more at 300 000 plants/ha, but when the population was increased to 600 000 plants/ha in combination with narrow rows, yields increased significantly.

G-2261 maturity changed very little in either season, but mungbean matured 6 d earlier in the WS. Consequently, G-2261 maturity was only 1 day longer than the mean maturity of the mungbean cultivars in the DS, but 8 d longer in the WS. Compared with those of the two mungbean cultivars, plant height, number of nodes per plant, and number of pods per plant of the dwarf soybean were less affected by season.

An economic analysis showed that losses can be expected from all WS alternatives. Low yields and

Table 1. Yields and plant attributes of mungbean and soybean as influenced by row-center spacing and plant density, IRRI, 1982 DS and WS.

Variety	Treatment		DS					WS				
	Density (plants/ha)	Spacing (cm)	Yield (t/ha)	Plant height (cm)	Nodes (no./plant)	Pods (no./plant)	Maturity (d)	Yield (t/ha)	Plant height (cm)	Nodes (no./plant)	Pods (no./plant)	Maturity (d)
Mungbean												
Pag-asa 1	300 000	50	1.89	75	10	13	71	0.34	1	7	7	65
VC-1647B	300 000	50	2.06	67	11	21	71	0.16	30	7	9	65
Soybean												
UPLSY-2	300 000	50	2.29	84	13	28	76	0.92	59	14	24	79
G-2261	300 000	50	2.43	44	10	35	72	1.17	42	12	22	73
G-2261	300 000	25	2.65	47	10	33	72	1.25	44	12	29	73
G-2261	600 000	25	2.75	60	9	23	72	1.37	49	11	18	73
						CV (%)						
			7	7	9	12	2	8	8	12	16	0.3

high insecticide costs were the major factors contributing to the losses. Analysis of the DS data showed that all alternatives were profitable, but because of the high local price for mungbean ($730/t) compared with that for soybean ($325/t), either mungbean cultivar was superior to any soybean alternative (Table 2). For all alternatives, insecticide and fertilizer costs were recognized as excessive but constant treatments under the conditions of this experiment. In summary, G-2261, while clearly agronomically superior to mungbean, was at a disadvantage because the mungbean market price exceeded the soybean price by a factor greater than 2.

ROOT AND OTHER MORPHOLOGICAL DIFFERENCES AMONG PEANUT CULTIVARS

Multiple Cropping Department

Crop root characteristics (rooting depth and root volume) contribute to the drought tolerance of

Table 2. Economic analysis of mungbean and soybean production alternatives. IRRI 1982 DS and WS.

Input-output	50-cm row spacing, 300 000 plants/ha				25-cm row spacing,	
	Pag-asa 1	VC-1647B	UPLSY-2	G-2261	300 000 plants/ha G-2261	600 000 plants/ha G-2261
				Dry season		
Labor input ($)						
Land preparation	33	33	33	33	33	33
Seeding	9	9	9	9	9	9
Spraying insecticide	20	20	20	20	20	20
Interrow cultivation and weeding	60	60	60	60	60	60
Harvesting and threshing	170	189	118	102	102	103
Total labor cost	291	311	240	223	224	225
Material cost ($)						
Seeds	11	12	18	19	19	37
Insecticides	259	259	259	259	259	259
Fertilizers	65	65	65	65	65	65
Total material cost ($)	335	336	343	344	343	362
Total variable cost ($)	626	647	571	567	567	586
Returns ($)						
Gross	1382	1507	786	786	858	890
Return over total variable cost	756	860	170	219	291	304
				Wet season		
Labor input ($)						
Land preparation	33	33	33	33	33	33
Seeding	9	9	9	9	9	9
Spraying insecticide	20	20	20	20	20	20
Interrow cultivation and weeding	60	60	60	60	60	60
Harvesting and threshing	42	40	65	72	75	75
Total labor cost	164	162	186	194	197	197
Material cost ($)						
Seeds	9	11	10	11	11	20
Insecticides	259	259	259	259	259	259
Fertilizers	65	65	65	65	65	65
Total material cost ($)	333	335	334	335	335	345
Total variable cost ($)	497	497	521	529	532	541
Returns ($)						
Gross	263	117	298	379	404	443
Return over total variable cost	−233	−380	−223	−150	−127	−98

grain legumes. Determination of the rooting characteristics of a large number of cultivars in the field is laborious and time consuming. A labor-saving hydroponic technique was used to determine the rooting characteristics and other gross morphological attributes of 21 peanut cultivars. The objectives were to evaluate the hydroponic technique as a means of obtaining an adequate characterization of root systems and to examine the relationships among root and other plant attributes.

Single plants were grown for 70 d on modified Hoagland solution in hydroponic vessels made of 100-cm long, 10-cm-diameter polyvinyl chloride pipes sealed at one end. The vessels were aerated continuously and algae growth was prevented by adding streptomycine to the solution. A completely randomized design with eight replications was used. Measurements were made on root length, root volume, number of secondary roots, stem length, leaf area, specific leaf weight, and root and shoot dry weights. Root volume was determined by a water displacement technique and leaf area by an automatic leaf area meter.

Selected attributes of the 21 cultivars are listed in Table 3. Eleven plant attributes were highly correlated (Table 4). Through factor analyses to examine the pattern of relations in this matrix, two factors were identified. The first factor accounted for 60% of the total variability and the second for 14%. The first factor, which was strongly associated with total shoot, root, and leaf dry weight and leaf area, and root volume, was regarded as a plant size factor (Fig. 1). The second factor was regarded as a specific leaf weight factor because of its strong association with that attribute. The second factor had expected moderate associations with total shoot, and leaf dry weights. The moderate associations with root length and number of secondary roots were not expected. The analysis revealed the strong redundancy inherent in total root, shoot, and leaf dry weight and leaf area, and root volume determinations, and indicated that the number of pegs per plant, root length, number of leaves, specific leaf weight, and number of secondary branches may require separate determinations if they are of significant interest in future research. The determinations of the three root characteristics (length, volume, and dry weight) were made with comparative ease.

Table 3. Selected root and shoot characteristics of 21 peanut cultivars at 70 DAS. IRRI, 1982.

Genotype	Root length (cm)	Root volume (cc)	Root dry wt (g)	Secondary roots (no.)	Leaf area per plant (cm^2)	Specific leaf wt (mg/cm^2)	Shoot wt (g)
234	64	42	3.3	30.2	1274	3.19	7.6
805	63	35	2.6	30.1	1415	3.43	8.6
810	66	32	2.4	24.0	1399	2.99	9.0
758	64	41	3.3	22.2	283	3.09	8.5
F334-33	75	43	3.3	31.1	1425	2.88	9.7
266	72	43	3.1	26.1	1300	2.81	9.2
258	59	35	3.1	27.1	1199	3.02	7.8
331	63	31	2.5	20.8	978	2.62	8.2
BPI-P9	60	33	2.6	18.9	1085	2.87	7.1
330	69	44	3.4	32.6	1585	2.81	11.7
717	56	50	3.7	28.6	1692	3.34	10.2
PI-118200	70	56	4.8	29.2	1896	3.19	11.8
CES 101	71	46	4.6	21.5	1755	3.01	11.1
199	91	43	5.1	17.4	1801	2.30	15.4
CES 102	74	47	4.7	21.9	1617	2.91	11.2
268	80	53	4.8	20.0	1815	2.75	13.3
720	64	40	3.4	31.7	1436	3.02	9.9
M-10	68	46	4.1	24.0	1565	2.97	10.6
261	75	49	5.0	20.5	1663	2.63	12.3
ACC-12	75	54	5.3	27.6	1409	3.24	10.2
332	73	52	4.9	29.7	1707	2.93	12.0
Mean	68	44	3.8	25.6	1492	2.96	10.3
LSD 5%	10.7	9.5	1.1	9.7	232	0.29	1.8

Table 4. Simple correlation coefficients (x) for root and shoot characteristics of 21 peanut genotypes. IRRI, 1982.

	Root length (cm)	Root volume (cm^3)	Root wt (g)	Leaves (no.)	Leaf area (cm^2)	Leaf wt (g)	Specific leaf wt (mg/cm^2)	Pegs/ plant	Shoot dry wt (g)	Total dry wt (g)
Secondary roots (no.)	−0.407	0.122	−0.169	0.211	0.015	−0.274	−0.543**	0.090	−0.237	−0.227
Root length (cm)		0.386*	0.638**	0.698	0.506*	0.707**	0.609**	0.730*	0.729**	0.732**
Root volume (cm^3)			0.863**	0.248	0.762**	0.596**	−0.031	0.538**	0.615**	0.726**
Root dry wt (g)				0.404	0.777**	0.766**	0.261	0.559**	0.796**	0.900**
Leaf number					0.479*	0.649**	0.522	0.308	0.670**	0.615**
Leaf area (cm^2)						0.887**	0.146	0.485*	0.844**	0.862**
Leaf dry wt (g)							0.577**	0.472*	0.974**	0.952**
Specific leaf wt (mg/cm^2)								0.238	0.599**	0.516
Pegs/plant									0.611**	0.623**
Shoot dry wt (g)										0.980**

Before hydroponic techniques are used to screen cultivars for root differences, the correlation between hydroponic- and field-expressed attributes and their significance to moisture stress tolerance must be determined.

FITTING IMPROVED RICE PLANT TYPES INTO FLOOD-PRONE AREAS

Multiple Cropping, Plant Breeding, and Plant Physiology Departments

At the multiple cropping site at Solana, Cagayan, Philippines, 224 entries in an observation nursery were tested and yield trials were conducted on 42 lines. The main physical constraints for the rice crop in this area are flash floods in the seedbed and stagnant flooding depths (negligible to 1 m), depending on site and year.

Rains accompanying Typhoon Weling flooded the observation trial in stratum 3 (lowest lying) at 1 DT on 14 Oct.

Table 5 shows the submergence survival of entries in relation to the submergence tolerance (or lack of it) of the parents.

The findings represent an important step in introduction of MVs into flood-prone areas because the excellent survival of lines with FR13A parentage was achieved in modern short-stature plant types.

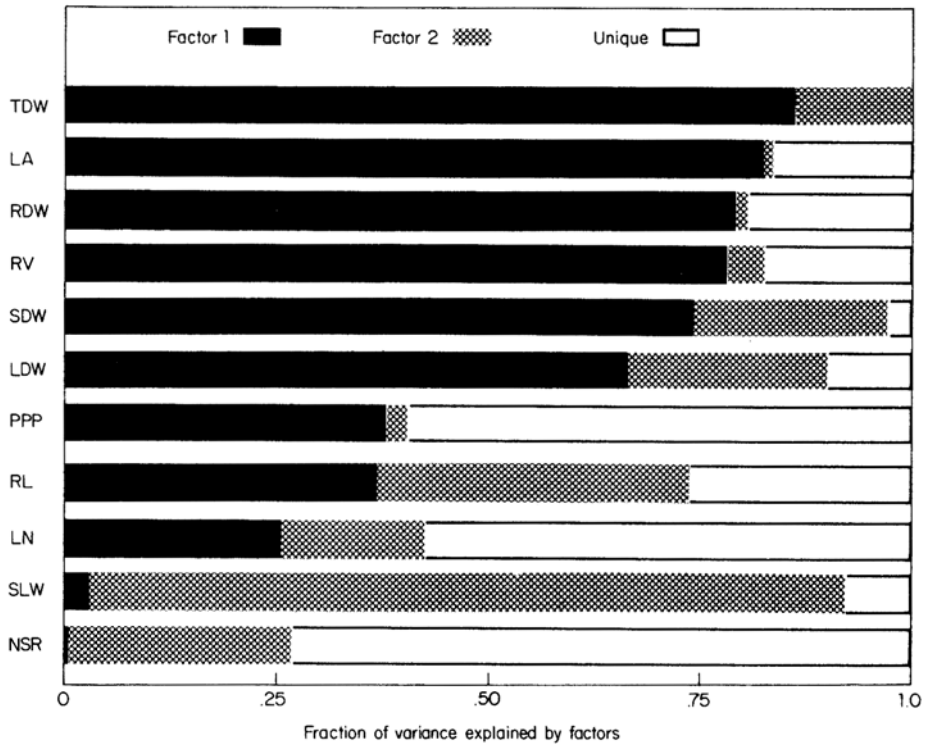
The best lines were from the following crosses:

IR26702	FR13A/IR48//IR42	(18 lines)
IR31031	FR13A/CR 1002//IR48	(4 lines)
IR31406	Kurkaruppan/CR 1002 //IR13415-9-3	(3 lines)

VARIETAL TESTING

Multiple Cropping Department

At IRRI, varietal testing on crops for rice-based cropping systems can be divided into three environments: dryland crops planted before rice, yield trials of both early- and medium-maturing rices, and dryland crops after rice. The nonrice crops are mungbean, bush sitao, cowpea, soybean, peanut, maize, sorghum, and sweet potato. Dryland-crop varieties tested during the 1981-82 season came from the breeding and screening programs of the Institute of Plant Breeding, University of the Philippines at Los Baños (UPLB) and some



1. First and second factor and unique components of total dry weight (TDW), leaf area (LA), root dry weight (RDW), root volume (RV), shoot dry weight (SDW), leaf dry weight (LDW), pegs per plant (PPP), leaf number (LN), specific leaf weight (SLW), and number of secondary roots (NSR) obtained in a hydroponic culture study of 21 peanut cultivars. IRRI, 1982.

national programs. Test sites were at Los Baños and Solana, Cagayan, which were directly managed by IRRI, and at the national cropping system research sites at Matanao, Davao Sur; Del Monte, Agusan Sur; Pangantucan, Bukidnon; Koronadal, South Cotabato; Dumarao, Capiz; and Naujan, Oriental Mindoro.

Dryland crops before rice. *Mungbean.* Ten early mungbean cultivars (plus an additional one at Cagayan) were planted before rice. Six promising indeterminate and disease-tolerant varieties were also planted at Cagayan to be tested for their green manure potential. Two primings were the maximum for mungbean before rice. Fertilizer was not applied.

Pag-asa 1 and M350 yielded the highest at IRRI (1.01 t/ha); MG 50-10 A(Y) at Cagayan (1.03 t/ha). The farmers' LV ranked fifth at Cagayan. Fodder was collected at IRRI immediately after the second priming. Pag-asa had high bean and fodder yields. CES J-2Y had the highest fodder yield but the lowest grain yield.

Table 5. Submergence survival as a function of parentage in a naturally flash-flooded area in Solana, Cagayan, Philippines, 1982.

Entries (no.)	Submergence score[a]	Submergence tolerance parentage[b]		
		FR13A	Other	None
1	2	100	0	0
2	2.5	100	0	0
4	3	100	0	0
10	3.5	90	0	12
7	4	43	14	43
8	4.5	38	12	60
8	4	38	0	70

[a]Av SES scores taken at 20 and 60 d since the start of the flash flood. [b]Percentage of lines having FR13A as a submergence-tolerant parent, another parent known for submergence tolerance, or no parent with submergence tolerance.

At Cagayan, CES 1F-5 and CES 1T-2 yielded significantly higher amounts of green manure (1.75 and 1.55 t/ha), with Pag-asa 1 ranking third (1.45 t/ha). The farmers' LV ranked fourth. The three

highest yielders, with a growth duration of 68 d, matured in 57 d; the LV, with a growth duration of 66 d, matured in 55 d. CES 1T-2 had the highest fodder yield (20.3 t/ha) followed by CES 1F-5 (18.7 t/ha) and Pag-asa 1 (14.8 t/ha). The LV had a significantly lower fodder yield. All the entries produced from 40 to 73 nodules/plant. CES U-1 had the highest nodule count.

Bush sitao. Eight bush sitao cultivars were tested at IRRI and Cagayan. Green pod yield ranged from 2.91 to 6.10 t/ha at IRRI and 1.78 to 4.11 t/ha at Cagayan (Table 6). Fodder yields were taken immediately after the last priming. Fodder yield was much higher in IRRI than at Cagayan. The number of nodules per plant was much higher at Cagayan than at IRRI. BS_3 (6-14 R × AS) had the most nodules at both locations.

Cowpea. Ten determinate cowpea cultivars were tested for green pod production at the IRRI and Cagayan sites (Table 7). Yields in Cagayan were lower because of much less moisture. Vita 3 had the highest fodder yield in Cagayan and CP4-2-3-1 the highest at IRRI. Growth duration, ranged from 72 to 79 d at IRRI and 70-77 d at Cagayan. There was much more nodulation in Cagayan (224-474) than at IRRI.

Soybean. At IRRI, five early-maturing soybean cultivars (not more than 95 d) were tested at IRRI. Yields ranged from 0.70 (Guntar) to 1.53 t/ha (UPLSY-2). Cultivar 1682-1343-1-10 ranked second (1.26 t/ha) but had the latest maturity (92 d). Guntar had an excellent nodulation rating. UPLSY-2 had bigger seeds but fewer pods per plant.

Sweet maize and glutinous maize. Fourteen sweet maize cultivars were tested at South Cotabato and eight at IRRI; seven glutinous maize cultivars were also tested at IRRI. Hawaiian Supersweet #9 yielded highest at IRRI, but yielded significantly lower at South Cotabato because of severe downy mildew infection prevalent in the southern Philippines. Downy mildew-tolerant Sweet DMR Comp. Pop 31B yielded highest in South Cotabato (1.86 t/ha).

Yields among the glutinous maize cultivars did not differ significantly; they ranged from 2.87 to 4.20 t/ha. Glutinous Syn. #22 yielded the highest, followed by DMR Comp. Pop 41A (3.77 t/ha) and the local variety Macapuno (3.61 t/ha).

Rice yield trials. *Early-maturing rice*. Twenty-four cultivars were planted in the flood-prone areas of Cagayan, 14 at IRRI, and 11 at the South Cotabato, Davao Sur, Pangasinan, and Capiz research sites. In Cagayan, trials were in four sets, two each in strata 1 and 2. Yields of the four tests averaged 1.05-3.55 t/ha. IR9830-26-3-3 yielded the highest, followed by IR4829-89-2 (3.51 t/ha) and IR13429-150-3-2-1-2 (3.12 t/ha). The farmers' LV ranked fourth (2.98 t/ha) and matured in 160 d compared with the MVs, which matured in only 110 d. IR21015-182-3-2 was the most stable yielder (3.05 t/ha).

At IRRI, yield levels did not differ significantly among the 14 cultivars. IR36, used for cropping

Table 6. Yields of eight bush sitao cultivars evaluated before wetland rice at two Philippine test sites, 1982 WS.

Cultivar	Bush sitao yield (t/ha)				
	IRRI, Los Baños[a]			Solana, Cagayan[b]	
	Dry beans	Green pods	Fodder	Green pods	Fodder
BS_1 (6-14 R X AS)	0.43 bcd	5.35 ab	21.78 a	4.11 a	9.08 a
BS_6 (LBBS #1 X CO_1) 4-1-1-1	0.41 cd	3.45 cd	6.56 b	2.28 b	6.10 ab
Los Baños Bush Sitao #1	0.62 ab	3.62 cd	4.44 b	2.22 b	8.74 a
EG BS #2	0.73 a	4.75 bc	8.22 b	1.96 b	6.96 ab
BS_7 (LBBS #1 X CO_1) 4-1-1-2	0.51 bc	3.10 de	5.94 b	1.91 b	5.40 b
BS_3 (LBBS #1 X AS)	0.28 d	2.91 de	21.00 a	1.78 b	6.48 b
BS_4 (MP X 21)	0.72 a	6.10 a	6.67 b	–	–
UPL BS #4	0.29 d	2.21 e	4.39 b	–	–
Av	0.49	3.94	9.88	2.38	7.13
			CV (%)		
	20.96	16.54	27.35	20.10	22.58

[a]Rainfall: 686.2 mm. [b]Rainfall: 546 mm.

Table 7. Yields of 10 determinate cowpea cultivars evaluated before wetland rice at two Philippine test sites, 1982 WS.

Cultivar	Cowpea yield (t/ha)				
	IRRI, Los Baños[a]			Solana, Cagayan[b]	
	Grain	Green pods	Fodder	Green pods	Fodder
CP 4-2-3-1	0.47 a	6.28 a	17.3[ns]	3.56 a	8.92 bc
TVx 7-5H	0.40 ab	2.70 def	15.2[ns]	1.36 c	11.61 b
CP 2-3-1	0.37 ab	4.41 b	14.7[ns]	3.03 ab	12.28 b
TVx 1836-19E	0.36 ab	3.70 bcd	16.2[ns]	1.78 bc	10.85 b
Vita 3	–	–	–	0.67 c	19.84 a
TVx 1850-01E	0.45 a	3.55 bcd	13.7[ns]	–	–
Pelungga	0.42 ab	3.08 cde	7.6[ns]	–	–
All Season	0.30 ab	4.23 bc	14.1[ns]	–	–
V59-41	0.27 ab	1.98 ef	9.8[ns]	–	–
TVx 2949-01D	0.23 b	1.54 f	12.9[ns]	–	–
Av	0.36	3.50	13.5*	1.88	12.7
			CV (%)		
	12.0	10.4	21.2	17.0	21.3

[a]Rainfall: 686.2 mm. [b]Rainfall: 546 mm.

pattern testing, ranked third (3.18 t/ha). The most promising entries were IR9729-67-3 (3.43 t/ha) and IR22097-41-4-3 (3.41 t/ha). IR50 yielded lowest (2.77 t/ha).

At South Cotabato, IR13429-196-1-2-1 was the most promising (3.36 t/ha). IR36 (3.25 t/ha) and IR50 (2.87 t/ha) ranked second and fourth. In Davao Sur, IR9209-249-1-2-3-2 (5.55 t/ha), IR13429-196-1-2 (5.45 t/ha), and IR9752-71-3-2 (5.30 t/ha) yielded better than IR36 (5.15 t/ha). IR50 yielded lowest (2.80 t/ha). In Pangasinan, six new cultivars outyielded IR36 (1.88 t/ha). The most promising cultivars were IR8608-125-3-3 (2.41 t/ha), IR19743-25-2-2 (2.33 t/ha), IR8455-78-1-3-3 (2.27 t/ha), and IR9209-249-1-2-3-2 (2.17 t/ha). In Capiz, IR19746-28-2-2-3 (3.91 t/ha), IR19735-5-2-3-2-1 (3.84 t/ha), and IR19743-25-2-2-2-3-1 (3.60 t/ha) yielded best. IR50 (3.20 t/ha) ranked sixth and IR36 (3.08 t/ha) eighth. IR50 was less disease tolerant than IR36.

Medium-maturing rice. Twelve entries were tested at IRRI and in South Cotabato, 11 entries in Pangasinan and Capiz, and 42 entries at two planting dates in Cagayan. In Cagayan, C168 (2.68 t/ha), BR10 (2.51 t/ha), and IR52 (2.37 t/ha) outyielded the farmers' LV (2.05 t/ha). In dry-seeded trials at IRRI, there were no significant yield differences. IR18348-36-3-3 (3.42 t/ha), IR13429-109-2-2-1 (3.21 t/ha), and IR18272-12-3-3-2 (3.20 t/ha) yielded highest. The IR52 check ranked seventh (2.94 t/ha).

At South Cotabato, only IR13423-17-1-2-1 (5.50 t/ha) and IR13423-10-2-3 (4.90 t/ha) outyielded IR52 (4.77 t/ha). In Pangasinan, IR15318-2-2-2-2 (5.72 t/ha), IR54 (5.71 t/ha), and IR13423-10-2-3 (5.61 t/ha) yielded best. IR52 yielded lowest (2.65 t/ha). At Capiz, IR17494-32-1-1-3-2 (4.32 t/ha), IR42 (3.77 t/ha), and IR13540-56-3-2-1 (3.69 t/ha) yielded highest. IR52 ranked fourth (3.07 t/ha).

Dryland crops after rice. *Mungbean.* Thirteen cultivars were tested at IRRI and in Mindoro, and 14 cultivars, including the farmers' LVs, in Cagayan. Trials were not tilled at IRRI and in Cagayan, but were tilled in Mindoro. Yields ranged from 1.09 to 1.55 t/ha at IRRI and 0.12 to 0.47 t/ha in Cagayan. Extremely poor performance in Cagayan was attributed to drought with no rainfall occurring during 2 wk before planting. At IRRI, CES 2G-4 (1.55 t/ha), EG MG 174-3 (1.46 t/ha), and CES U-1 (1.43 t/ha) were the most promising. CES 2G-4 had the most pods per plant but the beans were small. Pag-asa (1.29 t/ha) showed better tolerance for powdery mildew. At Cagayan, CES 1T-2 (0.47 t/ha) yielded highest. The farmers' LV ranked seventh. Trials with high tillage in Mindoro showed no significant yield differences. Pag-asa 1 (0.78 t/ha) and CES 2G-4 (0.78 t/ha) yielded best. Across the three locations, CES 1T-2 (0.85 t/ha) had the highest mean yield; EG MG 174-3 (0.83 t/ha) and CES 2G-4 (0.82

t/ha) the next highest.

Soybean. Ten cultivars were tested at IRRI and in Cagayan (zero tillage) and South Cotabato, and Mindoro (high tillage). As with all crops after rice in Cagayan, the soybean yield was low because only residual soil moisture was available. At IRRI, six entries yielded more than 1 t/ha, with 7207-1 (1.79 t/ha), UPLSY-2 (1.28 t/ha), and 50106-4-7 (1.15 t/ha) yielding best. 7207-1 had the most pods per plant (30) and UPLSY-2 was the tallest (48 cm). In Cagayan, yields ranged from 0.07 (30290-11-11) to 0.62 t/ha (Multivar 80). Plant height ranged from 19 to 30 cm, Clark 63 being the tallest. With high tillage, UPLSY-2 (1.49 t/ha) and Multivar 80 (1.44 t/ha) yielded highest in South Cotabato and Clark 63 yielded highest (1.20 t/ha) at Mindoro Oriental. UPLSY-2 ranked second in both locations. Plants were taller at both locations; heights ranged from 50 to 73 cm in South Cotabato and 43 to 58 cm in Mindoro Oriental. Days to maturity differed among locations with the average ranging from 88 d in South Cotabato to 80 d in Cagayan. UPLSY-2 had the highest mean yield across all locations (1.10 t/ha) followed by Clark 63 (0.90 t/ha) and Multivar 80 (0.88 t/ha).

Bush sitao. Nine cultivars were tested at IRRI and in Cagayan (zero tillage) and in Mindoro (high tillage). Both dry and green pods were harvested at IRRI and in Cagayan; only dried beans were collected in Mindoro. BS_7 (LBBS #1 × CO_1)4-1-1-2 had the highest grain yield at IRRI and BS_3 (16-14 R × AS) in Cagayan. BS_1 (6-14 R × AS) consistently had the highest green pod yield at IRRI (11.00 t/ha) and in Cagayan (6.27 t/ha) followed by BS_3 (16-14 R × AS). Maturity at both locations ranged from 68-71 d. Plant height was taller at IRRI (43 cm) than in Cagayan (38 cm). With high tillage, BS_4 (MP × 21) and UPL Bush Sitao #4 yielded more than 2 t/ha. Pods per plant ranged from 16-22 and number of seeds ranged from 13 to 17. UPL BS #2 had the most pods and BS_1 the most seeds per plot.

Cowpea. Eleven entries were tested at IRRI and 10 entries, including the farmers' LV in Cagayan, Mindoro, and South Cotabato. With zero tillage, yields ranged from 0.43 to 1.31 t/ha at IRRI and 0.23 to 0.57 t/ha in Cagayan. EG #2 was the highest yielder at IRRI in both grain (1.31 t/ha) and green pods (11.10 t/ha). Drought reduced yields in Cagayan; Vita 4 had the highest grain (0.57 t/ha) and green pod (4.55 t/ha) yields. Grain yield of the farmers' LV was 0.23 t/ha; pod yield was 2.35 t/ha. Maturity ranged from 65 to 74 d at IRRI and 63 to 73 d in Cagayan. The earliest maturing cultivar was Vita 4 in Cagayan, and Pelungga at IRRI.

In the high-tillage trials in South Cotabato and Mindoro, yields averaged 1.50 and 0.96 t/ha. In South Cotabato, the farmers' LV yielded similarly (1.86 t/ha) to the highest yielder TVx 2939-09D (1.88 t/ha). Pods per plant ranged from 8 to 16 with TVx 7-5H having the highest. In Mindoro, TVx 7-5H (1.49 t/ha), EG #2 (1.28 t/ha), and TVx 1948-01E (1.18 t/ha) had the highest grain yields. The Mindoro trials had more pods per plant (12-23). The farmers' LV yielded significantly lower (0.40 t/ha). Vita 4 and TVx 7-5H had the most pods. Maturity ranged from 66 to 76 d with the LV taking the longest. EG #2, the recommended variety, had the highest mean grain yield across the four locations (1.10 t/ha) followed by TVx 2939-09D (1.07 t/ha).

Peanut. With zero tillage at IRRI, peanut cultivars CES 101 (1.99 t/ha), F334-33 (1.87 t/ha), CES 2-25 (1.77 t/ha), and CES 103 (1.74 t/ha) had the most promising shelled-bean yields. UPL-PN-2, a recommended Philippine Seedboard variety, ranked fifth (1.55 t/ha). Most of the cultivars were harvested at 103-104 DE. Pods per plant ranged from 26 to 35 with CES 101 having the highest.

Sweet potato. Yields in the trials were similar to yields in normal dryland conditions. (Japan × US) 25 (20.4 t/ha), Minuras (20.1 t/ha), and Kinabakab (20.0 t/ha) had the best yields of marketable tubers. BNAS 51, recommended for normal cultivation, yielded the lowest (11.8 t/ha). Kinabakab and Hsinchu had the highest vine yields of 29.6 and 26.8 t/ha.

Maize. Seven green maize and eight early-maturing (less than 100 d) field maize cultivars were planted at IRRI (zero tillage), 12 field maize in Mindoro, and 14 field maize in South Cotabato. Among green maize cultivars, there were no significant yield differences. Glutinous Syn. 22 (5.16 t/ha) and Glutinous Syn. 41 (4.68 t/ha) were the high yielders. The LV Macapuno yielded 4.17 t/ha. Among early field maize cultivars, Early

DMR Comp. #2 (3.68 t/ha), Phil. DMR Comp. #1 (3.60 t/ha), and Early DMR Comp. #1 (3.38 t/ha) were the highest yielders. IPB Var 1, the local check, ranked fourth (2.46 t/ha). With high tillage in Mindoro, Phil. DMR Comp. #4 (4.96 t/ha), Early DMR Comp. #2 (4.83 t/ha), and Phil. DMR Comp. #2 (4.82 t/ha) were the highest yielders. The farmers' LV ranked 11th (4.25 t/ha). Maturities ranged from 81 to 95 d with DMR Comp. #2 the earliest. At South Cotabato, Suwan DMR #5 (5.30 t/ha), Phil. DMR Comp. #4 (4.60 t/ha), and Phil. DMR Comp. #1 (4.10 t/ha) yielded highest. Maturities ranged from 88 to 94 d. The farmers' LV yielded 2.97 t/ha. IPB Var 1, the recommended variety, yielded the lowest in Mindoro (3.72 t/ha) and South Cotabato (3.20 t/ha).

Sorghum. Twelve entries were tested at IRRI and in Cagayan (zero tillage) and Mindoro (high tillage). At IRRI, CS 271 (3.47 t/ha), CS 253 (3.40 t/ha), and CS 182 (3.37 t/ha) were the most promising cultivars. UPL SG-5, used for cropping pattern testing, ranked ninth (2.93 t/ha). CS 268 matured earliest (98 d) and yielded the lowest. Plant heights ranged from 89 to 107 cm with C 271 the tallest. Drought greatly affected trials in Cagayan and Mindoro. No rain fell from planting to harvesting in Cagayan. Yields ranged from 0.43 to 0.66 t/ha in Cagayan and 1.10 to 1.38 t/ha in Mindoro. The most promising cultivars were CS 182 (0.66 t/ha) and IS 2940 (0.55 t/ha) in Cagayan and CS 116 (1.38 t/ha) and CS 292 (1.33 t/ha) in Mindoro. In Cagayan, plant heights ranged from only 65 to 85 cm because of the drought; in Mindoro, they ranged from 166 to 194 cm.

Regional Integrated Agricultural Research Systems. To strengthen the Philippine Ministry of Agriculture's rice-based cropping systems research, Regional Integrated Agricultural Research Systems (RIARS) were formed in the country's 12 regions. Distribution of dryland crop seed materials for crops after rice started in October 1982. So far, 64 trials of maize, sorghum, soybean, peanut, mungbean, cowpea, and bush sitao have been distributed to the 12 regions. Varietal trials for rice-based cropping systems are now conducted at the RIARS stations, the Rainfed Agricultural Development Outreach Sites, and other sites.

Cropping systems program

Agronomic management in rice-based cropping patterns

Multiple Cropping Department

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With adequate water, maize has a high yield potential. It is suitable as a DS crop as well as an early or late WS crop before or after rice. Several important management factors affecting maize productivity were examined in experiments completed in 1982.

Plant density and nitrogen fertilizer response. New maize hybrids with improved adaptation to tropical conditions have become available in recent years. Like open-pollinated varieties, hybrids are responsive to N fertilization and plant density. The effects of these two management variables on a hybrid (Pioneer 6181) and on an open-pollinated variety (IPB-1) were examined in an experiment planted in June.

The experiment used a split-plot design with four replications. All factorial combinations of cultivars and three plant densities (53 000, 64 000, and 80 000 plants/ha) were assigned to the main plots; the N levels (0, 75, 150, and 300 kg N/ha), applied in equal splits at planting, 30 DE, and at tasseling, were assigned to the subplots. Weeds and insect pests were adequately controlled, but the crops was moderately damaged by typhoon Ruping at the hard-dough stage.

Both cultivar and plant density affected yields, but the interaction of these two factors was not significant. Figure 1 shows that the hybrid was higher yielding by an average of 0.7 t/ha than the open-pollinated variety at all plant densities. An increase in plant density from 53 000 to 64 000 plants/ha increased yield by an average of 0.5 t/ha across other treatments. The second plant density increment did not increase yield.

N fertilizer increased yield significantly, but yields did not differ among the three N treatment levels. The response to 300 kg N/ha was only 0.4 t/ha, more than half of which was accounted for by the first 75 kg N/ha.

Nitrogen source and application timing. Because of frequent periods of heavy rainfall, N fertilizer may be lost by leaching or denitrification during the WS. Furthermore, side-dressed N fertilizer may not be applied on schedule or at all because of wet field conditions. In this experiment, two N sources, SCU and USG, which interact more slowly with the soil than PU, were evaluated.

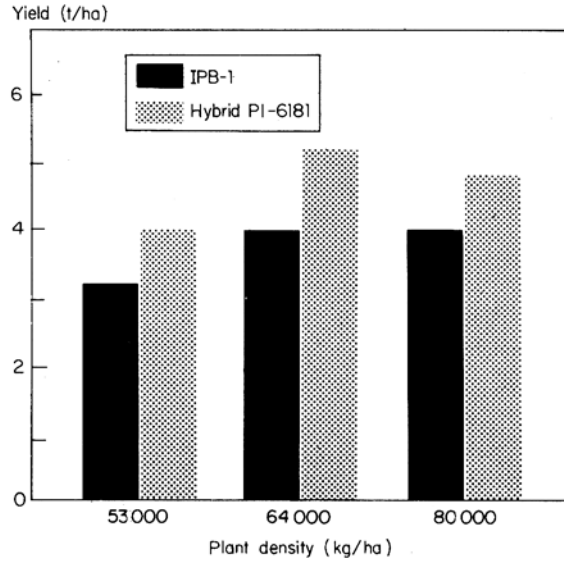
For the test, the maize cultivar IPB-1 was planted at 51 000 plants/ha in July 1982. N treatments were applied in three replications of a randomized complete-block design. The PU (45% N), SCU (36% N), and USG (46% N) sources were applied at the rates shown in Figure 2. Weeds and insect pests were adequately controlled.

Grain yields (Fig. 2) show that the three N sources were about equally effective, although minor interactions with rates and timings occurred. N fertilizer increased yields but, because of typhoon damage and other WS factors, yield responses were low.

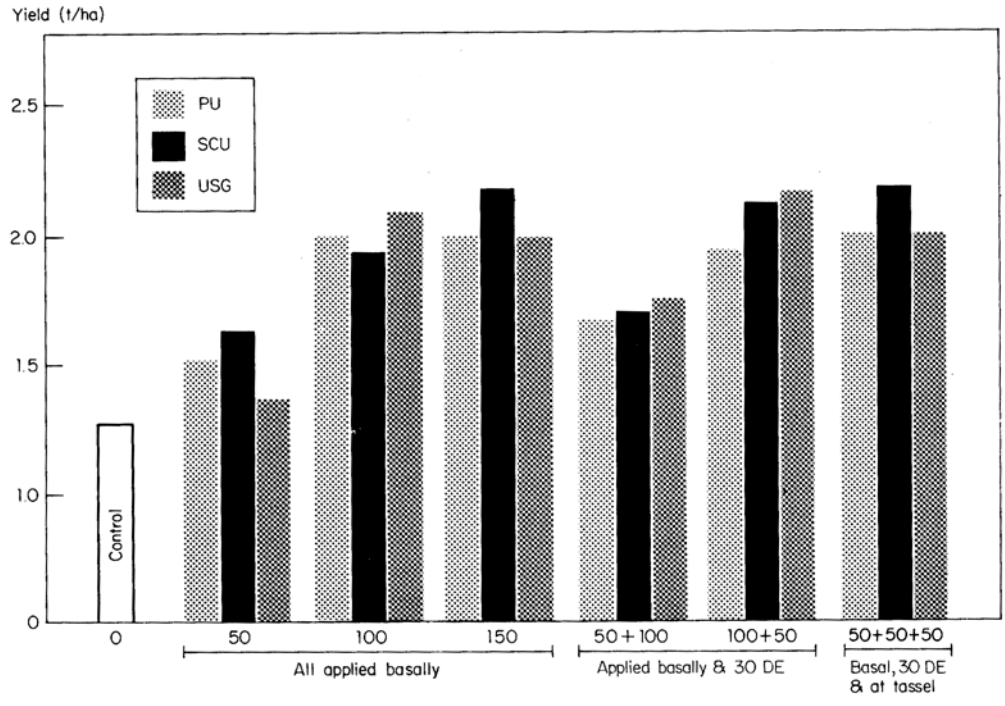
A comparison among treatments receiving only basal N fertilizer showed that the yield response was strongly linear up to 100 kg N/ha. A comparison among treatments receiving 150 kg N/ha, all basal or split between basal and 30 DE applications, suggested that the basally applied fertilizer was used more efficiently.

Nitrogen application frequency. For WS maize cultivation, the percentage of recovery of applied N is low. One way to increase the efficiency is to split applications.

Maize variety IPB-1 was planted at 53 000 plants/ha in July 1982. All plots received PU at 100 kg N/ha. Treatments, applied on the soil surface, included full application at planting (each hill); and



1. A comparison of a maize hybrid (PI-6181) and an open pollinated variety (IPB-1) at three plant densities, means of four N fertilizer levels and four replications. IRRI, 1982 WS.

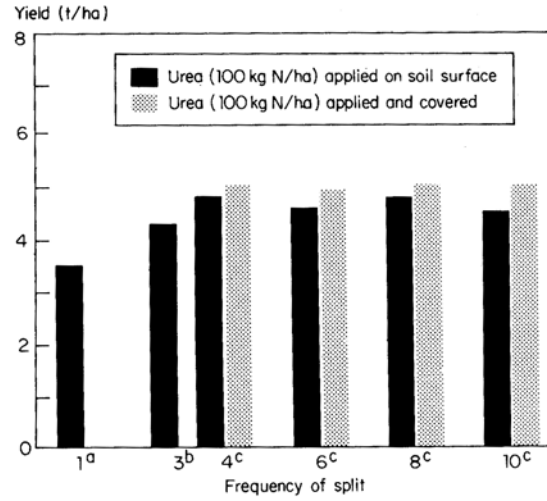


2. Effect of sources, rates, and methods of N application on maize grain yields of IPB-1. IRRI, July-October 1982.

the recommended application of three splits at planting (each hill) 30 DE (base of each hill), and at tasseling (base of each hill). Eight other treatment combinations, in which frequencies were increased to four splits every 18 d, six splits every 11 d, eight splits every 8 d, and 10 splits every 6 d, were placed at the base of each hill on the soil surface or incorporated into the soil. In the combination treatments, the first application was made 7 DE; all applications were made at the base of each hill. The 10 treatments were placed in a randomized complete block design with four replications. Weeds and insect pests were adequately controlled.

The single application at planting was clearly inferior (Fig. 3). Three applications were almost as beneficial as the more frequent applications, especially when the fertilizer was surface-applied. Soil-covered, frequent applications increased yields significantly, but only by 0.5 t/ha, on the average. Yield from the three-split application was only 10% (0.5 t/ha) less than the mean yield of the soil-covered, frequent applications.

Maize response to nitrogen, phosphorus, and potassium. Although maize grown in the WS has a pronounced response to N fertilizer, its response to P and K fertilizer in the new dryland portion of the IRRI farm has not been carefully evaluated.



a All at planting
b 1/3, 1/3, 1/3 at planting; 30 DE and tasseling
c At 18, 11, 8, and 6-d intervals, starting at 7 DE

3. Effect of number of split N applications on maize (IPB-1) grain yield. IRRI, 1982 WS.

An experiment was conducted to evaluate maize

response to P fertilizer applied in combination with N fertilizer. K was applied only at the maximum N and P fertilizer rates.

Maize variety IPB-1 was planted at 53 000 plants/ha in June 1982. Total N in the plow layer was 0.13%; Olsen P was 26 ppm; and exchangeable K was 1.3 meq/100 g air-dried soil. Nine treatments consisted of all factorial combinations of three N levels (0, 50, and 100 kg/ha) and three P levels (0, 13, and 25 kg/ha). To determine the response to K, a tenth treatment, 100-25-49 kg (N, P, K)/ha, was applied. The N source, ammonium sulfate (AS), was applied in three splits (at planting, 30 DE, and at tasseling). The P (ordinary superphosphate), and K (muriate of potash) materials were soil-incorporated at planting. A randomized complete block design with four replications was used to compare the treatments.

P, alone or in combination with N, did not increase yields; neither did K. However, a significant response to N gave an additional 1.4 t/ha from 100 kg N/ha. Corresponding to 0, 50, and 100 kg N/ha, the mean yields over replications and P levels were 1.4, 2.4, and 2.8 t/ha. For the yield levels obtained in this experiment, soil P and K were obviously adequate.

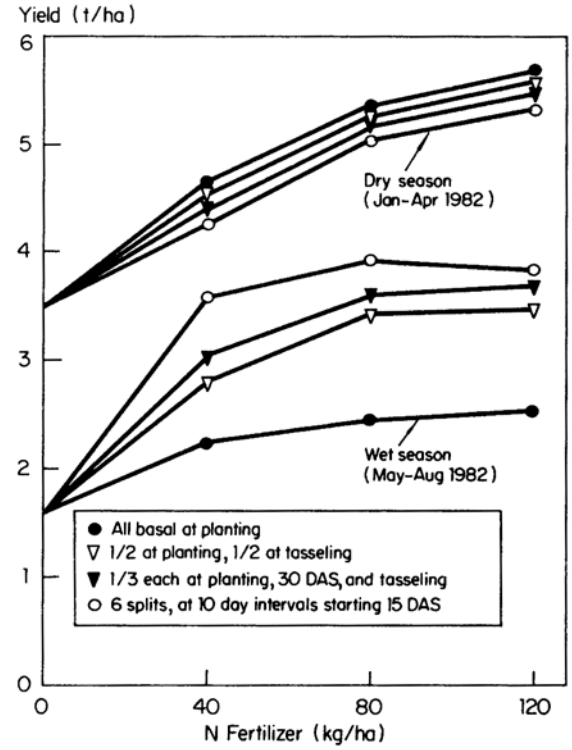
Wet- and dry-season maize responses to N rate and application timing. To study seasonal variations in maize yield response to N rates, experiments were conducted in January 1982 (DS) and May 1982 (early WS). Open-pollinated variety IPB-1 was planted at a population of 49 000/ha.

In experiment 1, treatments included a zero-N control and all factorial combinations of three rates of AS (40, 80, and 120 kg N/ha) and four application timings: 1) all at planting; 2) half at planting and half 30 DE; 3) one-third at planting, one-third 30 DE, and one-third at tasseling; and 4) one-sixth applied at 5-d intervals from 3 to 6 WE. In experiment 2, the plots were halved. To determine residual effects from experiment 1 applications, one half did not receive N fertilizer. The other half received the N treatments in experiment 1.

Mean yields from experiment 1 and the residual component in experiment 2 are shown in Figure 4. In both seasons, where N fertilizer was applied directly, rate and timing and the interaction had significant effects. Without N fertilizer, DS yields were about twice as high as the WS yields. The DS yield maximum was also clearly higher than the WS maximum. The WS yield plateau of about 3.75 t/ha was achieved within the treatment range. In the DS, the yield plateau appeared beyond 120 kg/ha even with the most efficient application timing (Fig. 4).

Frequent N applications were most advantageous at the low and intermediate rates during the WS. Full application at planting was less efficient in the WS when leaching and denitrification losses are greater. Although the residual treatments showed expected trends, the variability in the absence of direct N application was high (CV=36%) and statistical tests were insensitive. The residual effects of 40 and 80 kg N/ha applications were less than 0.2 t/ha. The mean residual of 120 kg N/ha was 0.8 t/ha.

Yield potential of dry season-planted maize in the tropics. Low maize yields in the WS are probably caused by low solar radiation, poor N efficiency, flood damage, and wind damage. However, in areas where partial irrigation is available during the DS, maize can be planted when solar



4. Direct effects of N fertilizer on maize grain yield. IRRI, 1982.

Staff changes

January

Dr. James A. Litsinger, entomologist, completed a 1-yr sabbatical leave at the University of Hawaii.

Mr. Charles J. Moss resigned as agricultural engineer, IRRI/Egypt Rice Project.

February

Dr. David J. MacKill of International Crop Research Institute for the Semi-Arid Tropics joined the Plant Breeding Department as associate plant breeder.

Dr. Leonard R. Oldeman of the World Meteorological Organization began a 1-yr assignment as visiting scientist, Multiple Cropping Department.

Dr. Mun Hue Heu resigned as plant breeder, Plant Breeding Department.

Dr. Jeff R. Simpson, Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, completed a short-term assignment as visiting scientist, Soil Chemistry Department.

Mr. Henry M. Beachell resigned as plant breeder, AID-492-1310 (Indonesia).

Dr. Keh-Chi Ling, plant pathologist, passed away.

March

Dr. Robert E. Huke of Dartmouth College completed a short-term assignment as visiting scientist, Agricultural Economics Department.

April

Dr. M. S. Swaminathan joined the IRRI staff as Director General.

Mr. Paul A. Cooper, a private consultant and formerly with USAID, began a 2-yr assignment as consultant, Administration (Director General's Office).

Mr. Walter G. Rockwood resigned as editor to join USAID, Washington, D.C.

Mr. Jack B. Duff, associate agricultural economist, completed a 1-yr sabbatical leave at the University of California, Davis.

May

Dr. John C. O'Toole, agronomist, completed a 1-yr sabbatical leave at the University of California, Davis.

Dr. Derk HilleRisLambers, plant breeder, IRRI cooperative projects with the Ministry of Agriculture and Cooperatives in Thailand, completed a 1-yr assignment as visiting scientist, Plant Breeding Department.

Dr. Keith Moody, agronomist, began a 1-yr sabbatical leave at the Weed Research Organization.

Dr. Victor A. Dyck resigned as entomologist to return to Canada.

Dr. Walter L. Griffeth resigned as crop production specialist, Rice Production Training and Research Department.

June

Dr. Benito S. Vergara, plant physiologist, completed a 1-yr sabbatical leave at the University of California, Davis.

Ms. Lina M. Vergara, librarian, completed a 1-yr sabbatical leave at the University of California, Davis.

Dr. Ray B. Diamond of the International Fertilizer Development Centre, began a 1-yr assignment as visiting scientist, Agronomy Department.

Dr. Jerry W. Maranville of the University of Nebraska began a 1-yr assignment as visiting scientist on the Joint IRRI/Institute of Plant Breeding (UPLB) Collaborative Project.

Dr. Igmidio T. Corpuz left the IRRI staff as agronomist; AID-492-1310 (Indonesia) was terminated.

Dr. James R. Hooper left the IRRI staff as associate agronomist; AID-492-1310 (Indonesia) was terminated.

Mr. Hugh T. Murphy, director for administration, began a 6-mo sabbatical leave at Harvard University.

Dr. Elvis A. Heinrichs, entomologist, began a 6-mo sabbatical leave at the University of Nebraska.

July

Dr. Tom W. Mew, plant pathologist, completed a 1-yr sabbatical leave at the North Carolina State University.

Dr. Richard A. Morris, agronomist, completed a 1-yr sabbatical leave at IBM de Mexico, S.A.

Dr. Edwin C. Price, agricultural economist, completed a 1-yr sabbatical leave at Yale University.

Dr. Derk HilleRisLambers rejoined the IRRI staff as plant breeder, Plant Breeding Department.

Mr. Edwin A. Tout formerly of the University of Arizona joined the Information Services Department as associate editor.

Dr. Frank D. Whisler of Mississippi State University began a 1-yr assignment as visiting scientist, Multiple Cropping Department.

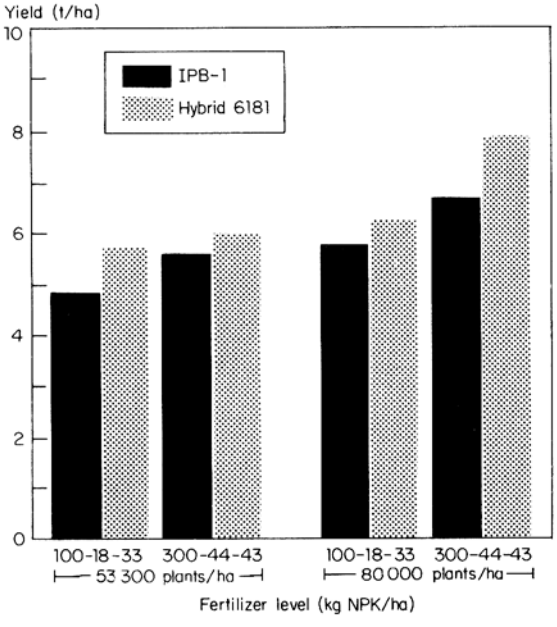
January 1982. Fertilizer was applied at 100-18-33 and 300-44-43 (N, P, K) kg/ha. One-third of the N and all P and K were applied at planting. One-third of the N was applied at 30 DAS and at tasseling. Adequate insect and weed control measures were applied. The crop was irrigated three times (30, 55, and 86 DAS). The duration of Pioneer 6181 was 109 d and that of IPB-1 103 d. The soil contained 0.14% N, 36 ppm available P (Olsen), and 1.2 meq exchangeable K/100 g air-dried soil.

Mean grain yields are shown in Figure 5. The main effects of all factors were highly significant, but all interactions were not significant. Across replications, plant densities, and fertilizer levels, the hybrid yielded 0.6 t/ha more than the open-pollinated variety. Yield was increased 1.1 t/ha by the high fertilizer level and 0.8 t/ha by the dense plant population. The hybrid yielded the highest (7.9 t/ha) at 80 000 plants/ha and at the high fertilizer application.

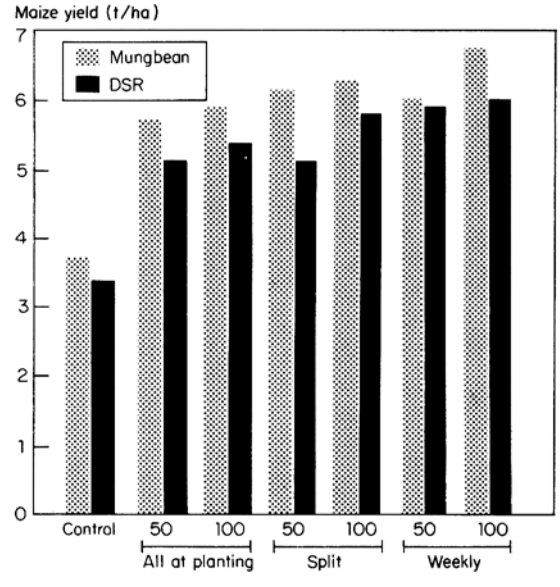
It was obvious that the yield potential of modern maize hybrids exceeds 8 t/ha during tropical DS conditions. Maize responded significantly to N fertilizer, but plant population also was important to high yields. Although maximum yields were obtained at the highest N treatment (240 kg N/ha), 87% of the maximum was obtained from 80 kg N/ha. Moreover, when N application was omitted at planting, 80 kg N/ha produced 90% of the yield obtained from 240 kg N/ha.

Effect of preceding dry-seeded rice and mungbean on maize yield. The first crop of a two-crop sequence can alter soil N availability for the second crop. The alterations caused by dry-seeded rice (DSR) and mungbean preceding maize were compared. Mungbean (Pagasa) and DSR (IR50) were planted on 4 Sep. DSR was fertilized with 100 kg N/ha. The two crops formed the main plots in a split-plot design used for the maize crops. The mungbean yielded 0.65 t/ha and the rice, 2.6 t/ha. Before plowing for the maize crop, the rice and mungbean crop residues were removed. Maize (IPB-1) was overseeded on 19 Dec and thinned 10 DE to obtain a population of 53 000 plants/ha. All factorial combinations of N rates (50 and 100 kg/ha) and application timings (all at planting, half at planting and half at 25 DE, and weekly applications to each hill over 10 wk) and a control (no N fertilizer) were compared. The experiment was replicated four times.

Mean yields are shown in Figure 6. Yields of maize after DSR were 0.5 t/ha lower than those of maize after mungbean. N rate and timing, but not their interaction, significantly influenced maize



5. Effect of fertilizer and plant density on maize yields. IRRI, 1982 DS.



6. Effect of a preceding crop (mungbean or DSR) on N efficiency in maize (IPB-1). IRRI, 1982 DS.

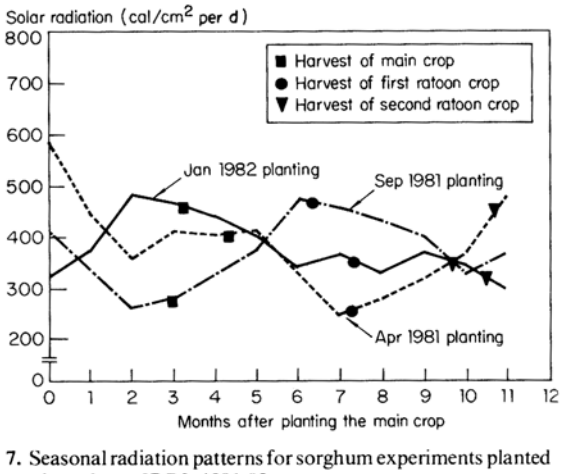
yields. N fertilizer management variables did not interact with the effects from the preceding crops. Split and weekly applications increased yields more effectively than the single application at planting.

SORGHUM MAIN CROP AND RATOON MANAGEMENT

By ratooning sorghum, labor for tilling and planting the second and third crops is eliminated, and time between crops is saved. In 1982, several experiments examining the effects of various management practices on grain yield of main and ratoon crops were completed.

Effects of plant density and cutting height. Three experiments were conducted to compare the effects of plant density (200 000, 300 000, or 400 000 plants/ha) and cutting height (ground level, one node above ground, or three nodes above ground) on the main crop and ratoon grain yields of three grain sorghum cultivars (Cosor 3, UPL SG5, and CS 110). The crops were planted in April and September 1981 and January 1982 to expose the main and the ratoon crops to different solar radiation regimes. The respective second ratoon crops were harvested in March, July, and December 1982. The solar radiation regimes are given in Figure 7.

Except for seasonal weather differences, the experiments were identical. Four replications in a split-split plot design with cultivars in main plots, plant densities in subplots, and cutting heights in sub-subplots were planted on each date.



7. Seasonal radiation patterns for sorghum experiments planted on three dates. IRRI, 1981-82.

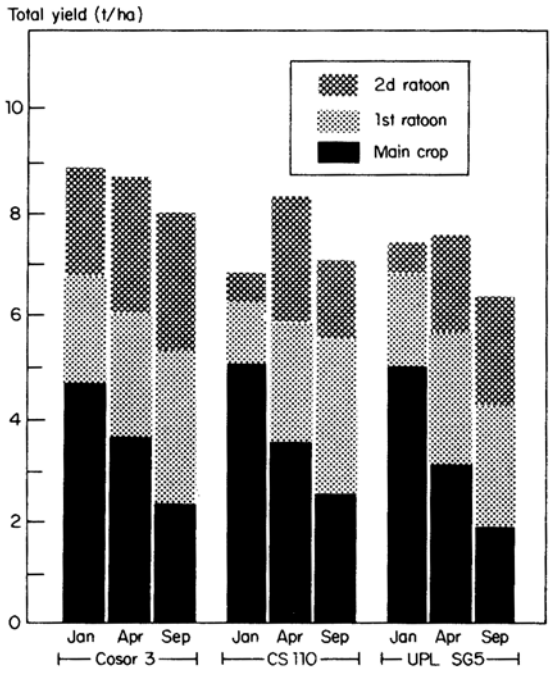
Fields for these experiments were thoroughly plowed and rotovated. A broadcast application of 60-13-25 kg (N, P, K)/ha was incorporated before the final rotovations. An additional 30 kg N/ha was side-dressed on the main crops before hilling up (27 DAS). Side-dressings of 50 kg N/ha were applied to the ratoons before hilling up. The main crops were overseeded at 60-cm row widths, and thinned to the required plant densities between 14 and 21 DAS. Main crops were irrigated after seeding and again at flowering. Ratoons were irrigated immediately after harvesting. Weeds, insect pests, birds, and diseases were adequately controlled.

The analyses of variance on the grain yields are summarized in Table 2. Cultivar effects were significant on all yields except those of the main crop from the January planting and the first ratoon crop from the April planting. The yields are summarized in Figure 8. Cosor 3 outyielded CS 110 and UPL SG5, except in the January planting, when the main crop yields from the three cultivars averaged 4.9 t/ha. In all cases, Cosor 3 first and second ratoon yields were equal or superior to

Table 2. Summary analyses of variance on sorghum grain yield data.[a] IRRI, 1982.

Source	Jan	Apr	Sep
		Main crop	
Cultivar (C)	ns	**	**
Plant density (P)	*	**	ns
C X P	ns	ns	ns
		1st ratoon	
C	**	ns	**
P	ns	ns	**
C X P	ns	**	ns
Cutting height (H)	ns	ns	*
H X C	**	ns	ns
H X P	**	ns	ns
H X P X C	**	ns	ns
		2nd ratoon	
C	**	*	**
P	ns	*	ns
C X P	ns	ns	ns
CH	ns	**	ns
H X C	ns	*	ns
H X P	ns	ns	ns
H X P X C	ns	ns	ns

[a] ns= not statistically significant, * = significant at the 5% probability level, ** = significant at the 10% probability level.



8. The total yield from the main crop and first and second ratoons of the best variety (Cosor 3) exceeded 8 t/ha from the January, April, and September plantings. Populations in excess of 200,000 plants/ha and cutting height had only small influences on total yield. IRRI, 1982.

corresponding ratoon yields of the other cultivars. Ratooning superiority of Cosor 3 was most noticeable in the third harvest, especially in the January planting.

Plant density affected the main crop yields from the January and April plantings and the ratoon yields from the September planting (Table 3). The main crop yields had negative responses to plant densities exceeding 300 000 plants/ha, suggesting that only minor crop yield increases, if any, can be expected when densities exceed 200 000 plants/ha.

The effects of ratoon management variables of primary interest in this study were not consistent across plantings nor were they consistently of major agronomic importance even though statistically significant. At high densities, yields from the second ratoon of the April planting and the first ratoon of the September planting were slightly greater (Table 4). Moreover, the only significant cultivar-plant density interaction was found in first ratoon yields of the April planting. This interaction was attributed to declining yields (2.5 to 2.1 t/ha) as the population of CS 110 increased from 200 000 to 400 000 plants/ha, whereas the yields of the other cultivars fluctuated irregularly within a narrow range (2.4 to 2.6 t/ha) as plant densities increased. Although a yield advantage for the ratoon crop may come from a main crop population of 300 000 plants/ha, the inconsistent and low responses create doubts for the practice.

There was evidence that cutting height interacted with cultivar. As cutting height increased, Cosor 3 yields significantly increased in the first ratoon of the January planting and the second ratoon of the April planting (Table 5). The other two cultivars exhibited small increases, decreases, or no changes as cutting height increased. The significant cutting height-plant density interaction in the first ratoon yields of the January planting arose from a minor deviation in the general trend of increased yields

Table 3. Main-crop sorghum yields as affected by plant density and planting date.[a] IRRI, 1982.

Plant density (1000 plants/ha)	Yield (t/ha) of crop planted in		
	Jan	Apr	Sep
200	4.9 ab	3.6 a	2.3 a
300	4.0 a	3.4 a	2.2 a
400	4.8 b	3.2 b	2.1 a

[a]Av of four replications and three cultivars.

Table 4. First and second ratoon sorghum yields as affected by plant density and planting date.[a] IRRI, 1982.

Plant density (1000 plants/ha)	Yield (t/ha)							
	Jan		Apr		Sep		Mean	
	1st ratoon	2nd ratoon	1st ratoon	2nd ratoon	1st ratoon	2nd ratoon	1st ratoon	2nd ratoon
200	1.6 a	1.2 a	2.4 a	2.2 b	2.4 b	2.1 a	2.1	1.8
300	1.6 a	1.3 a	2.4 a	2.5 a	2.9 a	2.2 a	2.3	2.0
400	1.7 a	1.3 a	2.3 a	2.5 a	3.0 a	2.2 a	2.3	2.0

[a]Av of four replications of three cutting heights.

Table 5. Yields from the first and second ratoon crops of three sorghum cultivars as affected by cutting height and planting thee date.[a] IRRI, 1982.

Cutting height (nodes above ground level)	Cultivar	Yield (t/ha)					
		Jan		Apr		Sep	
		1st ratoon	2nd ratoon	1st ratoon	2nd ratoon	1st ratoon	2nd ratoon
0	Cosor 3	1.7	2.3	2.3	2.3	2.8	2.8
	CS 110	1.3	0.6	2.4	2.6	2.9	1.7
	UPL SG5	1.9	0.8	2.4	1.7	2.2	2.3
1	Cosor 3	1.8	2.3	2.4	2.7	3.0	2.6
	CS 110	1.3	0.7	2.2	2.4	3.0	1.5
	UPL SG5	1.8	0.8	2.6	2.1	2.5	2.1
3	Cosor 3	2.1	2.2	2.5	3.1	3.1	2.8
	CS 110	1.1	0.8	2.3	2.5	3.2	1.7
	UPL SG5	1.7	0.7	2.4	2.3	2.2	2.2

[a]Av of four replications and three plant densities.

from increased plant density. Similar minor deviations from general trends were also the source of the significant cultivar-plant density-cutting height interaction in the first ratoon grain yields of the January planting. Although such interactions were interesting, they were agronomically small for the most part and of doubtful repeatability.

Cosor 3 was superior to both CS 110 and UPL SG5 in total yields over the three harvests. A September planting was least favorable for all cultivars. Apparently, the low main crop yields from April and September plantings were attributable to low solar radiation levels (Fig. 7, 8). Ratoon yields from the April and September plantings, although equal to or only slightly less than main crop yields, did not compensate for lower main crop yields. Plant densities exceeding 200 000 plants/ha and a cutting height at the third node above the ground resulted in a ratoon yield advantage, but were not clearly superior to 200 000 plants/ha and a cutting height at the first node.

Plant density, row width, and ratoon cutting height. An experiment was conducted to examine the effects of plant density (100 000, 200 000, 300 000, or 400 000 plants/ha) and row width (40, 60, or 80 cm) on main crop and ratoon yields and of cutting height (ground level or three nodes above ground) on ratoon yields. The field was thoroughly plowed and rotovated and the main crop received a blanket application of 60-13-25 kg (N, P, K)/ha before the last rotovation. Cosor 3 was overseeded and thinned to the required plant densities at 19 DAS. Before hilling up, 30 kg N/ha was side-dressed on the main crop at 22 DAS, and 50 kg N/ha on each ratoon. Planting took place in April 1981 and the second ratoon was harvested in February 1982. The main crop was irrigated after seeding and again at flowering. Each ratoon was irrigated immediately after harvesting.

Weeds were controlled by a preemergence herbicide, hilling up at 22 DAS, and occasional hand weedings. Crops were adequately protected from insect pests, diseases, and birds. Four replications in a split-split plot design were planted with plant density treatments in main plots, row-width treatments in subplots, and cutting-height treatments in sub-subplots.

Separate statistical analyses were conducted. Yields were affected by only plant density in the main crop; by row width and cutting height in the first ratoon; and by row width, cutting height, and their interactions in the second ratoon.

The effect of plant density did not carry over from the main crop although trends were visible. Its effects on overall yield suggested that no yield gain would result from high plant densities, at least for an April planting.

Although cutting height only slightly affected first ratoon yields, its influence was strongly expressed on the second ratoon yields (Table 6). The significant row width — cutting height interaction in the second ratoon was attributed to the irregular mean grain yields from the 3 widths when cut at ground level. Although the yields of both the

Table 6. Yields of the first and second ratoon sorghum crops as affected by row width and cutting height.[a] IRRI, 1981 April planting.

Row width (cm)	Yield of sorghum cut at		Mean
	Ground level	Three nodes above ground level	
	1st ratoon		
40	2.2	2.4	2.3 a
60	2.4	2.6	2.5 b
80	2.4	2.6	2.5 b
Mean	2.3 a	2.5 b	
	2nd ratoon		
40	1.7	2.9	2.3 a
60	2.4	2.9	2.6 b
80	2.1	2.6	2.4 a
Mean	2.1 a	2.8 b	

[a]Av of four replications and four plant densities.

first and the second ratoons were comparatively insensitive to the range of row widths, cutting the crop at three nodes above the ground produced a yield advantage more strongly expressed in the second ratoon yields. This parallels the cutting height response observed in the second ratoon from the April planting in the experiments described earlier.

Nitrogen fertilizer management for ratooning. Two experiments were conducted to compare the effects of N management (timing, placement depth, and source) on ratoon yields. Fields for both experiments were thoroughly plowed and rotovated, 60-13-25 kg (N, P, K)/ha was broadcast applied before the last rotovation, and cultivars were overseeded in 60-cm row widths. The test plots were thinned to 300 000 plants/ha at 18-19 DAS. At 3 WAS, N was side-dressed before hilling up. Weeds, birds, and insects were adequately controlled. The main crop was irrigated after seeding and again at flowering. Each ratoon was irrigated immediately after harvesting.

In the first experiment, the experimental factors were:

- time of N application relative to harvest date (6 DBH, the day of harvest, or 6 DAH),
- the proportions of 60 kg N/ha applied 6 DBH and at PI of the ratoon crop (one-third near the harvest date + two-thirds at PI, two-thirds near the harvest date + one-third at PI, or all near the harvest date), and
- placement depth (on the soil surface or 10 cm deep and 5 cm to the side of the row).

These treatments were applied to the main plots, subplots, and sub-subplots of the split-split plot experiment and replicated four times. Cosor 3 was planted in June 1981; the second ratoon was harvested in April 1982. The mean main crop yield was 3.3 t/ha.

Statistical analysis indicated that only changes in the proportion of N fertilizer applied near the harvest date and at PI affected first ratoon yields (Table 7) and only N placement depth affected second ratoon yields (Table 8). The benefit from deep placement in the second ratoon may be attributed to a lack of moisture in the surface soil during the DS, which would reduce the availability of surface-applied N.

The crop in the second experiment was planted in April 1981 and the second ratoon was harvested in March 1982. Experimental factors were:

Table 7. First and second ratoon sorghum yields as influenced by the proportions of 60 kg N/ha applied near harvest and at PI. IRRI, 1981 WS.

Proportion applied at		Yield[a] (t/ha)		
Harvest	PI	1st ratoon crop	2nd ratoon crop	Total[b]
1/3	2/3	1.9 b	1.5 a	6.7
2/3	1/3	2.3 a	1.5 a	7.0
All	–	2.1 ab	1.6 a	7.0
			CV (%)	
		17	22	–

[a]Av of four replications. [b]Includes 3.3 t/ha from the main crop.

Table 8. First and second ratoon sorghum yields as influenced by N placement depth on the ratoon crop. IRRI, 1981 WS.

N placement depth	Yield[a] (t/ha)		
	1st ratoon crop	2nd ratoon crop	Total[b]
On soil surface	2.1 a	1.2 b	6.6
Deep placement (20 cm) beside the row	2.1 a	1.8 a	7.3
		CV (%)	
	15	28	–

[a]Av of four replications and six N proportions – timing treatments. [b]Includes 3.3 t/ha from the main crop.

- N fertilizer source (USG or AS),
- cultivar (Cosor 3 or UPL SG5), and
- cutting height (ground level, 1 node above ground, or three nodes above ground).

The last two factors were included to identify possible interactions with N sources. The ratoon crops received 50 kg N/ha from one of these sources just before hilling up.

Neither cutting height nor N source affected the yield of either the first or second ratoons. Yields from the main and second ratoons, however, were significantly affected by cultivars (Table 9).

From the experiments, it was concluded that the first ratoon, and perhaps the second, will use N fertilizer more efficiently when two-thirds or more of a 60 kg N/ha total application is applied within 6 DBH. For ratoon yields, deep N placement is not clearly more efficient than surface application.

Table 9. Main and ratoon yields of sorghum cultivars. IRRI, 1981 April planting.

Cultivar	Grain yield[a] (t/ha)			
	Main crop	1st ratoon crop	2nd ratoon crop	Total
UPL SG5	2.8 b	2.4 a	1.9 b	7.1
Cosor 3	3.4 a	2.5 a	2.9 a	8.7
		CV (%)		
	12	28	14	–

CULTURAL MANAGEMENT PRACTICES ON WHEAT PLANTED AFTER RICE

Wheat was tested as an alternative crop to grow after WS rice when annual temperatures are lowest. The cultural requirements of wheat in the tropics have not been well determined. Alternative cultural practices were tested in three experiments planted at the IRRI farm in January 1982.

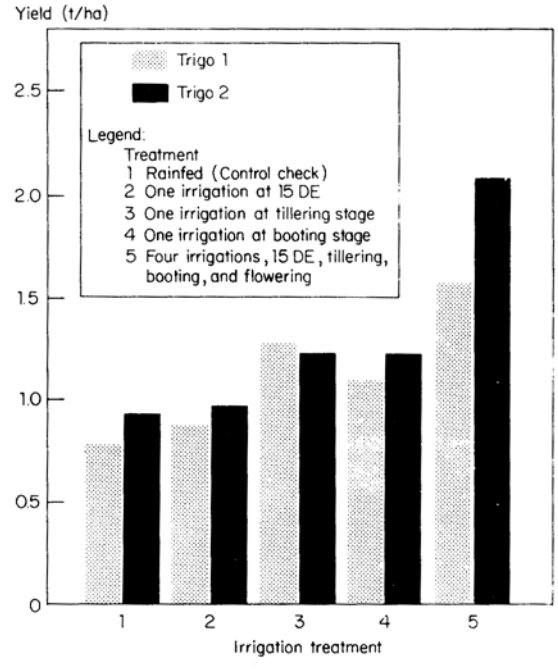
In the first experiment, factorial combinations of three tillage levels (zero, two, and four rotovations) and three planting methods (dibbling, drilling, and RIP injection) were compared in a split-plot design with four replications. The variety Trigo 1 was seeded in rows on 30-cm centers at 120 kg/ha, and fertilized with 90-17-34 kg (N, P, K)/ha. The crop was chemically protected from insects, diseases, and weeds. Irrigations were applied at planting, tillering, and flowering.

Neither tillage nor planting method, nor their interaction, influenced yields. The CVs were 9% for the main plot and 10% for the subplots. Mean yield over all treatments was 1.8 t/ha.

In the second experiment, the effects of irrigation timing were compared for Trigo 1 and Trigo 2. Plots were irrigated at 15 DE, tillering, booting, and flowering; at 15 DE only; at tillering only; or at booting only. A fifth treatment was unirrigated. Seeding rates, row widths, fertilizer rate, and crop protection were identical to those in the first experiment.

Yields were significantly affected by variety and irrigation timing and their interaction. Trigo 2 was the overall high yielder (Fig. 9), and it responded most to the high irrigation intensity (2.1 t/ha). Of the three single irrigation treatments, applications at tillering and booting were more effective than those at 15 DE.

In the third experiment, the responses of Trigo 1 to N and P applications and seeding rates were determined. All factorial combinations of three N rates (40, 80, and 120 kg/ha), three P rates (0, 30, and 60 kg/ha), and an unfertilized control were planted in main plots. All the P and half the N were



9. Yields of two wheat varieties given five irrigation treatments, means over four replications. IRRI, 1982 DS.

incorporated just before planting. The remaining N was applied at PI. Seeds at 100, 150, and 250 kg/ha were drilled in subplots in 30-cm wide rows. The experiment was irrigated at planting, 15 DE, tillering, booting, and flowering. Pests were chemically controlled.

Neither P nor seeding rate increased yields. The first 40 kg N/ha produced a sharp yield increase, but the last 40 kg produced no additional increase (Fig. 10).

To obtain the highest wheat yields after rice on the IRRI farm, irrigation should be frequent, 80 kg N/ha should be applied, and the seeding rate should be 100 kg/ha. No P is needed. The RIP can be successfully used in a zero-tillage situation.

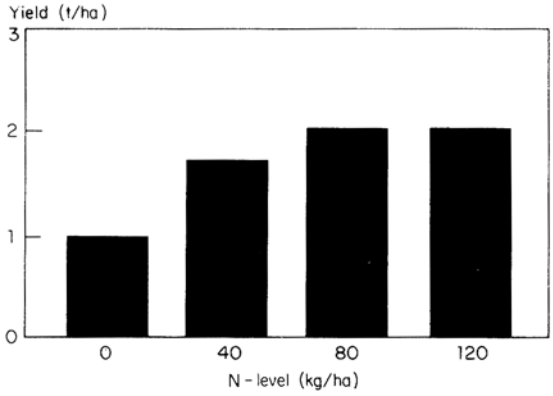
INTERCROPPING OF MAIZE AND SOYBEAN

Crop yield sensitivity to soybean varieties of differing growth characteristics and to plant density changes. Three soybean cultivars of different origins (Acc. 2120 from Taiwan, SJ-2 from Thailand, and UPL SY-2 from the Philippines) and growth characteristics were intercropped with maize (IPB Var 1). In the intercrops, combinations of two soybean populations (200 000 and 300 000 plants/ha) and two maize populations (20 000 and 40 000 plants/ha) were tested factorially with the soybean varieties. For the population treatments of both crops, distances between rows were constant; the population differences were obtained by adjusting the number of plants per row. Maize was planted in rows on 150-cm centers. Two soybean rows were planted between the maize rows, 50 cm from the maize and 50 cm from each other. Monocrops of the soybean varieties (300 000 plants/ha) and maize (53 000 plants/ha) were also grown.

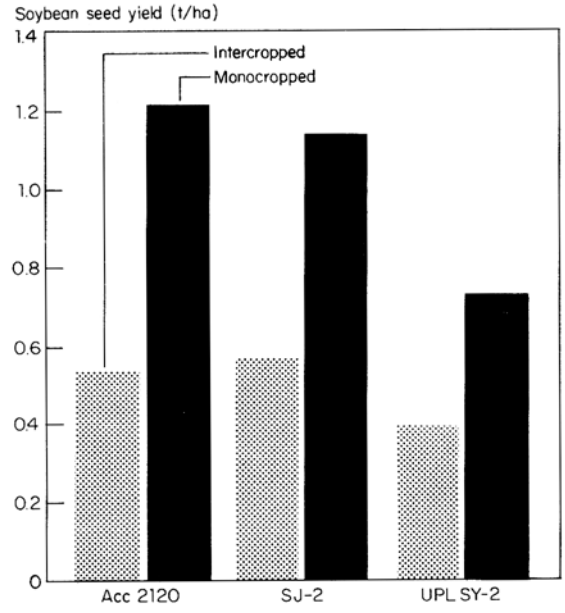
The experiment was replicated three times in a randomized complete-block design. The crops were planted in late December 1981 and harvested in mid-April 1982. Weeds, insects, and diseases were chemically controlled. The experiment was also hand weeded twice (1 and 4 WE). Before planting, 20-13-33 kg (N, P, K)/ha was broadcasted and incorporated. In addition to the basal application, seed-furrow applications of 20 kg N/ha were added to the maize. A side-dressing of 30 kg N/ha was applied at 4 WAS and at tasseling.

Neither maize nor soybean plant population differences influenced soybean yields. Although intercropping reduced yields considerably, Acc. 2120 and SJ-2 significantly outyielded UPL SY-2 (Fig. 11).

In monocropping and intercropping, Acc. 2120 produced significantly more pods per plant than SJ-2, and SJ-2 more than UPLSY-2. Reductions in pods per plant in intercropping averaged 31%. Between monocrops and intercrops, the difference



10. Yield response of wheat (Trigo 1) to N fertilizer. Means over four replications, three P rates, and three seeding rates except at 0 N, which is the mean over replications and seeding rates only. IRRI, 1982 DS.



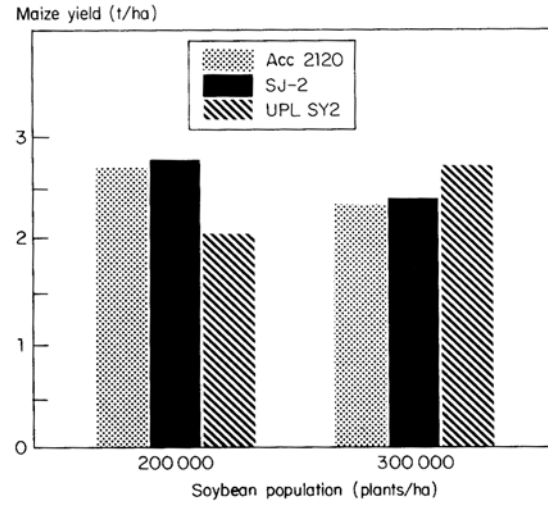
11. Yields of three monocropped and intercropped soybean varieties. Means of three replications. IRRI, 1981-82 DS.

in seed number per pod was insignificant, but among cultivars, variations were significant. The cultivars differed significantly in 100-seed weight.

Within the intercropping treatments, maize yields were significantly (P=0.01) affected by the interaction of soybean variety and population, but not by the main effects of any other factors or their interactions (Fig. 12). The average maize monocrop yield (3.6 t/ha) was significantly higher than the average intercrop yield (2.5 t/ha).

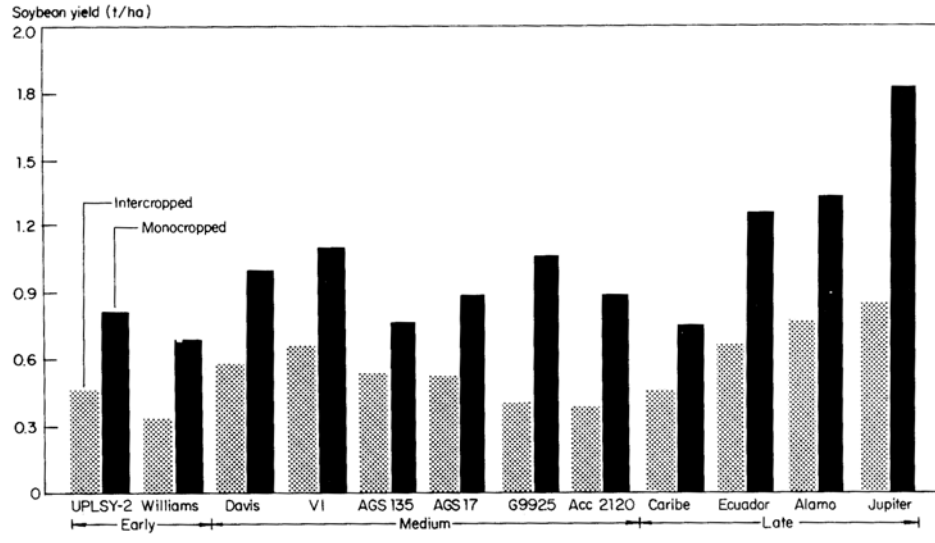
Comparative performance of soybean varieties. Twelve soybean cultivars were intercropped with maize (IPB-1) and, for comparative purposes, the soybean cultivars and the maize cultivar were also monocropped. The cultivars were planted early in January and harvested in April. For soybean, 300 000 plants/ha were used in both treatments; for maize 40 000 plants/ha were used in the intercropping and 53 000 plants/ha in the monocropping. The fertilizer rate was 20-13-33 kg (N, P, K)/ha. Weeds, insects, and diseases were chemically controlled. The 25 treatments were replicated three times in a randomized complete-block design.

Intercropping depressed all soybean cultivar yields (Fig. 13). Although the average yield of soybean intercropped with maize was 46% lower, soybean varieties interacted with the type of culture. Cultivars with superior yields in intercropped culture tended to have superior yields in monocropped culture. The rank correlation between the two cultures was 0.79 (significant at P=0.01). Jupiter, monocropped and intercropped, yielded significantly higher than any other variety (Table 10). Yields from intercropped varieties ranged from 0.34 to 0.83 t/ha.



12. Maize yields when intercropped with three soybean varieties at two soybean plant populations. Means over two maize populations and three replications. IRRI, 1981-82 DS.

Yield had a significant positive association with number of pods per plant, days to flowering, and days to harvest. In the monocrops, pods per plant



13. Yield of 12 intercropped and monocropped soybean varieties (early < 85 and late > 90 d). IRRI, 1982.

Table 10. Seed yields of 12 soybean varieties monocropped and intercropped with maize.[a] IRRI, 1981-82 DS.

Variety	Yield (t/ha)		Pods/plant		Seeds/pod		100-seed weight (g)	
	Mono-cropped	Inter-cropped	Mono-cropped	Inter-cropped	Mono-cropped	Inter-cropped	Mono-cropped	Inter-cropped
Williams	0.69 de	0.34 d	11 e	9 c	2.00 ab	2.00 a	14.8 ab	13.9 cd
Davis	1.00 cd	0.56 bcd	19 bcd	11 bc	2.04 a	1.86 ab	12.6 cd	13.9 cd
Alamo	1.32 b	0.75 ab	22 bc	15 bc	2.15 a	2.12 a	12.6 cd	13.8 cd
Ecuador	1.26 bc	0.67 abc	17 bcde	13 bc	1.88 ab	1.81 ab	15.2 ab	16.2 ab
Jupiter	1.82 a	0.83 a	22 bc	16 bc	2.04 a	1.97 a	16.4 a	16.6 a
VI	1.12 bcd	0.67 abc	16 cde	12 bc	2.08 a	2.07 a	12.0 de	12.8 d
Caribe	0.76 f	0.45 cd	23 b	16 b	1.89 ab	1.84 ab	10.5 e	11.0 e
AGS 135	0.76 ef	0.54 bcd	14 de	9 c	1.93 abc	1.88 ab	13.9 bc	13.7 cd
AGS 17	0.89 def	0.53 bcd	16 cde	11 bc	1.67 c	1.66 b	14.8 ab	14.8 bc
G 9925	1.06 cd	0.40 cd	17 bcde	10 bc	1.76 bc	1.96 a	12.0 de	13.7 cd
UPLSY-2	0.82 ef	0.46 cd	14 de	9 bc	1.93 ab	1.91 ab	15.2 ab	15.5 ab
Acc 2120	0.89 def	0.38 d	41 a	32 a	1.99 ab	1.97 a	5.0 f	5.1 f
Mean	1.03 a	0.55 b	19 a	14 b	1.94 a	1.93 a	12.9 b	13.5 a

[a]Means in columns (excluding means in the bottom row) followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test. Means in the bottom row followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

varied from 11 to 41; in the intercrops, they varied from 9 to 32. Intercropping reduced the pods per plant about 30%. Seeds per pod varied significantly among the 12 varieties in both cultures. Differences in 100-seed weight among the cultivars were also significant in both cultures and between cultures.

Although number of days to flowering and to harvest varied among cultivars, culture type did not alter duration significantly. Williams flowered earliest at 26 DE and Acc. 2120 latest at 45 DE. UPLSY-2 was the first to mature (78 DE) and Jupiter the last (101 DE).

The competition from maize caused a 7-cm increase in plant height of the intercropped soybean cultivars. At 75 DAS, mean dry matter yield of the intercropped soybean was only 0.1 t/ha greater than that of the monocropped, suggesting that competition with maize did not significantly inhibit vegetative growth of soybean.

Monocropped maize yielded 4.6 t/ha and intercropped maize, 3.0 t/ha (averaged over intercropped treatments). Intercropped maize yields ranged from 2.5 to 3.6 t/ha. A significant inverse trend between maize and soybean yields indicated crop competition. The average 34% higher yield of monocropped maize over intercropped maize could be partly attributed to the 33% higher plant population in the monocropped maize.

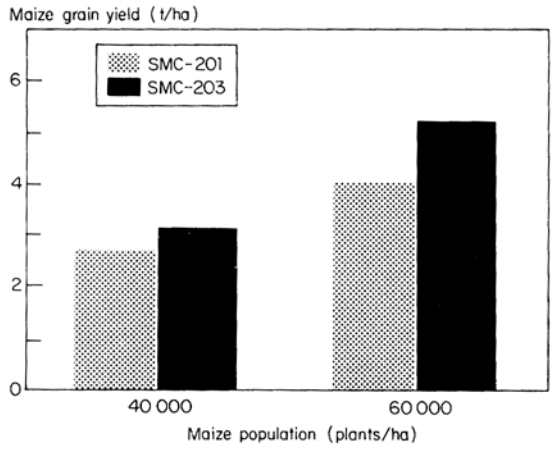
Effect of maize leaf erectness and canopy adjustment. The effect of maize leaf erectness and changes in the maize canopy on yield performance of soybean and maize was determined. Two maize varieties, SMC 201 (erect leaf) and SMC 203 (normal leaf), were planted at 40 000 and 60 000 plants/ha. The soybean variety Jupiter was planted at 300 000 plants/ha. Row distances were the same as those in the previous experiments.

Within intercrop treatments, the maize canopy was unmodified, detopped above the ear 24 d after silking, detasseled and defoliated below the ear 10 d after silking, or removed (the entire above-ground crop was harvested) 20 d after silking.

Planting was done in June and harvesting in September. The experiment, with three replications, used a split-split plot design. It was arranged so that the maize monocrops (four treatment combinations of hybrids and populations) were included in the analysis of variance with the intercropped and canopy treatments. Soybean monoculture was handled similarly.

Maize yields were significantly affected by population, hybrid, and canopy treatments (intercropping and canopy modifications). Yields were also influenced by population-hybrid, hybrid-canopy treatments, and population-canopy treatment interactions.

The effects of plant populations and hybrids and their interaction on yield are shown in Figure 14. The normal-leaf hybrid was higher yielding than the erect-leaf hybrid, especially at the higher plant



14. Maize yield of two hybrids, SMC 201 (erect leaf) and SMC 203 (normal leaf), at two populations. Means over four treatments and three replications. IRRI, 1982 WS.

population. For both hybrids, 60 000 plants/ha resulted in higher yields.

Yields of the maize intercrops averaged 0.6 t/ha lower than those of the monocrops (Table 11). The difference was greater at 60 000 plants/ha. Among the intercropped treatments, that with the low population of plants detasseled and defoliated below the ear had the greatest yield depression.

Hybrid-canopy treatment interaction was apparent (Table 11). Both hybrids as monocrop yielded about equally well, but intercropping depressed SMC 201 yields much more than SMC 203 yields. Within intercropped treatments, canopy modification of both hybrids depressed yields about equally.

Intercropped soybean yields were affected by maize canopy treatments and the maize population-hybrid-canopy treatment interaction. Yields of detopped maize were the least depressed; yields of the maize with unmodified canopy were the most depressed.

Regardless of the maize canopy, the maize hybrid, or the plant population, soybean yields were strongly depressed when intercropped. The monocrop soybean yield was 1.41 t/ha, whereas the highest yield among intercropping combinations was only 0.62 t/ha. Across all intercropping treatments, soybean yields averaged only 32% of the monocrop yield. No clear pattern was evident to explain the maize population-hybrid-canopy treatment interactions. Because of major yield depressions from intercropping, it is doubtful that any interaction would be sufficiently strong to justify exploitation.

When intercrops with the two maize hybrid leaf types were compared, soybean yields did not differ significantly. Mean soybean yields were 0.51 t/ha with 40 000 maize plants/ha and 0.40 t/ha with 60 000 plants. The difference was not significant, but because the means came from the main plots, the statistical sensitivity for comparison was low.

It was apparent that the maize and soybean crops were competitive because soybean yields decreased as maize yields increased.

EFFECTS OF PREVIOUS SOIL MANAGEMENT, TOPOPOSITION, AND TILLAGE LEVEL ON MUNGBEAN AND SORGHUM

To determine the effects of tillage and planting combinations and puddling of the preceding rice crop on growth and yield of mungbean and sorghum planted after wetland rice in three topopositions, a series of experiments was conducted

Table 11. Maize yields from eight population-canopy type treatments and eight hybrid-canopy type treatments.[a] IRRI, 1982 WS.

Canopy type	Population (plants/ha)			Maize yield (t/ha)		
	40 000	60 000	Mean	SMC 201	SMC 203	Mean
Monocrop	5.0 bc	6.3 a	5.7	5.8 a	5.6 a	5.7
Intercrop, unmodified	4.8 c	5.4 b	5.1	4.8 b	5.4 a	5.1
Intercrop, detopped[b]	4.2 de	4.6 cd	4.4	4.1 c	4.7 b	4.4
Intercrop, detasseled and defoliated[c]	3.8 e	4.8 c	4.3	4.0 c	4.6 b	4.3
Mean	4.4	5.3		4.7	5.1	

[a] Av of three replications. [b] Plant tops above the ear removed 24 d after silking. [c] Detasseled and defoliated below the ear 10 d after silking.

on the IRRI dryland farms. The topopositions were represented by adjacent-level rice fields, with the highest level 43 cm above the intermediate and 83 cm above the lowest. In each topoposition, the treatments were replicated four times in a split-split plot design.

Puddling and nonpuddling were compared in the main plot, mungbean and sorghum in the subplot; and three tillage and planting combinations in the sub-subplot. The tillage-planting combinations are described in Table 12. Because of their different moisture regimes, the high, intermediate, and low fields were seeded on different dates (Fig. 15). Because of heavy disease at the early-flowering stage of mungbean, reliable data were not obtained from the lowest position.

Mungbean (CES-1D) was seeded at 50- × 7.5-cm plant spacings (267 000 plants/ha) and sorghum (Cosor 3) seeded at 50- × 15-cm spacings (133 000 plants/ha). In the zero-tillage treatments, fertilizer was side-dressed at planting; in the high-tillage treatments, it was incorporated by the last harrowing. Both crops received 40-18-33 kg (N, P, K)/ha; sorghum received an additional side-dressing of 40 kg N/ha at 30 DE. Butachlor (1.0 kg ai/ha) was applied at planting and was followed by two hand weedings. Azodrin EC was applied at 0.25 kg ai/ha at 5 and 15 DE, and at 1.5 kg ai/ha at 35 and 45 DE. The experiment was intended to be rainfed only, but to save crops from severe drought, 30 mm water was sprinkler-irrigated on 15 Feb. Seasonal rainfall and class A E_{pan} values are in Figure 15.

Grain yield, total dry matter yield, and changes in the soil moisture profile to 100 cm (determined by neutron attenuation) were recorded.

Across the three topopositions for both crops, neither grain yield nor total dry matter yield was influenced by puddling of the previous rice crop. Furthermore, tillage and planting treatments did not interact with previous puddling to cause any effects.

Within the high and intermediate positions, mungbean was not affected by the tillage and planting combinations (Table 12). The lower mungbean yields in the intermediate position were caused by powdery mildew, which infected the crop during the early reproductive stage.

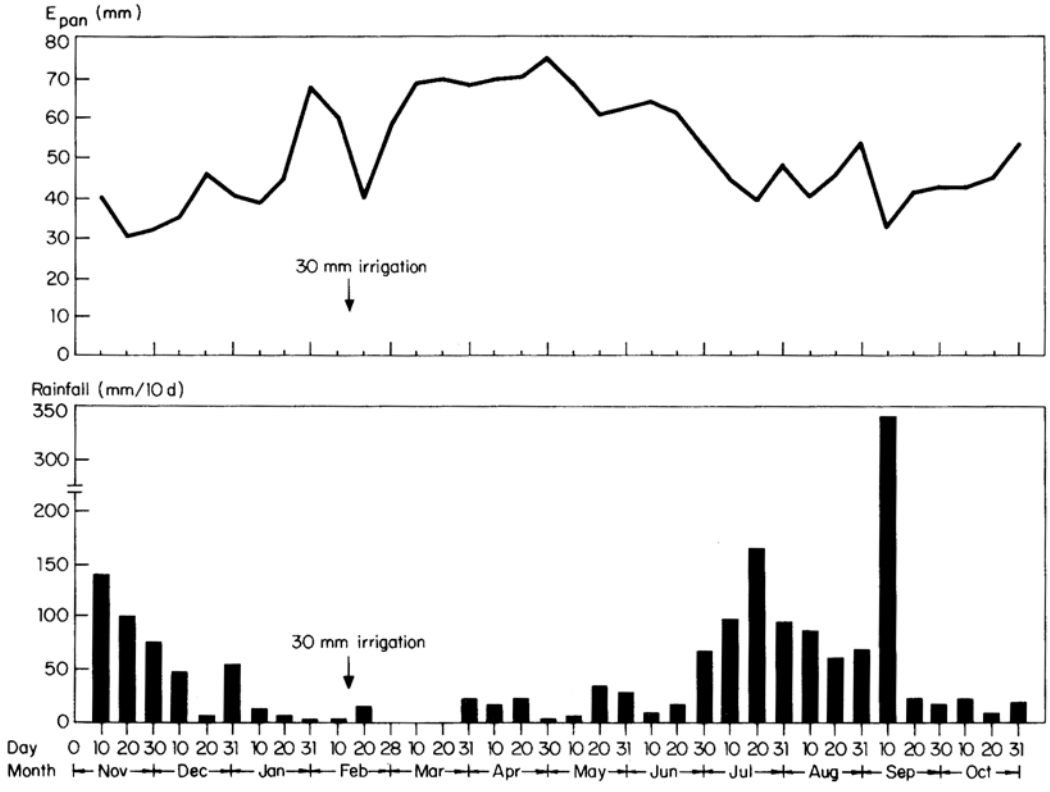
Within the high position, sorghum grain yields were relatively low and not affected by tillage-planting combination (Table 12). The low yields were attributed to inadequate water. Within the intermediate and low positions, the yields from the high-tillage and mechanical-planting combination, although not high, were unexpectedly good under the limited water conditions. The low grain yields from the zero-tillage treatments were attributed to plant population reductions resulting from the poor aeration caused by heavy rainfall 10-14 DAS.

Figure 16 shows that, across topopositions, there was a tendency for more water to be extracted from the previously puddled profiles than from the nonpuddled profiles. Mean initial and final soil water profiles under the puddled treatments were similar in the high and intermediate positions. Likewise, soil water profiles in the two positions

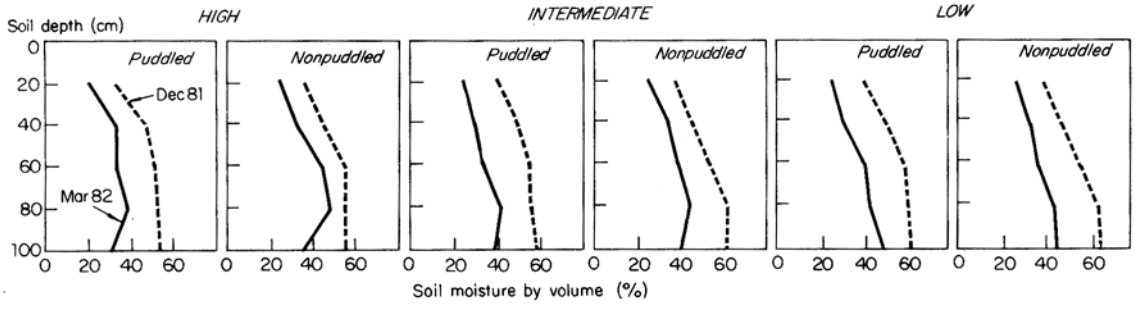
Table 12. Grain and total dry matter yields of mungbean and sorghum from three tillage-planting combinations at three topositions. IRRI, 1982.

Tillage-planting combination[a]	High		Intermediate		Low
	Mungbean	Sorghum	Mungbean	Sorghum	Sorghum
		Grain yield (t/ha)			
Zero + RIP	0.83 a	1.58 a	0.48 a	1.27 b	1.84 a
Zero + dibbled	0.87 a	1.36 a	0.55 a	0.97 c	1.97 a
High + conventional	0.91 a	1.53 a	0.59 a	2.69 a	2.45 a
		Total dry matter yield (t/ha)			
Zero + RIP	1.95 a	6.06 a	2.14 a	3.75 a	5.16 a
Zero + dibbled	1.72 a	5.92 a	2.13 a	3.44 a	4.61 a
High + conventional	1.97 a	4.86 a	2.40 a	4.04 a	5.66 a

[a]Zero + RIP – zero tillage with seed placement by RIP (rolling injection planter); Zero + dibbled – zero tillage with seed placement by hand-drilling into narrow furrows made by a handtractor drag stick; High + conventional – high tillage (three rotovations) with seed placement by a small hand-pushed mechanical planter into furrows made by a wooden harrow.



15. Seasonal rainfall and class A E_{pan} during the experiments on three topopositions. Dryland crops were seeded on 9 and 16 Dec and 13 Jan in the high, intermediate, and low positions, respectively. IR52 was direct seeded on nonpuddled soil on 27 May on all topopositions.



16. Mean initial and final soil moisture profiles under sorghum and mungbean which had been planted on three topopositions in soils previously puddled or nonpuddled for wetland rice. IRRI, 1981-1982.

were similar in the nonpuddled treatments. However, the initial and final soil water profiles in the puddled and nonpuddled treatments were wetter in the low position than in the higher topopositions, especially below 60 cm. The higher water contents indicated that, in the low topopositions, water entered the soil profile by lateral movement from higher terrains.

PRODUCTION POTENTIAL OF DRYLAND RICE RELAY-CROPPED INTO MUNGBEAN

Under dryland rainfed conditions, early WS rainfall is inadequate to start a dryland rice crop but can support a mungbean crop. To examine the potential of a mungbean - dryland rice cropping pattern under the variable WS rainfall common to

Los Baños, two rows of dryland rice (IR43) were relay-planted between rows of mungbean (Pagasa) at 45 DAS; on the same day, rice was also planted on fallow plots. Mungbean was planted following the first April rains. Two mungbean management alternatives were compared. Mungbean plants were cut and relay-planted to rice rows after the first priming (at 66 DAS) or after the second priming (at 77 DAS). The mungbean treatments served as main plots in a split-plot design replicated four times. Four N fertilizer rates (0, 40, 80, and 120 kg/ha) were used as subplot treatments. Half the N was applied at tillering and half at PI.

The first mungbean priming yielded 0.84 t/ha and the second priming an additional 0.1 t/ha. Rice after fallowing yielded 1.5 t/ha, whereas relayed rice yielded 1.4 t/ha. Although results suggested that relaying would not strongly suppress dryland rice yields, the low yields caused by frequent drought during the rice-growing period prevented the drawing of clear conclusions. However, total production was much greater where mungbean had been planted before rice than where land had remained fallow.

EFFECTS OF PHOSPHORUS AND POTASSIUM ON TRANSPLANTED-RICE YIELDS

On the new IRRI farm, rice responds to N fertilizer, but its response to P and K, and possible interactions with N have not been examined. IR56 was planted in a randomized complete block design (four replications) in the WS. Ten treatments selected from the factorial combinations of four N rates (0, 40, 80, and 120), three P rates (0, 13, and 27), and two K rates (0 and 25) were compared. One-third of the N and all the P and K were incorporated by the final harrowing. One-third of the N was applied at 30 DT and the remainder at PI. Neither P and K increased grain yields, but the N increased yields substantially. Interactions were not significant. Mean grain yields corresponding to 0, 40, 80, and 120 kg N/ha were 2.4, 3.5, 3.8, and 3.7 t/ha, indicating no response to N beyond 80 kg/ha.

FERTILIZER RESPONSE OF DRYLAND RICE

In June, a rice cultivar (UPL Ri5), regarded as adapted to dry-seeded wetland and dryland conditions was drilled under nonbunded and nonpuddled conditions in the IRRI dryland area. Incorporation of rice straw (2 t/ha) plus farmyard manure (4 t/ha) and inorganic N, P, and K fertilizers were applied in selected treatments to determine the contributions of these amendments to grain yield response. Straw plus manure and P and K fertilizers were applied during land preparation. Half of the N was applied 25 DE and the remainder at PI. Treatments were arranged in four replications of a randomized complete block design. Mean yields are in Table 13.

Statistical contrasts showed that P, K, and straw plus manure did not increase yield beyond the level produced by both the first and second 60 kg/ha increments of N fertilizer.

INFLUENCES OF TOPOPOSITION AND PAST TILLAGE ON GRAIN YIELD OF DRY-SEEDED IR52

Puddling is a common method of preparing soil for transplanting or direct wet-seeding of rice. Dry-seeding, however, reduces the costs and time required to puddle, and moves the crop forward in the season. Where the WS is short, the grain-filling period is less likely to coincide with dry soil conditions. Furthermore, by advancing the harvest dates, a dryland crop can be planted earlier on a soil more favorable for root development.

At the IRRI dryland farm, a trial was conducted to determine if the effects of puddling are carried through to subsequent years. The test area consisted of three adjacent-level rice fields. The highest was 43 cm above the intermediate field; the lowest was 40 cm below the intermediate. At each level, puddled and nonpuddled plots were available from a previous study of the tillage effects on wetland

Table 13. UPL Ri5 yield as affected by rice straw, farmyard manure, and N, P, and K and fertilizer. IRRI, 1982 WS.

Treatment	Yield (t/ha)
Control	0.88
60 kg N/ha + 2 t/ha rice straw + 4 t manure/ha	1.69
60 kg N/ha	1.66
120 kg N/ha	2.24
120 kg N + 24 kg P/ha	2.25
120 kg N + 24 kg P + 50 kg K/ha	2.25

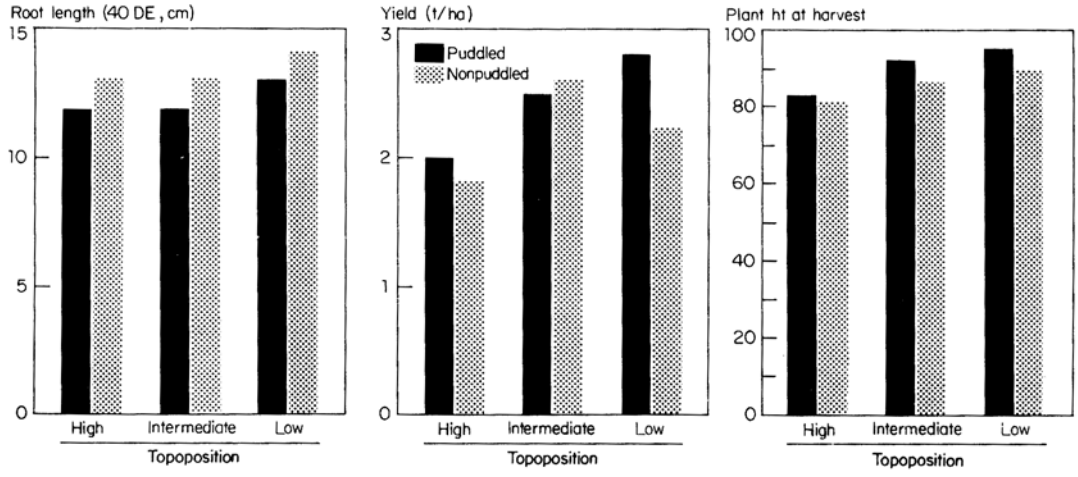
rice. These two residual tillage treatments, which had been repeated for the WS rice crop the past 4 yr, formed the second factor in the 1982 study. In both the previously puddled and nonpuddled soils, land was rototilled for the DSR crop. IR52 was dry-seeded in furrows in all plots on 27 May.

Seasonal rainfall and evaporation are in Figure 15. Grain yield and plant height (Fig. 17) of the six treatments indicate that toposequence was a more important factor than previous tillage practice. Although the residual puddling influence resulted in taller plants and shallower root penetration (Fig. 17) in all topopositions, previous tillage practices did not consistently influence grain yield. Moreover, the comparatively low yields in the nonpuddled, low topopositions were caused by high incidences of sheath blast and sheath blight. Although the residual effect of puddling was apparent on plant height and root extension, it was not strong, nor did it influence grain yield appreciably. Reasons for higher disease levels in this treatment are unknown. Whereas plots that had not been puddled in previous years tended to contain less water in the profile, this tendency was not consistent over topopositions with time. Figure 18 shows that, in June, water was withdrawn at all depths from all treatments, but depletion was less in the lowest position. The large quantity of water available in the intermediate and low topopositions probably accounted for higher yields and taller plants.

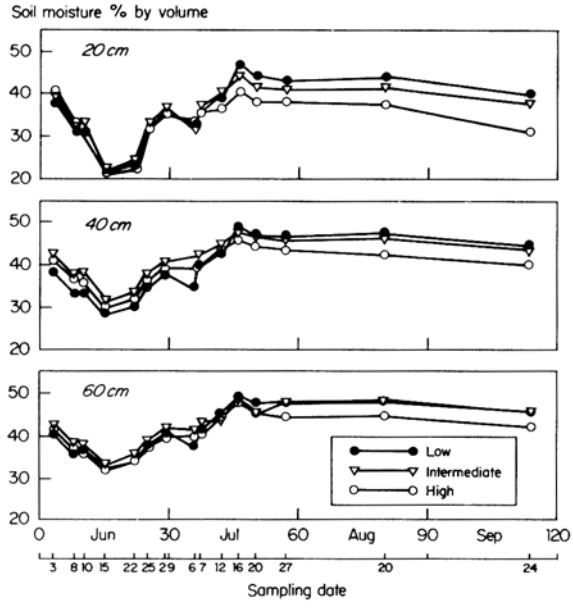
DECREASES IN LEGUME SEED VIABILITY CAUSED BY DRYING, THRESHING, AND STORAGE

Cowpea, mungbean, soybean, and peanut crops are frequently planted before or after rice. In the tropics, low grain legume seed viability is a widespread problem causing poor plant densities. Factors that could contribute to seed viability loss of four recommended grain legumes are cultivar, drying and threshing method, storage temperature and container, and storage duration.

The cultivars were CS-1D-21 and MG-5 (mungbean), All-season and EG-2 (cowpea), UPLSY-2 and Clark 63 (soybean), and Kidang and PBI P9 (peanut). To start with seeds that had matured under similar field conditions, these eight cultivars were planted in the latter part of October 1981. The two soybean cultivars had to be replanted because they were damaged by a typhoon in late November. After harvest, half the pods were sun-dried and half were dried in a flat bed dryer. The dried pods were divided into three equal parts to be threshed by hand, flail, or machine. From each drying and threshing combination, 20 samples of 50 seeds each were counted for each cultivar. Half the samples were placed into paper envelopes and half into sealed plastic envelopes. The packets were kept at room temperature (21°-28° C) and in cold storage (4° C) at predetermined intervals. Germination was tested five times: before storage and after 1, 2, 4, and 8 mo.



17. Root length at 40 DE, yield, and plant height at harvest of dry-seeded IR52 grown on three topopositions 1 yr after soils were puddled or nonpuddled for wetland rice. IRRI, 1982.



18. Mean soil moisture content at three soil depths of three topopositions, with dry-seeded IR52. IRRI, 1982.

Because the seeds tested immediately after threshing had not been subjected to the different storage containers, temperatures, and durations, they were analyzed separately.

An analysis of variance on the germination percentages of the zero storage-duration sample indicated that the species and threshing factors and their interaction affected germination percentage. Germination for all combinations of species and threshing methods ranged from 90 to 96% except for peanut when flailed (86%) or mechanically threshed (60%).

Analysis of variance on the germination percentages of stored seeds indicated that species, storage temperature, and storage duration had pronounced effects on germination percentage. There were strong species-threshing method and species-temperature interactions. Storage container and duration and interactions of species-drying method, species-duration, temperature-duration, and species-temperature-duration were also significant, but contributed less to percentage differences.

The species-threshing interaction (Table 14) was similar to that detected before the seeds were stored. Mechanical threshing decreased peanut germination 45% and soybean germination 10%, suggesting that mechanical and probably flail threshing should not be used in harvesting these legumes for seed.

The interactions of species, storage duration, and storage temperature are in Table 15. Mungbean viability was not appreciably affected by storage for 8 mo at room temperature. Although room storage temperature and long duration reduced germination percentage of other species, the effects were not consistent across species. Peanut viability was maintained under cold storage for 8 mo and at room temperature for 4 mo.

Table 14. Germination percentage of four grain legumes threshed by three methods.[a] IRRI, 1982.

Threshing method	Germination (%)			
	Mungbean	Cowpea	Peanut	Soybean
Hand	92 a	84 b	92 a	85 b
Flail	92 a	82 b	82 bc	86 b
Mechanical	93 a	86 b	50 d	78 c

[a]Means over two cultivars per species, two drying methods, two storage temperatures, two storage containers and four storage durations.

Table 15. Germination percentages of four grain legumes stored under room and cold temperature conditions for four durations.

Storage duration (mo)	Germination (%)							
	Mungbean		Cowpea		Peanut		Soybean	
	Room	Cold	Room	Cold	Room	Cold	Room	Cold
1	91 abcde	92 abcde	87 bcde	86 cdefg	78 hi	72 ij	95 a	96 a
2	91 ab de	92 abcde	78 ghi	91 abcde	69 j	69 j	83 fgh	92 abcde
4	93 abcd	92 abcde	78 hi	86 defgh	80 fgh	79 fghi	79 j	95 ab
8	95 a	94 abc	82 fgh	85 efgh	65 j	84 efgh	41 k	95 ab

[a]Means of two cultivars per species, two drying methods, three threshing methods, and two storage containers.

Apparently prolonged storage at room temperature adversely affected soybean viability. The decline appeared within 6 mo, and by 8 mo, viability had dwindled to less than half. These results emphasize the need for adequate seed-storage facilities or a fresh supply of seed if soybeans are to be grown on a commercial scale. The viability of cowpea was depressed only slightly by prolonged storage at room temperature.

FERTILIZER MANAGEMENT OF RATOON RICE

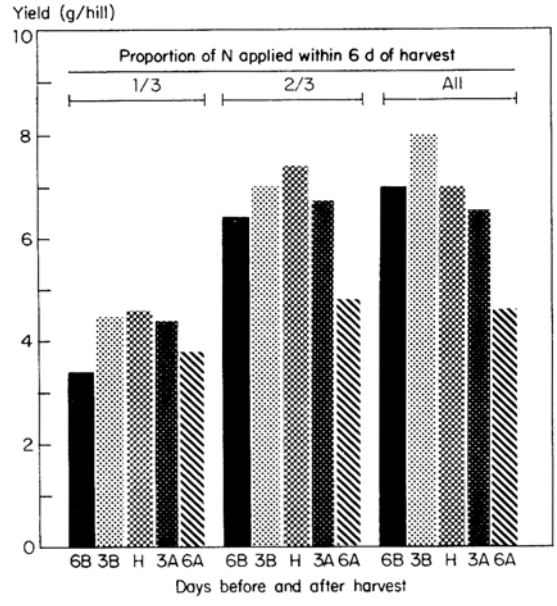
In rainfed wetland areas where there is insufficient rainfall to grow a full second rice crop, ratooning may be a means of using the 30- to 50-d periods during which excess water makes growing of a nonrice crop risky.

Ratoon yields consistently above 2 t/ha have not been demonstrated in field studies. In 1982, two pot experiments were conducted to examine the contribution of early fertilizer applications.

Influence of fertilizer. Full factorial combinations of the different times of early N fertilizer application relative to main crop harvest (6 DBH, 3 DBH, at harvest, 3 DAH, and 6 DAH); the application of early N fertilizer with and without 13 kg P/ha; the proportions of 60 kg N/ha applied early (6 DBH to 6 DAH) and at PI (all early, 2/3 early and 1/3 at PI, and 1/2 early and 1/2 at PI); and fertilizer placement depth (on soil surface and 10 cm below) were put in a split-split plot design with four replications. Time of early fertilizer treatments was in main plots, N and P fertilizer levels applied early and at PI in subplots, and fertilizer depth treatments in sub-subplots.

IR22103-6-2 seedlings (19 d old) were transplanted into 240 10-liter plastic pots (four seedlings per pot) that had been filled with 8 kg (dry weight) of Maahas clay soil. The main crop received 60-13-25 kg (N, P, K)/ha hand incorporated before transplanting and 30 kg N/ha side-dressed at PI. The ratoon was fertilized according to the fertilizer treatments. At 35 DT, plants were reduced to two per pot. The crop was transplanted in August 1981 and harvested in January 1982.

In the main crop, water depth was maintained at 5 to 7 cm until the ripening stage, after which water was drained from the pots, but the soil was maintained at near saturation. At harvest, the plants were cut 20 cm above the soil level, and water was brought to a 2-cm depth for the next 10 d. A 5-cm depth was maintained from that time until the ratoon crop was harvested.



19. Yield response to the proportion of 60 kg N/ha applied within 6 DBH or 6 DAH of the main crop. IRRI, 1982.

The major factors contributing to the ratoon yield differences were the proportion of N fertilizer applied early and the placement depth. P applications did not affect yields, but the time of early N application relative to main crop harvest affected yields slightly and interacted with the proportion of N applied early. The interaction between time of early N and proportion of early N (Fig. 19) shows that the highest N application at 3 DBH produced the highest ratoon grain yield. The ratoon yield (8 g/hill) was 41% of the main crop yield. Ratoon yield was 0.8 g/hill higher when N was placed at 10-cm depth than when it was placed on the soil surface (5.4 g/hill).

N rate and time of application. IR36 and IR54 and two hybrids (V20A/IR54 and IET3257A/IR54) received the eight N treatments summarized in Table 16. The varieties and hybrids were assigned to main plots and fertilizer treatments to subplots in six replications of a split-plot design. Four 20-d-old seedlings were transplanted into plastic 10-liter pots that had been filled with 9 kg

Table 16. N fertilizer rates and times of application in eight N treatments applied to the main crops of two rice varieties and two hybrids. IRRI, 1982 DS.

N fertilizer rate (kg/ha)				
Basal	Maximum tillering	PI	50% heading	Total applied
0	–	–	–	0
50	–	–	–	50
50	25	25	–	100
25	25	25	25	100
50	50	50	–	150
37.5	37.5	37.5	37.5	150
100	50	50	–	200
50	50	50	50	200

(dry weight) of Maahas clay soil. In addition to N fertilizer applied according to the test treatments, 22-42 kg (P, K)/ha was hand-incorporated before transplanting. Plants were thinned to two per pot at 29 DT. Water depths were maintained at the levels used in the previous experiment. The ratoon crop was side-dressed with 60 kg N/ha when the main crop was harvested. The experiment was planted in December 1981 and the ratoon was harvested in June 1982.

Cultivar affected main crop and ratoon yields, and N treatment affected main crop, but not ratoon, yields. Interaction between cultivar and fertilizer treatment was not significant. The response to total N applied at or before PI was essentially linear. N applied at 50% heading did not contribute appreciably, if at all, to main crop yield. Although N applications at 50% heading of the main crop tended to increase ratoon yields, the responses were not statistically significant. Moreover, in this experiment, mean ratoon yields were only 18% of the main crop yields, compared with 30% in the previous experiment. As is often the case in rice ratoon research, yield variability in the ratoon was excessive (CV=41%); therefore sound comparisons were impossible.

Main crop yields of the hybrids were 20% higher than those of IR54, but only 9% higher than those of IR36 (not statistically significant). The ratoon performance did not favor the hybrids. In this experiment, hybrid IET3257A/IR54 and IR54 were superior to hybrid V20A/IR54 and to IR36.

RESPONSES OF FOUR GRAIN LEGUMES TO SOIL MOISTURE GRADIENTS

In rainfed areas of the tropics, grain legumes are normally grown in a postmonsoon rice environment with erratic and rapidly diminishing rainfall and residual soil moisture. The crops often encounter moisture stress, especially during the reproductive and maturation stages. Four grain legumes often planted after rice are mungbean, cowpea, soybean, and peanut. Understanding the effects of various degrees of drought during their growth and development would be useful in planning crop intensification schemes for rainfed areas.

The experiment was conducted in January to April 1982 on a silty clay soil in the dryland area of the IRRI farm. Mungbean (CES ID), cowpea (EG No. 2), soybean (UPLSY-2), and peanut (Kidang) were subjected to varying degrees of drought during their entire growth and maturation periods. Levels of moisture stress were developed by the LSS irrigation system, which applied progressively decreasing amounts of irrigation water with increasing distance from the sprinkler line. Before planting, the field was plowed once and rotovated twice. A uniform application of 30-13-25 kg (N, P, K)/ha was broadcast before the last rotovation. Mungbean and cowpea were planted in one block and soybean and peanut in an adjacent block. The crops were drilled thickly in 50-cm rows parallel to the sprinkler lines. The mungbean, cowpea, and soybean plants were thinned to about 300,000/ha and peanut plants to 160,000/ha at 18 DE. Weeds were controlled with a preemergence spray of butachlor followed by hand weeding. Insect pests and diseases were minimized by the use of monocrotophos and decamethrin insecticides and benomyl fungicide. Seeds were treated with carboxin-captan fungicide.

The experimental design was strip-split plot with four replications. Each plot measured 5.1 × 13 m and was subdivided into five strips (5.1 × 2.5 m), representing different moisture regimes: 1 (closest to the sprinker line), 2, 3, 4, and 5 (farthest from the sprinkler line). Three planting methods were also compared. The test crops were planted on ridges, in furrows, and on flat ground. Crop species and planting methods were randomized within each replication; moisture regimes were fixed.

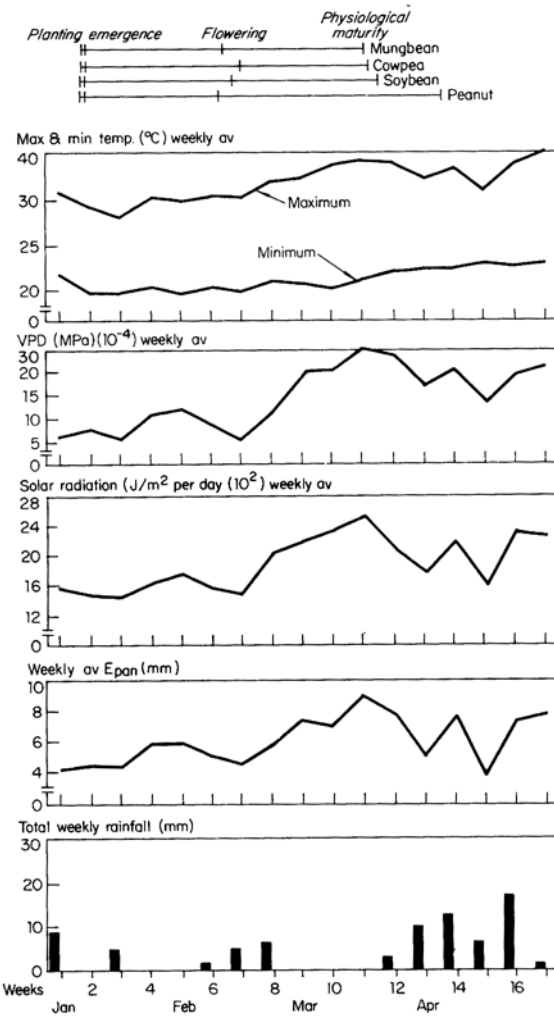
The entire experimental field was given a 15-mm irrigation to ensure uniform crop emergence. At 15 DE, LSS irrigation treatments were begun and were repeated at different intervals thereafter. The amount of water applied each time was recorded using catch cans placed at canopy height within each of the water-regime plots. The amount of water applied was the daily summation of 0.5 of E_{pan} measured at the experimental site since the previous irrigation. Irrigations were applied in the early morning before sunrise when winds were calm.

Soil moisture content at depths of 20, 40, 60, 80, and 100 cm was determined before and after each irrigation with a neutron scattering device lowered into the aluminum access tubes installed in the central rows of each moisture-regime strip. Crop water use was determined from applied irrigation water, rainfall, and the change in stored soil moisture and by assuming no deep drainage. LWP was measured at midday (1300 to 1400 h) using a pressure chamber. Canopy temperature (CT) was measured on selected dates with an infrared thermometer positioned 15 cm above the canopy. All measurements of leaf water status and CTs were taken from the same row and on plants close to the access tubes. Root length density was determined at 55 DE in the wettest and driest regimes with a soil core sampler.

Data for grain yield, plant dry matter, yield components, root distribution, and other crop growth determinants were obtained from the central undisturbed rows within each moisture regime.

The statistical analyses showed that the three planting methods did not affect seed yields and water use significantly; therefore data over all planting methods were pooled, increasing the number of replications from 4 to 12 per water regime.

The weather data during the experimental period were collected from a weather station about 150 m from the experimental site and are presented with the phenology of the crops in Figure 20. Air temperature, vapor pressure deficit, E_{pan}, and solar radiation generally increased as the season progressed. Light rains occurred at flowering, but quickly evaporated; those that occurred at later

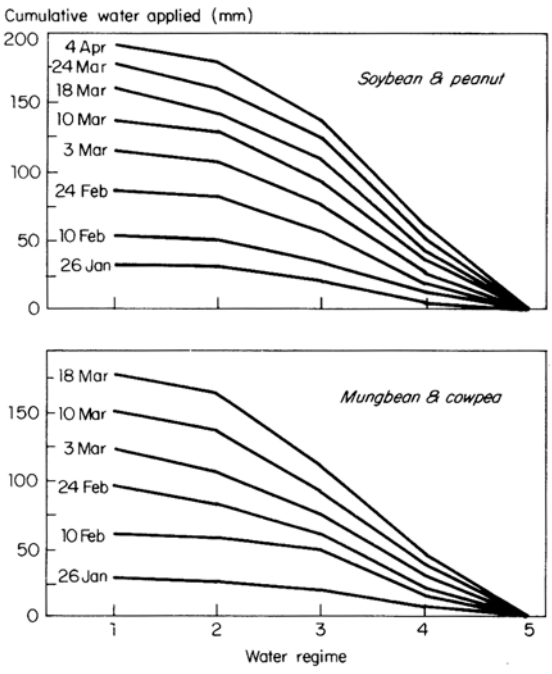


20. Weekly values of rainfall, E_{pan}, solar radiation, vapor pressure deficit (VPD), and maximum and minimum temperature during the crop growth period. IRRI, 1982.

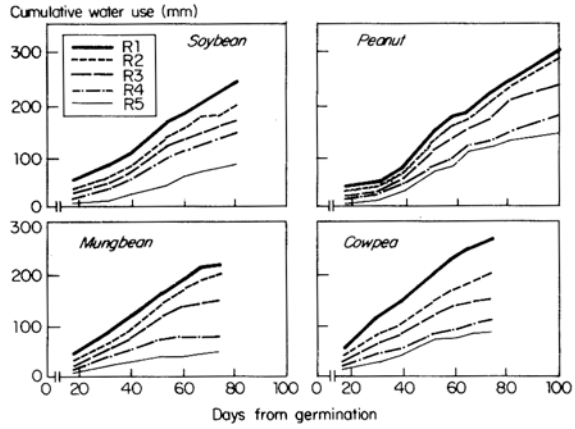
growth stages did not affect the trial as the crops were mature and about to be harvested.

Water measured in the catch cans showed that LSS applied a relatively uniform amount of water to each crop at each irrigation date (Fig. 21). The amount of cumulative water applied decreased gradually from the wettest regime (R1) to the driest (R5). The soybean and peanut received two additional irrigations because they had longer growth durations.

Seasonal water use and root distribution. Figure 22 shows the cumulative water use by the four



21. Water applied at each of the five water regimes with respect to the line source of each date for four grain legumes. IRRI, 1982.



22. Cumulative water use from germination to maturity by four grain legumes under five moisture regimes. IRRI, 1982.

legume species. Water use was consistently higher in the wet regimes than in the dry regimes. At the early stage, water uptake at the driest regime was similar among the four crops. Beginning about 50 DE, however, peanut used more water in the driest regime. At maturity, water use by peanut in the driest regime was 41% of that in the wettest regime; for cowpea it was 38%, for soybean, 37%, and for mungbean, 26% (Table 17).

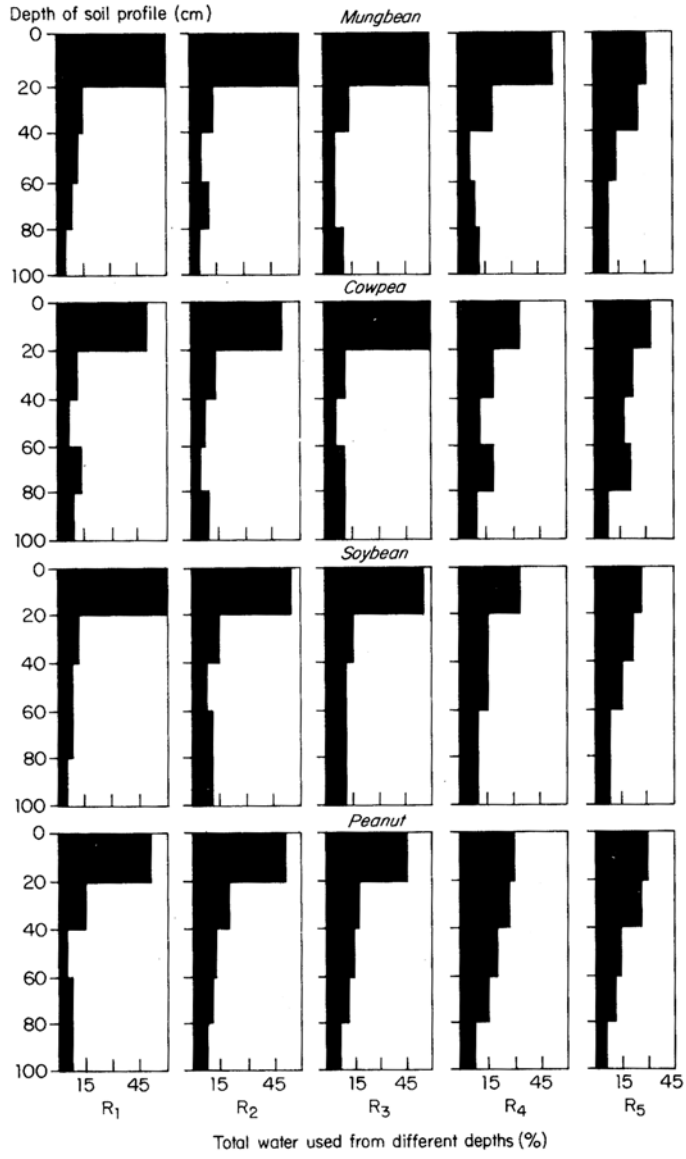
Water uptake patterns within the soil profile by the four crops are illustrated in Figure 23. Soil water extraction patterns in the wet regimes were similar for the four crops — a greater percentage of the extraction was in the upper 20-cm soil layer, below which little extraction occurred. In the dry regimes, however, peanut and cowpea extracted more water deeper in the soil than either mungbean or soybean. Figure 24 shows the change in soil water content from the start of the trial until harvest. By harvest, peanut and cowpea had clearly reduced the moisture content deep in the soil profile to a longer level than had either mungbean or soybean.

The greater ability of peanut and cowpea to exploit the soil water reserve in the drier regimes may be explained by their root distributions. Figure 25 shows the root densities measured at 55 DE in regimes 1 and 5. In the wet regime, most of the roots of all crops were concentrated near the soil surface; very few were below a 20-cm depth. In the dry regime, however, peanut and cowpea exhibited relatively profuse rooting in the 40- to 80-cm depth; mungbean and soybean roots were generally concentrated near the soil surface.

Seasonal changes in canopy temperature and leaf water potential. Figure 26 presents the changes in plant CT and LWP in the wet and dry regimes.

Table 17. Total water use by four food legumes under five moisture regimes. (R1-R5). IRRI, 1982.

Crop	Total water use (mm)					% of wet regime (R5/R1 X 100)
	R1	R2	R3	R4	R5	
Mungbean	228 c	224 b	174 b	89 c	59 c	26
Cowpea	268 b	228 b	183 b	120 b	99 b	37
Soybean	252 c	235 b	184 b	108 bc	91 b	38
Peanut	321 a	307 a	258 a	172 a	133 a	41

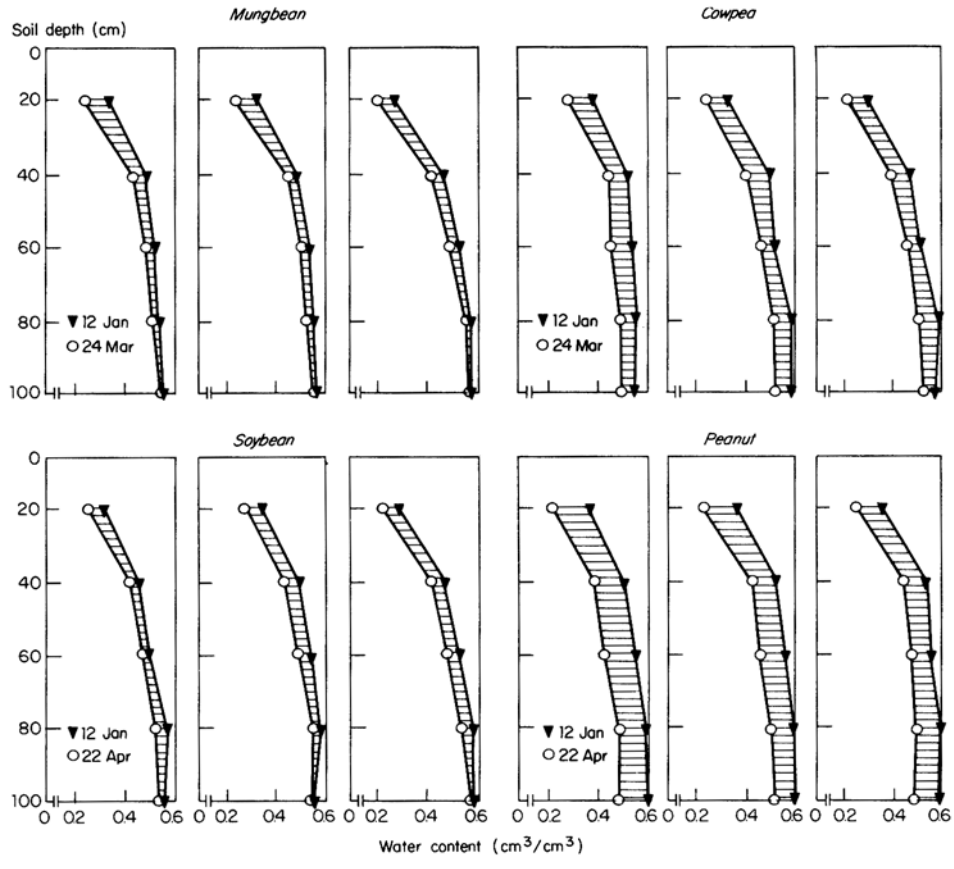


23. Percent of total water used from different soil depths in four grain legumes. IRRI, 1982.

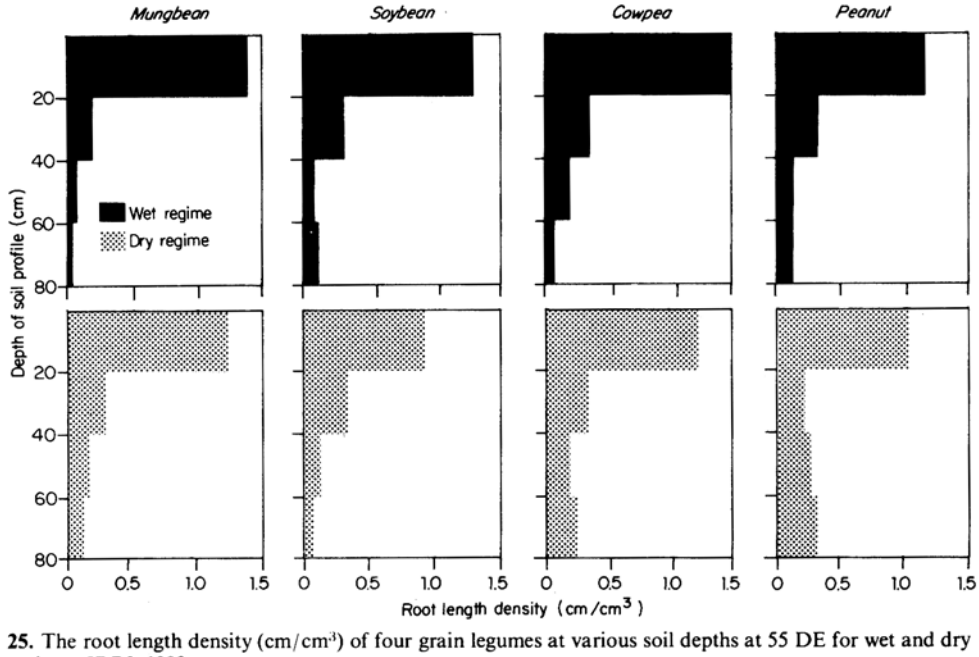
CT was higher and LWP lower in the dry regime than in the wet regime. All four crops generally increased in CT with decreasing LWP as crop growth proceeded to maturity and as moisture stress increased.

Peanut extracted more water to meet transpirational needs, and therefore had lower CT and higher LWP (closer to zero) than the other crops. It maintained a relatively more stable CT and LWP up to maturity. In contrast to soybean and mungbean, peanut showed little difference in both its CT and LWP in the wet and dry regimes. Cowpea exhibited an intermediate behavior. At 67 DE the peanut LWP in the dry regime was -9.6 bar, significantly lower than the LWPs of cowpea, mungbean, and soybean (-11.5, -12.6 and -17.6 bar, respectively).

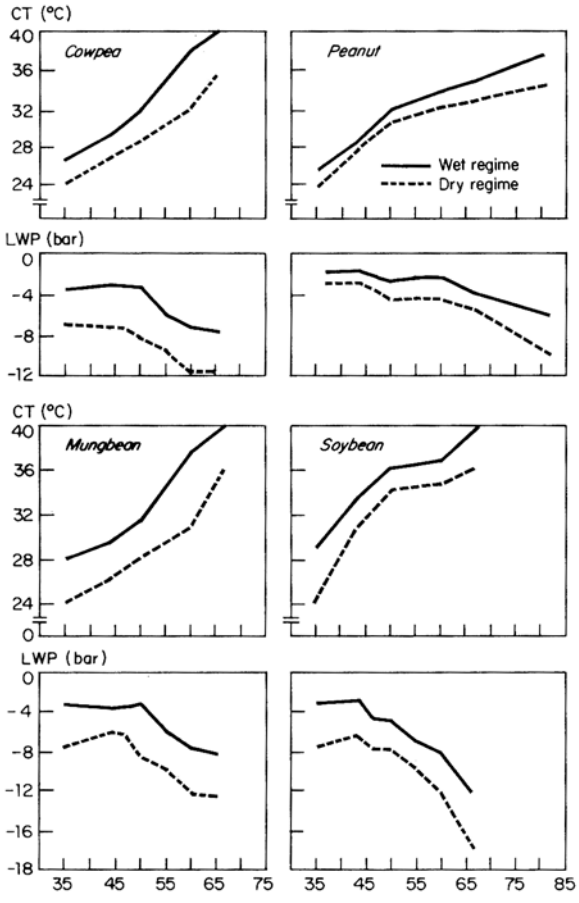
The diurnal changes in LWP and CT on a



24. Water extraction pattern of four grain legumes for regimes 1, 3, and 5 at different depths. IRRI, 1982.

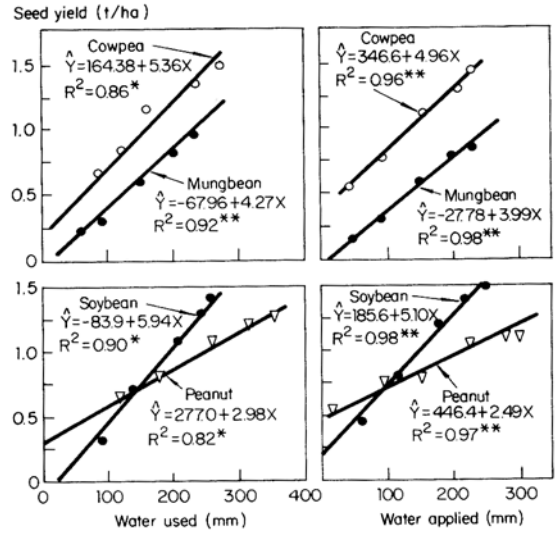


25. The root length density (cm/cm^3) of four grain legumes at various soil depths at 55 DE for wet and dry regimes. IRRI, 1982.

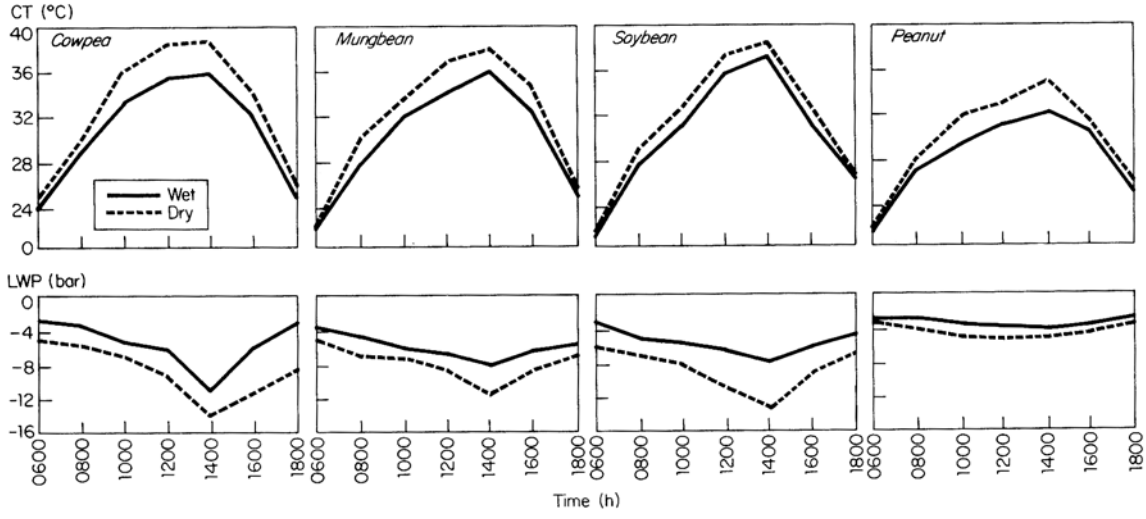


26. Seasonal changes in LWP and CT of four grain legumes in wet and dry regimes. IRRI, 1982.

selected date are shown in Figure 27. As expected, CT was lowest and LWP highest in the early morning (0600 h) for all the crops. CT was highest and LWP lowest at midday (1400 h) when evaporative demand was highest. Peanut maintained a lower diurnal temperature range and a higher LWP even at midday in the dry regime. Even in the wet regime where soil water deficit was not minor, peanut exhibited the lowest CT among the four crops.



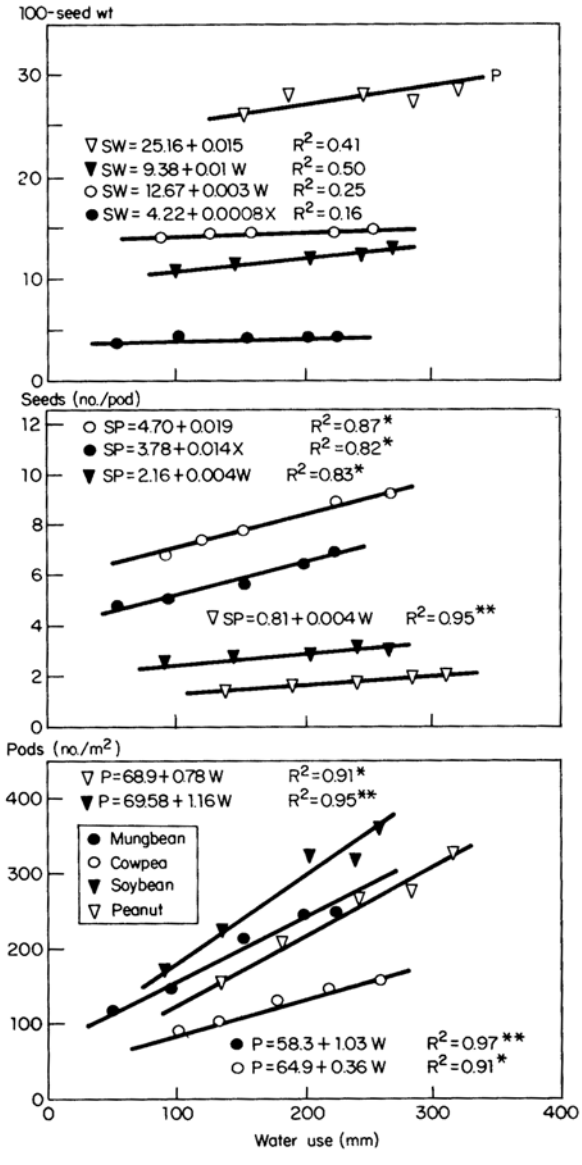
28. The relationship between seed yield and water use and between seed yield and water applied including rains for four grain legumes. IRRI, 1982.



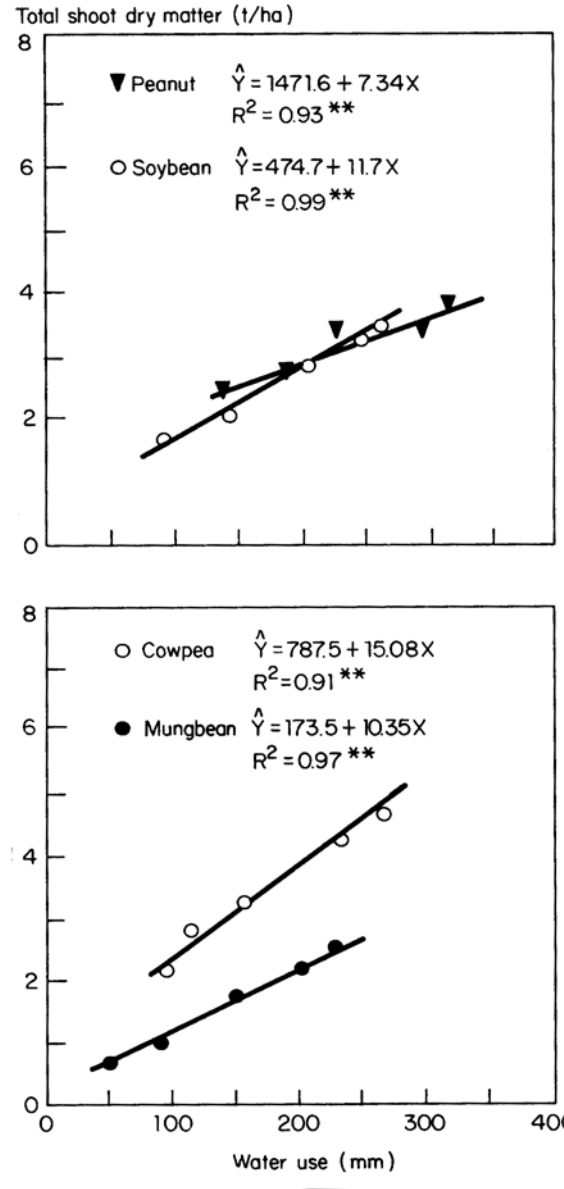
27. Diurnal variation in LWP and CT in four grain legumes on day 60 (12 Mar). IRRI, 1982.

Table 18. Effect of moisture stress on seed yield and yield components of four food legumes. IRRI, 1982.

Crop	Moisture regime					Reduction (%) (5 vs 1)
	R1	R2	R3	R4	R5	
			Seed yield (t/ha)			
Mungbean	0.8 d	0.8 d	0.6 e	0.3 g	0.1 h	83
Cowpea	1.4 a	1.3 ab	1.2 bc	0.8 d	0.5 ef	65
Soybean	1.4 a	1.4 a	1.2 c	0.7 d	0.5 f	66
Peanut	1.2 c	1.1 c	1.1 c	0.8 d	0.6 e	46
			Pods/m²			
Mungbean	286 d	253 f	223 gh	152 jk	105 m	63
Cowpea	156 j	147 kl	141 l	110 m	85 n	46
Soybean	367 a	320 b	303 c	225 g	178 i	51
Peanut	317 b	286 d	265 e	218 h	150 jk	53
			Seeds/pod			
Mungbean	6.93 c	6.30 d	5.70 e	5.10 f	4.60 f	34
Cowpea	8.97 a	8.70 a	7.70 b	7.20 cd	6.70 cd	25
Soybean	3.10 g	3.10 g	2.80 gh	2.80 gh	2.40 j	23
Peanut	1.90 ij	1.80 j	1.73 j	1.43 j	1.40 j	26
			100-seed wt (g)			
Mungbean	4.58 i	4.34 i	4.30 i	4.20 i	4.39 i	4
Cowpea	14.02 cd	13.48 cd	12.32 cd	12.70 d	12.60 d	10
Soybean	13.34 cd	11.60 de	10.87 e	11.22 de	10.67 e	20
Peanut	32.36 a	30.30 a	28.80 a	30.57 a	24.63 b	10



29. The relationship between total water use and yield components of four grain legumes. IRRI, 1982.

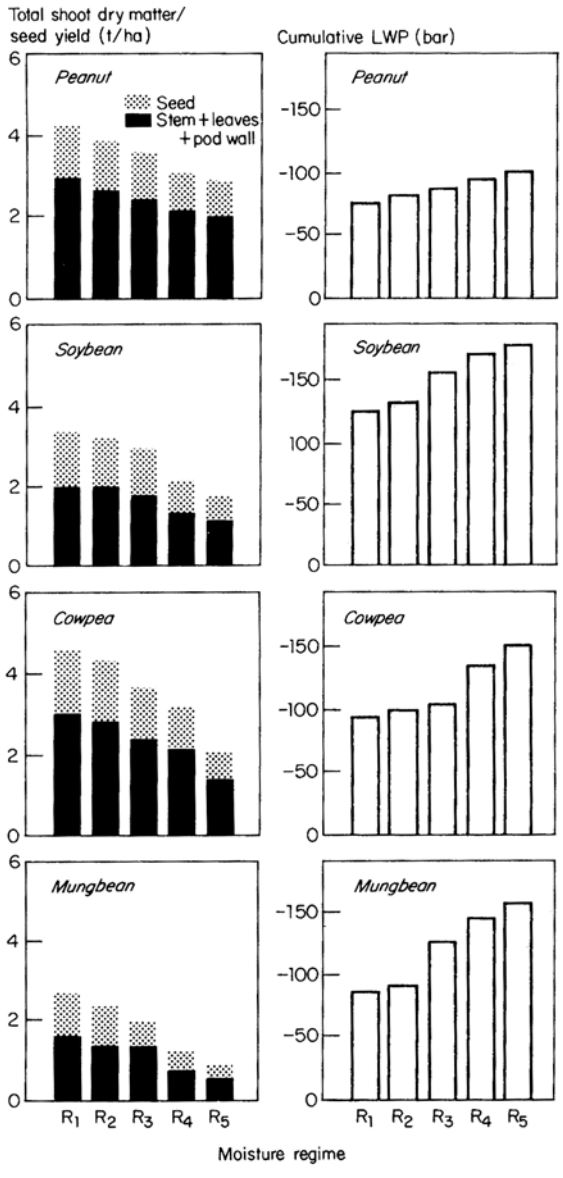


30. The relationship between total shoot dry matter at harvest and water use in four grain legumes. IRRI, 1982.

Seed yield, yield components, and shoot weight. Seed yields for all four crops showed a linear relationship for total water use and water applied (Fig. 28). Seed yield reduction from the wettest to the driest regime was most severe in mungbean (83%) and least severe in peanut (46%) (Table 18).

Among yield components, the number of pods/m^2 was the most sensitive to water deficit in all the four crops. Seed weight was least affected by moisture stress (Fig. 29). Compared to the wettest regime, the driest regime reduced the pod numbers by 46 to 63% (Table 18). The seed weight reduction was greatest in soybean and least in mungbean (Table 18).

In all four crops, shoot dry matter and water use were linearly related (Fig. 30). Increased moisture stress, as reflected by decreased cumulative LWP, reduced total shoot weight of mungbean, cowpea,



31. The total shoot dry matter and seed yield and cumulative LWP at five moisture regimes for four grain legumes. IRRI, 1982.

and soybean more than that of peanut (Fig. 31). Shoot weight in the dry regime was reduced by 78% in mungbean, 62% in soybean, 60% cowpea, and 37% in peanut.

The stronger adaptive mechanisms of peanut demonstrated its potential for cultivation in the post rice environment where moisture stress progressively increases with crop growth, particularly in light soils where pod formation would not be as detrimentally affected as in clayey soils. Cowpea and soybean performed better than mungbean, but cowpea has better adoption potential because it is not adversely affected when planted in the short-day periods that are common after rice.

Cropping systems program

Preproduction testing of improved cropping systems

Rice Production Training and Research, Agricultural Engineering, and Agricultural Economics Departments

ON-FARM TESTING OF THE ROLLING INJECTION PLANTER **456**
TECHNOLOGY EVALUATION IN TWO RAINFED CROP PRODUCTION PROGRAMS **456**
Iloilo **457**
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ON-FARM TESTING OF THE ROLLING INJECTION PLANTER

Rice Production Training and Research and Agricultural Engineering Departments

In Miagao, Iloilo, Philippines, field experiments were conducted on plateau and plain landscape positions to evaluate various methods of establishing dryland crops after a single dry-seeded rice crop. Dryland crop establishment with high tillage was a component of the recommended technology that needed further study following the recent introduction of the rolling injection planter (RIP).

The RIP, designed to punch seeds into an untilled soil, was compared with recommended high-tillage establishment and the local farmers' practice.

At Kirayan Takas (the plateau location in Miagao), only mungbean and cowpea yielded satisfactorily with any establishment method (Table 1). Maize suffered severe moisture stress; sorghum was stunted and chlorotic and did not exhibit the drought tolerance for which it has been noted. Mungbean yields were significantly increased when herbicide (Gramoxone) was applied just before RIP establishment.

At Dawog (the plain location in Miagao), the trial was established 30 d after the one at Kirayan Takas (Table 1). Again, maize yielded nothing with all establishment methods and sorghum yielded poorly, except with the high-tillage treatment. With RIP, mungbean and cowpea established and yielded well.

The results showed the potential of the RIP for zero-tillage establishment of mungbean and cowpea.

TECHNOLOGY EVALUATION IN TWO RAINFED CROP PRODUCTION PROGRAMS

Rice Production Training and Research Department

In 1982, a study was started to evaluate the performance of double cropping of rice in the rainfed crop production programs in Iloilo and South Cotabato, Philippines. Double cropping is possible through·

- direct dry-seeding of the first rice crop at the beginning of the WS,

Table 1. Effects of establishment method on weeds and dryland crop yields grown after rice at two sites in Iloilo, Philippines, 1982.

Treatment	Plateau			Plain		
	Weed count (0.5 m^2)	Weed wt (g/m^2)	Crop yield (t/ha)	Weed count (0.5 m^2)	Weed wt (g/m^2)	Crop yield (t/ha)
Mungbean (12% MC)						
RIP	41 a	58.6 a	1.19 b	108 a	52.0 a	1.30 a
RIP + herbicide	9 b	35.3 a	1.73 a	47 ab	39.2 a	1.15 ab
Farmer's practice	32 ab	51.3 a	1.10 b	85 a	45.2 a	0.99 b
High tillage	24 ab	48.0 a	0.99 b	32 b	44.0 a	0.54 c
Cowpea (12% MC)						
RIP	44 a	38.0 a	0.65 a	71 a	78.0 a	0.64 a
RIP + herbicide	11 b	89.3 a	0.89 a	42 a	65.2 a	0.71 a
Farmer's practice	35 a	83.3 a	0.65 a	85 a	59.2 a	0.40 a
High tillage	22 ab	60.7 a	0.73 a	46 a	42.6 a	0.36 a
Sorghum (14% MC)						
RIP	56 a	38.0 ab	0.04 a	100 a	77.0 a	0.02 a
RIP + herbicide	25 a	31.3 ab	0.03 a	62 ab	52.0 a	0.02 a
Farmer's practice	36 a	90.7 a	0.02 a	104 a	46.0 a	0.03 a
High tillage	33 a	34.7 a	0.04 a	44 b	62.0 a	0.44 b
Maize						
RIP	49 a	82.7 a	0	107 a	69.2 a	0
RIP + herbicide	14 b	172.7 a	0	65 a	86.6 a	0
Farmer's practice	47 a	122.0 a	0	72 a	80.0 a	0
High tillage	29 ab	124.6 a	0	31 b	28.0 b	0

- use of preemergence herbicide, and
- use of early-maturing rice varieties.

During 1982, production plots of the two-rice crop system were placed throughout the production program target areas of the two provinces. Technology performance in the research-supervised plots was compared with farmers' patterns and yields. Superimposed trials were also conducted to determine the importance of technology components. Production program participants and nonparticipants were interviewed to assist in understanding the factors affecting adoption of the program-recommended technology. Preliminary results are presented.

Table 2. Yield from 1000-m^2 production plots at various locations in Iloilo, Philippines, 1982.

Rainfall zone	Landscape	Yield (t/ha)		
		First crop	Second crop	Total
Wet	Sideslope	4.51 (n=6)	3.99 (n=6)	8.50
	Plain	4.82 (n=6)	3.24 (n=6)	8.06
Intermediate	Plateau	4.03 (n=2)[a]	0.48 (n=2)	4.51
	Plain	4.05 (n=5)[a]	1.83 (n=3)[b]	6.37[c]
Dry	Plateau	3.91 (n=6)	*d*	3.91
	Plain	3.49 (n=6)	—	3.49

[a]Four plots at the plateau site and one at the plain site were destroyed by flooding and herbicide toxicity, subsequently wet-seeded, and excluded from the study. [b]Two farmers did not participate for the second crop. [c]In computing the total for the intermediate plain, only those plots planted to both first and second crops were included. [d]Planted to dryland crops.

Iloilo. The study area was stratified according to rainfall pattern and landscape position, the two physical factors believed to be 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 2).

At each landscape in each rainfall zone, six production plots of approximately 1,000 m^2 were established in farmers' fields. At the intermediate plateau site, the flooding of four plots by heavy rainfall shortly after herbicide application resulted in a very poor stand and a decision to reseed. At the intermediate plain site, one plot was in this category. Because of the saturated soil, the five plots were wet-seeded and not considered in this analysis.

In all cases, the first rice crop was dry-seeded; the second, if established, wet-seeded. In the dry zone, there was no attempt to establish a second rice crop because of the shorter WS. Across Iloilo, 1982 was a relatively dry year with little rain after October and this was reflected in the yields (Table 2). In the wet zone, two rice crops were established and harvested in each production plot with little moisture stress. Landscape position did not appear to influence yield.

In the intermediate zone, because of the required wet seeding in five plots and the unwillingness of two farmers to participate for the second crop, the production data were limited. In the superimposed

Table 3. Effects of different fertilizer rates on IR36 yield in three rainfall zones.[a] Iloilo, Philippines, 1982.

Rainfall zone	Landscape	Crop	Grain yield (t/ha)[b]						
			90-13-25[c]	90-13-0	90-0-25	90-0-0	60-13-25	30-13-25	0-0-0
Wet	Sideslope	First (n=6)	4.97 a	4.99 a	4.96 a	—	4.91 a	4.30 a	4.33 a
		Second (n=6)	4.52 a	4.41 a	4.54 a	4.41 a	4.50 a	4.26 a	3.40 b
	Plain	First (n=6)	5.47 a	5.63 a	5.51 a	—	5.35 a	4.82 ab	4.46 b
		Second (n=6)	3.12 ab	2.99 ab	2.67 ab	3.32 a	2.83 ab	2.59 b	1.70 b
Intermediate	Plateau	First (n=6)[d]	4.17 ab	4.36 a	2.85 c	—	3.57 abc	3.52 bc	2.03 d
		Second (n=3)	1.86 a	0.84 a	0.86 a	0.77 a	1.94 a	1.91 a	0.94 a
	Plain	First (n=5)	4.23 a	3.80 a	3.85 a	—	3.77 a	3.60 ab	2.89 b
		Second (n=4)	2.48 a	2.21 a	2.21 a	2.04 a	2.25 a	1.80 ab	1.34 b
Dry	Plateau	First (n=6)	5.31 ab	5.35 a	5.15 ab	—	5.19 ab	5.19 ab	4.98 b
	Plain	Frist (n=6)	3.35 a	2.88 ab	2.91 ab	—	2.66 b	2.73 ab	1.90 c

[a]Superimposed trials conducted with production plots. [b]Separation of means, in a row, by Duncan's multiple range test at the 5% level. [c]kg (N, P, K)/ha. [d]Plots that were not seeded over the dry-seeded crops that failed were included in this analysis.

Table 4. Yield from 20 production plots at various locations in South Cotabato, Philippines, 1982.

Location	Yield[a] (t/ha)		
	First crop[b]	Second crop[c]	Total
Norala			
Bo. 1 #1	3.78	4.04	7.82
Bo. 1 #2	2.35	4.41	6.76
Bo. 2	2.39	3.34	5.73
Bo. 7	5.66	3.51	9.17
Poblacion #1	4.73	4.25	8.98
Kibid	3.32	1.23	4.55
Simsiman #1	4.00	5.21	9.21
Simsiman #2	4.01	4.35	8.36
Mean	3.78	3.79	7.57
Surallah			
Bo. 10	4.93	4.33	9.26
Bo. 12 #1	5.20	5.88	11.08
Bo. 12 #2	4.47	2.42	6.89
Dajay #1	4.00	3.60	7.60
Dajay #2	4.22	3.77	7.99
Mean	4.56	4.00	8.56
Santo Niño			
Bo. 4 #1	3.70	4.04	7.74
Bo. 4 #2	3.87	5.21	9.08
Bo. 9	2.38	0	2.38
Bo. 10	1.24	2.17	3.41
Mean	2.80	2.85	5.65
Koronadal			
Mabini #1	2.94	4.07	7.01
Mabini #2	0	2.33	2.33
Mabini #3	2.87	1.98	4.85
Mean	1.93	2.79	4.72
Mean (all plots)	3.50	3.51	7.01

[a]Average of three 20-m² harvest sample areas. [b]IR36. [c]IR56.

fertilizer trials conducted with every production plot, the recommended fertilizer rate was chosen for evaluation because 1) fertilizer response may be influenced by rainfall pattern and landscape position requiring more specific local recommendations, and 2) fertilizer is a major component (30-40%) of the total cash costs of the new technology package.

K did not appear to limit yield at any location, although most areas responded to N and some to P (Table 3). At the intermediate sites, several of the no-P treatments (90-0-25) showed classic P deficiency symptoms: dark green color (darker than in 90-13-25), reduced plant height, reduced tillering, and delayed maturity. It was only at the plateau site however, that the effect was statistically significant.

South Cotabato. Twenty-four 1,000-m² production plots and superimposed trials were established. Four were dropped from the study because of mole cricket damage to the dry-seeded seedlings. A second rice crop was planted in 19 plots.

Landscape position was less critical than in Iloilo. Most of the production plots were within the floodplains of the Allah and Banga Rivers. The plots and superimposed trials were distributed across the range of soil conditions.

Mean yields for the first and second crops (Table 4) were only about 75% of the area's usual two-crop yield probably because the April-December rainfall was 54% of the 14-yr average. The 1982 drought in Mindanao and elsewhere in the Philippines was a highly publicized calamity.

Although the production program in South Cotabato was conceived essentially for rainfed crops, farm visits during 1982 revealed that nine of the 20 production plots were partially irrigated. The water came from springs and diversions from rivers and creeks. Partial irrigation boosted yield 3.3 t/ha, with almost 2 t/ha coming from the irrigated second crop.

The superimposed trials showed a response to N but no clear response to P or K.

MULTILOCATION TESTING OF NITROGEN PLACEMENT MACHINES

Rice Production Training and Research, Agricultural Economics, and Agricultural Engineering Departments

During the 1982 WS, trials were conducted on farmers' fields to evaluate two N placement machines developed by the Agricultural Engineering Department. These were the curved spring auger for PU placement and the Rockwood plunger for USG placement. The machines were compared with hand placement of USG, researchers' best split of PU, and farmers' split of PU at seven locations (Table 5).

In six of seven locations, the yields in plots where USG was placed by the plunger did not differ significantly from those in plots where it was placed by hand.

Significantly higher yields resulted from the researchers' best split of PU in only one of the seven trials. This was not surprising because, in most of

Table 5. Summary of results from placement machine trials at various locations in the Philippines. 1982 WS.

Location	Yield (t/ha)[a]				
	PU			USG	
	Farmers' split	Researchers' split	Curved spring auger	Hand	Plunger
Luzon					
Buguey, Cagayan	4.44 b	4.34 b	5.10 a	5.34 a	5.41 a
Gugo, Naic, Cavite	3.74 b	4.04 ab	3.76 b	4.49 a	4.03 ab
Molino, Naic, Cavite	2.84 c	3.28 ab	3.09 b	3.37 a	3.21 ab
Visayas					
Mina, Iloilo	5.35 a	5.37 a	5.32 a	5.32 a	5.66 a
Ajuy, Iloilo	4.23 a	4.33 a	3.75 b	3.79 b	4.25 a
Mindanao					
Koronadal, South Cotabato	4.13 a	4.29 a	4.18 a	5.26 a	4.41 a
Tantangan, South Cotabato	5.04 a	5.09 a	5.11 a	5.55 a	5.31 a

[a]Separation of means, in a row, by Duncan's multiple range test at the 5% level.

the trial sites, basal incorporation was being practiced and the only difference with researchers' split was the relative amounts applied.

The yield advantages of the plunger over the farmers' split for the seven trials ranged from 5 to 22%, averaged 8.8%. In two trials, yield differences were statistically significant.

The yield advantage of the curved spring auger over the farmers' split in the seven trials ranged from -11 to 15% and averaged 2%. In two trials, yields were significantly higher with the curved spring auger split; in one trial, the yield was significantly higher with the farmers' split.

Cropping systems program

Asian Cropping Systems Network

Multiple Cropping Department

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NATIONAL PROGRAMS

The Asian Cropping Systems Network (ACSN) is a scheme established in collaboration with national programs for developing cropping systems technology suitable for major rice environments in Asia. The cropping systems research methodology developed by IRRI and ACSN is now used by many national programs in Asia with some modifications to fit their financial and manpower resources. It is also used in dryland crop-based cropping systems.

Cropping systems research is now part of the research system in collaborating countries. The Philippine Government recently created the Soil Resource and Farming Systems Institute at the University of the Philippines at Los Baños (UPLB) and the Agriculture Research Office (ARO) in the Ministry of Agriculture. The institute will conduct basic research at UPLB, provide technical assistance to the provincial technology verification teams (PTVT) and the Regional Integrated Agricultural Research System, and provide training to farming systems scientists. ARO farming systems research uses the same methodologies as the ACSN. It established 12 regional research teams composed of five senior scientists (agronomist, soil scientist, economist, animal scientist, and extension specialist). It also organized 64 PTVTs throughout the Philippines.

Thailand also reorganized its Department of Agriculture, the research agency of the Ministry of Agriculture and Cooperatives. Six institutes were established, one of which is the Farming Systems Research Institute. The ACSN collaborators in Thailand are now the senior scientists of the new institute. The main work of the institute is rice-based farming systems in rainfed wetland and irrigated fields.

The number of ACSN sites continues to increase. In 1982, there were 108 operational rice-based sites in 10 countries in Asia (Table 1). The work at the sites is concentrated on design and testing of cropping patterns in rainfed wetland, partially irrigated, rainfed dryland, irrigated, and deepwater rice. Philippines, Thailand, and Bangladesh established dryland crop-based cropping systems using the same methodology. The sites represent a broad range of climatic zones, soil types, soil textures, and socioeconomic conditions in Asia. The main objective in each site is to increase cropping intensity from one to two or more and from two to three or more crops per year and, at the same time, increase the production of each crop in the pattern and over-all net income.

In 1982, China officially joined ACSN. It now conducts cropping system research at two locations: Tux Xi County, Beijing, and Sho Xiang County, Zhejiang. Taiwan, China, also joined with one site in Kaohsiung. Pakistan sent a representative to the 13th working group meeting in Bangkok and has indicated its interest in joining ACSN. Vietnam has also shown similar interest. Two Vietnamese trainees attended the 6-mo cropping systems course.

Table 1. Number of cropping systems research sites in collaborating countries in Asia, 1982.

Country	Research sites (no.)					
	In national programs	Rainfed wetland	Partially irrigated	Irrigated	Rainfed dryland	Deepwater
Philippines	23	15	1	6	14	–
Bangladesh	25	14	2	10	–	2
Indonesia	21	6	–	–	16	1
Burma	7	2	4	2	–	–
Nepal	6	5	2	1	–	–
Sri Lanka	7	3	1	1	–	–
Thailand	7	7	–	1	–	–
Korea	9	–	–	9	–	–
India	1	–	–	–	1	–
China	2	–	–	2	–	–
Total	108	52	10	32	31	3

Cropping systems research. *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, the research site and multilocation tests in Iloilo resulted in a provincial cropping systems program covering 6,302 ha of rainfed rice in the 1981-82 crop year. In 1982-83, the program will cover 13,000 ha. There are pilot production programs in South Cotabato (800 ha), Pangasinan (839 ha), and North Cotabato (97 ha). Multilocation tests are conducted in Agusan, Bukidnon, and Capiz.

At the site in Walagambahuwa, Sri Lanka, a tank-based village, researchers successfully developed a system for establishing rainfed dry-seeded and early-maturing varieties as a first rice crop followed by a second rice crop or a dryland crop, depending on rainfall. The production program is now widespread in Anuradhapura and Kurunegala Districts.

The research teams in Indonesia identified technology for two-rice-crop systems that replace the single crop system in Barambai, South Kalimantan; Bantoa, South Sulawesi; and Blega, Madura. Production programs covering hundred of hectares are now implemented at those sites.

Other national programs started pilot production and multilocation testing. The Bangladesh Rice Research Institute started multilocation testing in 1982 using data from the Bhogra rainfed wetland site. The yield levels of the MV rice - MV rice pattern were very encouraging. The change in yield over the farmers' cropping pattern ranged from 52 to 262%.

Multilocation testing was initiated in several districts of Nepal in 1981-82. The results of 175 successfully completed winter-crop trials indicated that technology developed in the cropping systems sites can be extrapolated in similar areas. Pilot production was started in 1980 to extend the technology within the cropping systems sites in Parsa, Pumdi Bhumdi, Lele, and Chauri Jahari. Contiguous areas of 20 ha or more were used as production blocks to demonstrate the impact of the technology in 1982.

Cropping pattern testing. The first collaborative research in the ACSN was cropping pattern testing, which started in 1975 in five cropping systems sites in the Philippines, Indonesia, and Thailand. In 1982, 31 sites in 10 countries in Asia were carefully selected to represent major Asian rice-growing environments (Table 2). In almost all cases, the objective at each site is to increase production, net income, and cropping intensity.

In Nepal and Bangladesh, where some sites have high cropping intensity, the aim is to improve crop production and net income. Rainfall distribution is the major determinant of crop performance. The experimental cropping patterns are always compared with the farmers' dominant cropping pattern at each site. In most cases, the experimental patterns result in better total production and

Table 2. Number of cropping systems research sites involved in cropping pattern monitoring, 1982.

Country	Sites (no.)					
	In cropping pattern monitoring	Rainfed wetland	Partially irrigated	Irrigated	Rainfed dryland	Deepwater
Philippines	4	3	1	1	3	–
Burma	4	2	3	–	–	–
Indonesia	4	2	–	–	2	1
Korea	3	–	–	3	–	–
Nepal	3	2	1	1	–	–
India	1	–	–	–	1	–
Bangladesh	3	1	–	1	1	1
Sri Lanka	3	2	1	–	–	–
Thailand	4	3	–	1	–	–
China	2	–	–	2	–	–
Total	31	15	6	9	6	2

income than the farmers' cropping pattern (Table 3). However, to fit the crops into the pattern, a shorter turnaround time between the two crops is needed.

Varietal testing. The Institute of Plant Breeding (IPB) at UPLB received a grant from the International Development Research Centre (Canada) to develop varieties of dryland crops for rice-based cropping systems. The project includes screening of lines and varieties from three international centers (ICRISAT, IITA, and AVRDC) and national breeding programs and hybridization of selected promising varieties and selection. The breeding program concentrates on soybean, peanut, and mungbean. Hybridization, selection, and screening are done at UPLB and further screening and evaluation in Santa Maria, Pangasinan.

In 1982, IPB evaluated 2,227 mungbean cultivars/lines and 17 soybean cultivars before rice. Mungbean emergence was very erratic because of diverse seed sources. Three hundred and sixty-one entries failed to germinate and 449 had emergence below 10%. Maturity ranged from 62 to 79 d. Bean yield after the first priming ranged from 1 to 1.3 t/ha. The soybean trial had abnormally low yields because of poor germination and stunted growth.

Table 3. Rainfall, number of crops in farmers' and researchers' patterns, and promising cropping patterns in various Asian rice-growing environments in 10 countries. 1982.

Site	Rainfall[a]		Crops in pattern (no.)		Promising cropping pattern[b]
	Wet months (no.)	Dry months (no.)	Farmers'	Researchers'	
Rainfed wetland					
Capiz, Philippines	8	8	2	2	Rice - rice
Agusan, Philippines	9	2	2	2-3	Mungbean - rice - rice
Solana, Philippines	5	4	1-2	2-3	Mungbean - rice
Shwelongkyu, Burma	5	5	1-2	2	Rice - cowpea Rice - sunflower
Bantoa, Indonesia	5-6	3-5	1	2	Rice - rice Rice - maize + peanut
Katapotha, Sri Lanka	2+2	1	1-2	2	Rice - rice Rice - cowpea
Serang, Indonesia	3-4	5-6	1	2	Rice - rice
Ratna Nagar, Nepal	4	8	1-2	2-3	Rice - fallow - maize Rice/lentil + lathyrus
PiMai-Thailand	2	6	1	2	Peanut - rice
Kamphaeng Phet, Thailand	2	6	1	2	Rice - fallow
Alimganj, Bangladesh	4	8	1-2	2-3	Rice - chickpea
Rainfed wetland (with cooler temperature)					
Pumdi Bhumdi, Nepal	4	8	2-3	2-3	Rice - wheat - maize
Parsa, Nepal	6	6	2-3	2-2	Rice - wheat - dhancha Rice - mustard - maize
Yezin, Burma	4	6	1-2	2	Rice - peanut
Alimganj, Bangladesh	4	8	1-2	2-3	Rice - rice Rice - barley + chickpea
Partially irrigated					
North Nawin, Burma	4	6	1	2	Rice - sunflower
Paranthan, Sri Lanka	3	9	1	2	Rice - mungbean
Walagambahuwa, Sri Lanka	3	9	0	2-3	Rice - rice Rice - soybean
Patheingyi, Burma	0	7	1	2	Sesame - rice Peanut - rice
Rainfed dryland					
Capiz, Philippines	8	3	1-2	2-3	Maize - peanut
Bukidnon, Philippines	6	3	2	2-4	Rice + maize - maize + peanut

Continued on opposite page

Table 3 continued

Site	Rainfall[a]		Crops in pattern (no.)		Promising cropping pattern[b]
	Wet months (no.)	Dry months (no.)	Farmers'	Researchers'	
Agusan, Philippines	9	2	2	2-5	Maize + peanut - maize + mungbean - rice
Tajau Pecah, Indonesia	6	4	2-3	4-5	Rice + maize/cassava/ cowpea
Baturaja, Indonesia	5-6	3-2	2-3	4	Rice + maize/cassava/ peanut
Ranchi, India	3	6	1	2	Rice + pigeon pea peanut + pigeon pea
Irrigated					
Salna, Bangladesh	—	—	2	2-3	Rice - rice - wheat
Iri, Korea	—	—	1-2	2	Barley - rice Potato - rice
Milyang, Thailand	—	—	2	2-3	Sweet maize - rice wheat - rice
Phrae, Thailand	—	—	2	2-3	Maize - rice - peanut Maize - rice - mungbean
Parsa, Nepal	—	—	2-3	3	Rice - mustard - maize Rice - wheat - dhancha
Bukidnon, Philippines	—	—	2	3	Rice - rice - rice
Ratna Nagar	—	—	2	3	Rice - wheat - mung-bean Rice - potato - maize
Deepwater and tidal swamp					
Daudkandi, Bangladesh	5	7	2	2-3	DW rice - fallow - potato DW rice - potato - sesame
Barambai, Indonesia	7	4	1-3	4-6	Rice - rice in field and peanut/cassava + sorghum on bunds

[a]Wet months = number of consecutive months with 200 mm/mo or more rainfall; dry months = number of consecutive months with 100 mm/mo or less rainfall. [b]Based on total production and net income compared with the farmers' patterns.

Yield ranged from 0.03 to 0.16 t/ha.

After-rice evaluation consisted of a general trial, a primary yield trial, and germplasm screening. Plantings were done in late October and November 1982. Peanut was grown only in Pangasinan. A total of 3,020 entries were tested at IPB and 3,564 at Pangasinan.

In October 1982, IPB began hybridization of mungbean, soybean, and peanut. Starting in January 1983, 54 soybean crosses, 55 mungbean crosses, and 6 peanut crosses will be harvested.

The most promising entries from IPB, the international centers, and national programs are submitted to IRRI for seed increase and distribution to ACSN countries. Soybean, peanut, mungbean, cowpea, bush sitao, maize, and sorghum are included in the varietal testing. In 1982, entries varied from 8 to 10 per crop. The soybean entries came from IPB, AVRDC, and the Thailand Field Crops Research Institute; mungbean, peanut, and sorghum from IPB; cowpea from IITA; and maize from CIMMYT (Thailand), IPB, and Indonesia.

Trials are conducted before rice or after rice. Trials by country for the 1982-83 cropping pattern season are in Table 4.

Farm implements for intensive rice-based cropping systems. The ACSN working groups are collaborating on a simple seeding experiment. The objective is to evaluate the performance of the rolling injection planter (RIP), designed by IITA and modified by IRRI, on the establishment and performance of dryland crops grown after rice

Table 4. Breakdown of 47 trials before, and 152 trials after, wetland rice in the ACSN 1982-83 cropping pattern year.

Country	Trials (no.)						
	Mungbean	Cowpea	Bush sitao	Soybean	Peanut	Sorghum	Maize
			Before wetland rice				
Vietnam	2	1	1	2	2	–	1
Burma	1	–	1	1	1	–	1
Nepal	1	1	–	–	1	–	–
Nepal	3	–	–	2	2	2	1
Thailand	3	3	–	–	1	–	–
Philippines	4	1	3	–	–	–	–
Indonesia	1	–	–	1	1	–	2
Total	15	7	4	6	8	2	5
			After wetland rice				
Malaysia	1	–	–	–	1	–	–
Thailand	2	2	–	2	2	2	2
Vietnam	2	–	–	2	–	1	2
Sri Lanka	2	2	2	2	2	2	2
Bangladesh	2	1	–	3	3	1	4
Burma	1	1	–	1	1	–	1
Indonesia	3	2	1	4	4	2	4
Philippines	14	10	14	11	7	8	14
Total	27	18	17	25	20	16	29

under zero and optimum tillage conditions. The experiment and data format were finalized during the 1982 rice conference. Maize, sorghum, mungbean, wheat, soybean, and cowpea are the dryland crops in the trial. Treatments include the traditional or broadcast, RIP, and furrow seeding. The experiment is conducted at either the experiment station or the cropping systems site.

IRRI distributed nine RIPs to Indonesia, two to Thailand, and one each to Bangladesh, Korea, Nepal, Sri Lanka, and Burma. Burma obtained an additional nine planters for its cropping systems sites. Korea dropped from the study because a Korean-developed seeder is better-suited to Korean cropping systems practices than the RIP.

In Burma, initial tests with soybean, sunflower, maize, and sorghum were successful in establishing dryland crops after rice in a rice field freshly harvested with a 1-m reaper. The other collaborating countries began RIP testing in October-December 1982.

Long-term cropping pattern and fertilizer studies. There is a major concern in the ACSN that increased intensive crop production may result in a rapid loss of soil fertility and productivity. Because there is limited data on the effects of continuous cropping in these areas, the ACSN scientists are collaborating in long-term cropping pattern and fertilizer studies at irrigated wetland sites in Korea, Nepal, Indonesia, Burma, Thailand, and China; dryland sites in Indonesia and Nepal; and rainfed wetland sites in Bangladesh, Burma, and Indonesia. Each study is based on local environmental conditions.

In Indonesia, five studies at many locations include:

- effectiveness of partially acidulated phosphate rock in year-round cropping patterns,
- crop and soil response to lime and P treatments in cropping patterns over time,
- controlled release N fertilizers (SCU) in dryland cropping patterns,
- evaluation of effects of crop residue management on soil and production in year-round cropping systems, and
- long-term effects of S-free and S-containing fertilizers on the fertility status of soils.

In 1982, IRRI initiated long-term fertility studies on wetland DSR - TPR - mungbean and rice - wheat and crops residue management studies on dryland rice - maize and TPR - TPR - mungbean.

China and Korea have ongoing long-term cropping pattern studies. In 1982, Burma initiated long-term fertility trials on rice - soybean - maize and residue management trials on DSR - maize - mungbean.

Rice - wheat cropping systems. Rice and wheat are two important cereal crops. In Asia, where about 90% of all rice is grown, rice is often planted during the WS and wheat during the cooler DS. Rice - wheat cropping patterns are very common in subtropical Asia. CIMMYT and IRRI are using their joint expertise to help ACSN countries increase food production through two- or three-crop patterns. Currently, collaboration is focusing on identification of better varieties with multiple pest and disease resistance that makes them fit the rice - wheat patterns (rice - wheat, rice - rice - wheat, rice - wheat - dryland crop).

In 1982, CIMMYT provided 14 wheat varieties from its breeding program. National programs provided the local check. Wheat was planted immediately after the rice crop harvest. There were 33 trials in 13 countries.

RESEARCH INFORMATION SHARING

The 13th working group meeting, held in Bangkok and Chiang Mai, Thailand, was cosponsored by the Thailand Department of Agriculture and IRRI. Thirteen working group members from 10 countries and 21 resource persons and 27 observers, mostly from the Thailand Department of Agriculture and Universities, attended. The group visited the cropping systems research sites in Phrae and Phayao and the multiple cropping project in Chiang Mai University.

Discussions centered on planning the collaborative research on long-term cropping pattern and fertilizer studies, rice - wheat systems, and farm implements.

Machinery development and testing

Agricultural Engineering Department

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PT-5 power tiller. Continuing field testing of the PT-5 (3-hp) power tiller resulted in the frequent loosening of the handlebar friction joint that provides the handle-height adjustment. The hold of the handlebar bracket to the transmission casing by six bolts also frequently loosened. Some tiller operators expressed preference for the grip-type clutch lever located at the right-hand side of the handle, a feature of a popular imported tiller.

In view of these observations, two flat bars were welded on top of the transmission casing to strongly fasten the handlebar bracket to the casing. An L-shaped, box-type handlebar (Fig. 1) fabricated from a 1.9-mm steel sheet, instead of the standard pipe used in the old design, was bolted on these mounting brackets. To make its length adjustable, an extension pipe was inserted inside the handlebar and was supported by outer and inner sleeves fabricated from standard pipe. The outer sleeve was provided with a clamping bolt and bracket to permit adjustment and to prevent movement in any direction when the clamp bolt is tightened. The outer end of the extension pipe was welded to a clamp assembly that securely holds the base of a V-shaped handle made by bending a standard pipe. The handle can be adjusted to suit the operator's height by loosening the two clamp bolts.

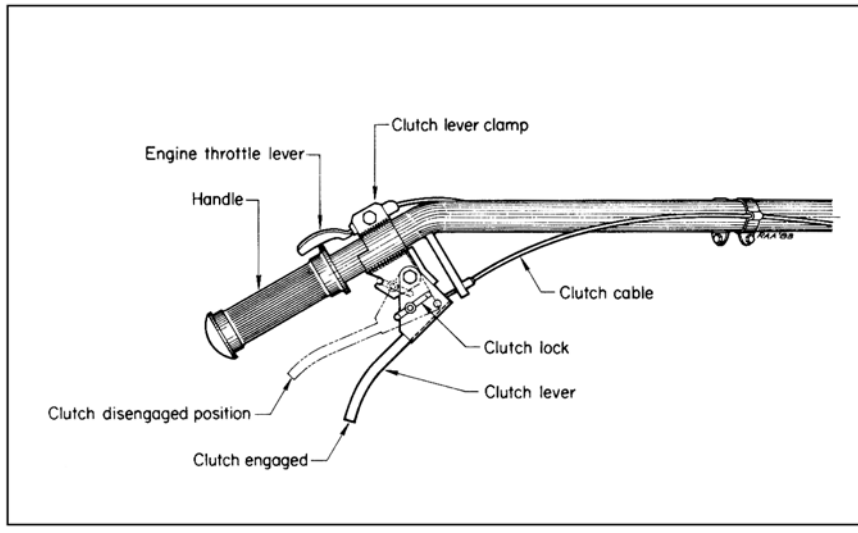
The grip-type clutch lever (Fig. 1) was equipped with a spring-loaded hook that automatically locks when the lever is pressed to disengage the drive. The drive is reengaged by slightly gripping the lever to unhook the lock and release the lever. The clutch lever, installed at the right-hand side of the handle, was connected to the idler pulley in the normally engaged position, i.e., the pulley is pressed against the drive belt.

Efficiency measurement for the IRRI power tiller. The operational efficiency of every power tiller designed and fabricated at IRRI must be examined to ensure the best performance in actual field operation and decrease operating expenses. One method of measuring power tiller efficiency is using prony brakes (Fig. 2). The Institute of Agricultural Machinery (Japan) donated the prony break to IRRI. It has a maximum capacity of 10 hp, ideal for testing all IRRI-designed power tillers.

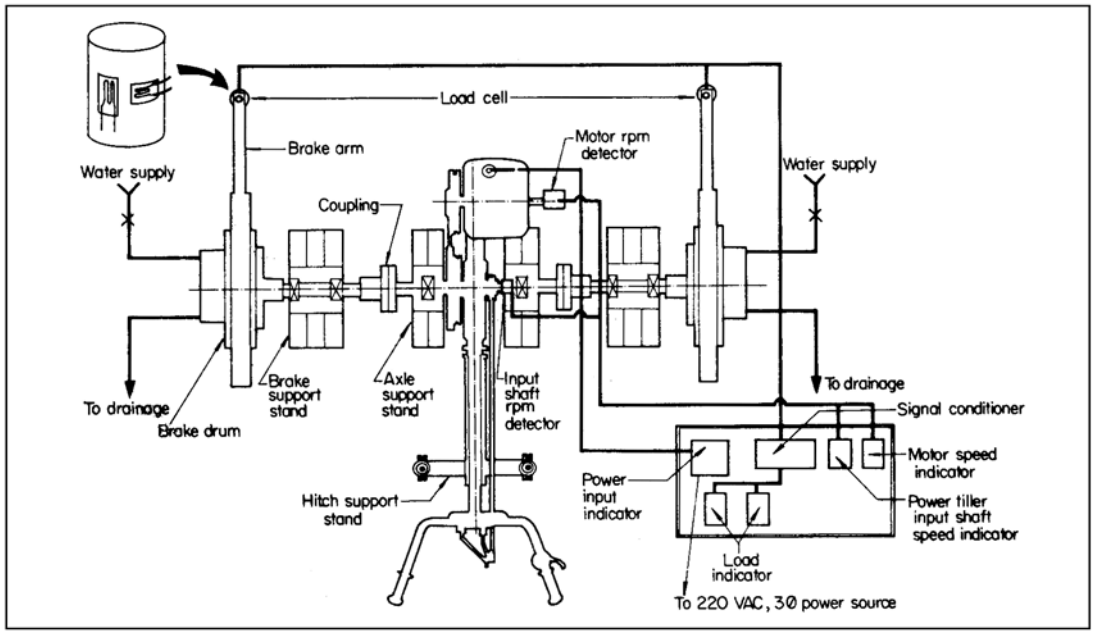
Efficiency is determined by measuring the input power of the calibrated electric motor and the output power determined by the prony brake.

In one trial of the PT-5, the efficiencies at different loads such as 0.746 kW (1 hp), 1.119 kW (1.5 hp), and 2.238 kW (3 hp) were 78.7, 85.0, and 88.1%, respectively.

The prony brake has proven to be an excellent instrument for measuring transmission efficiency



1. Grip-type clutch lever for the PT-5 tiller. IRRI, 1982.

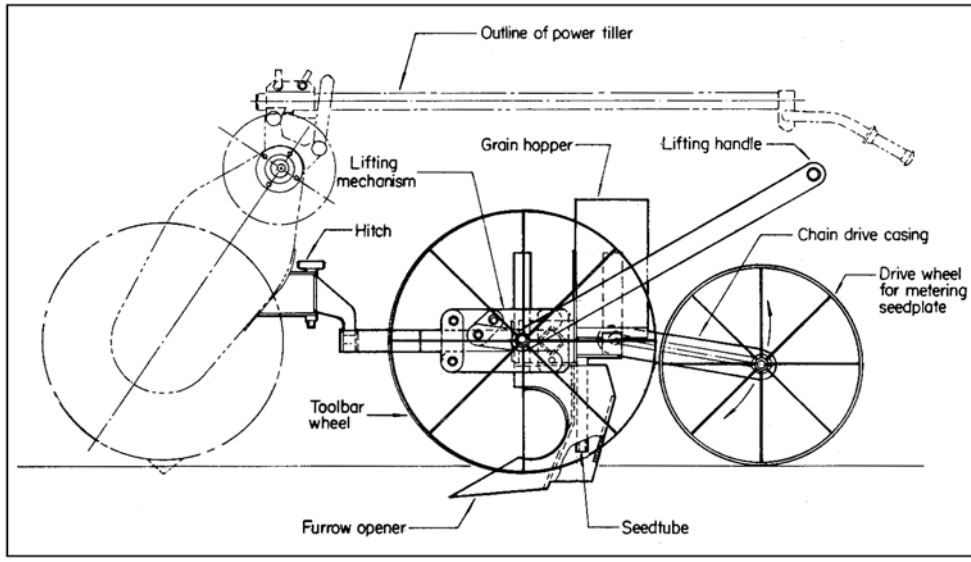


2. Prony brake set-up for measuring power tiller efficiency. IRRI, 1982.

and for the power tiller life test. It can handle loads at any setting and can be adjusted smoothly.

PLANTING EQUIPMENT

Inclined-plate planter. The development of the inclined-plate planter will provide an additional implement for the power tiller. Modifications are being planned to simplify the toolbar assembly for better depth control of the furrow openers. The toolbar will have wheels, fabricated from rounded flat bars, on both ends (Fig. 3) instead of one caster wheel supporting the middle portion as in the old design. The hopper will be attached directly above the furrow openers to shorten the distance travelled by the seeds from the metering system to the



3. Inclined-plate planter. IRRI, 1982.

furrow. Power from the ground wheels to the metering system will be provided by chains and sprockets.

International Institute of Tropical Agriculture rolling injection planter. Modifications made on the RIP were based on the results of a 1982 workshop.

The original seed-roller cover, which tended to pinch the seeds, and the brush cutoff device were replaced with rubber materials (Fig. 4). A stiffener was added to regulate seed metering, depending upon the requirement per hill of the given crop. The movable opener assembly of the 18- and 25-cm spacing was also improved for timely seeding and opening of the puncher. To avoid untimely opening caused by stones or hard soil clods, the movable puncher was shortened; and to reduce soil clogging, its foot was tapered (Fig. 4). To reduce seed loss during planting, the hopper funnel was lengthened (Fig. 4).

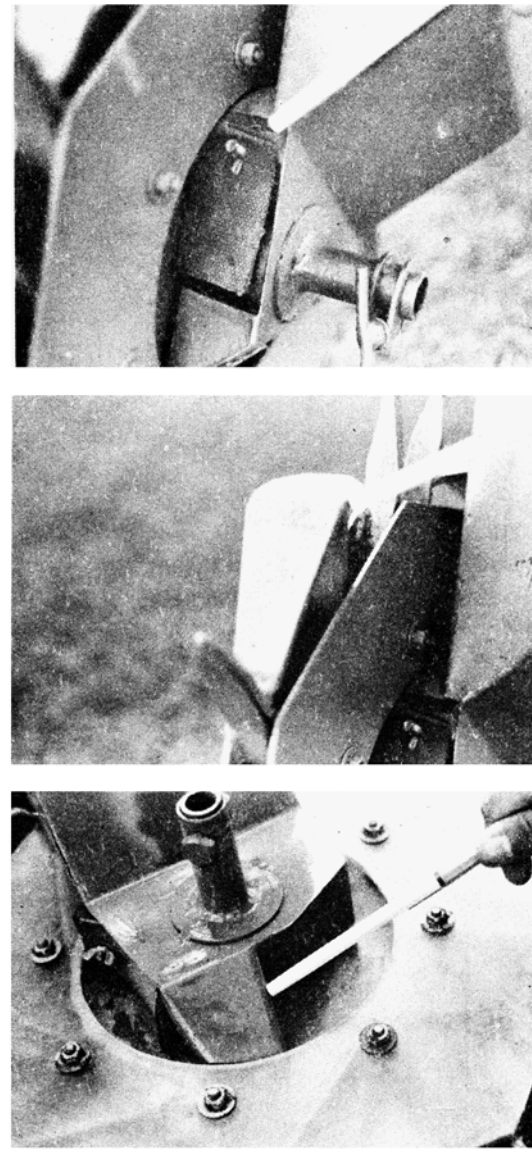
The improved RIP performed satisfactorily in tests at IRRI and other sites. Research on its use for establishing dryland crops on rainfed-bunded rice is under way in southern Philippines. The ACSN extended RIP use to other Asian countries.

DEEP PLACEMENT OF FERTILIZER

Development strategies. Studies at IRRI and elsewhere have shown that fertilizer-use efficiency can be substantially increased with deep placement at 5-15 cm in flooded rice fields. Most of the high fertilizer losses that result from conventional broadcasting methods are attributable to volatilization, nitrification, and denitrification. For more than a decade, the People's Republic of China and IRRI have been developing simple machines for root-zone fertilizer application in flooded rice fields. Some of the machines have performed well experimentally, but have not been accepted by farmers.

The following general conclusions have been drawn from the experience so far:

- PU is the only form of fertilizer used by most farmers in the tropical countries. Because of its ready availability, a much higher priority must be placed on the development of applicators for prilled fertilizers.
- Machines that can apply more than one form of fertilizer [such as PU and forestry-grade urea (FGU) or PU and USG] should be developed.
- The difficulty of transporting clean water to fields, the need for containers and extra labor, and the high cost of metering mechanisms will continue to be major constraints to liquid



4. RIP modifications: rubber material for the seed-roller cover and brush cutoff device (top), the tapered foot of the movable puncher (center), and the increased length of the hopper funnel. IRRI, 1982.

fertilizer acceptance in the developing countries. Because the demand will be small, a low priority should be placed on dissolved-fertilizer applicators.

- Because farmers have been reluctant to accept the long-recommended practice of incorporating fertilizer during the last harrowing operation and are generally applying fertilizer many days after transplanting, applicators for posttransplant operations may have a much better chance of acceptance.
- Single-row machines and most intermittent-type applicators require too much labor. To keep labor input for deep placement in line with that for conventional methods, continuous multirow applicators must be designed.
- Because human power is limited, the force required to push a machine must be very low.
- The options of combining fertilizer application with transplanting, weeding, or insecticide application have merit. A combination weeder-applicator may be of special interest because farmers prefer to apply fertilizer after weeding.
- Small farmers are generally not mechanically inclined, so machines should be relatively simple and sturdy. However, to reduce power needs and to improve machine mobility in wet rice fields, machines should be light. These conflicting demands will require design compromises.

Design criteria and new concepts. From the study of experimental manual and power-driven deep-placement applicators developed in the People's Republic of China and at IRRI, lists of farmer acceptance criteria were compiled.

Essential features of manually operated applicators.

- Must apply prilled fertilizer 5 to 10 cm deep.
- Operation must be continuous (nonintermittent).
- Must apply commercial grade fertilizer without further grading.
- Rate of application: 45 to 75 kg N/ha (two to three bags of urea).
- Must function in up to 5 cm of water.
- Must function from 5 to 20 DT.
- Maximum labor requirement: 8-12 h/ha per application.
- Lightweight (10-18 kg) — can be lifted at the end of the row.
- Approximate selling price: $45-$90.
- Must adequately seal ground-placement opening.
- Must last 4-6 seasons.
- Pulling or pushing force: 7-10 kg.
- Smooth, unidirectional manual movement during operation.

Desirable features of manually operated applicators.

- Can be used for both PU or USG.
- Mechanism rotary rather than oscillating.
- Rolls on wheels rather than on skids.
- Push-type for posttransplant operation.
- Multirow operation: two-four rows.
- Nonfurrow opener type.
- Mechanical injector type.
- Easy to manufacture by small shops.
- Should not require high precision in production.
- Pull-type for pretransplant operation.
- Can also be used for random-seeded crop.

Undesirable features of manually operated applicators.

- Intermittent operation.
- Multidirection action during operation.
- Use of liquid-conveying mechanism.
- Complex mechanisms.
- Delicate mechanisms.

Essential features of power-driven applicator.

- Must place prilled fertilizer 5-10 cm deep.
- Must apply commercial grade fertilizer without further grading.
- Rate of application: 45 to 75 kg N/ha.
- Must function in up to 5 cm of water.
- Continuous nonintermittent operation.
- Multirow design: six to nine rows.
- Must apply fertilizer before transplanting in fully puddled soils.
- If used after transplanting, must not damage plants.
- Maximum labor requirement: 3-4 h/ha per application.
- Approximate price as power tiller attachment: $170-$225; self-propelled: $350-$450.
- Must last 6-8 seasons.

Desirable features of power-driven applicator.

- Can be used for both PU or USG without

modification.

- Can be used for both row-planted and randomly planted fields.
- Tiller attachment small-powered rather than self-propelled.
- Rolling rather than sliding action for ground support.
- If self-propelled, single-wheeled rather than two-wheeled.
- High-velocity injection type, with pneumatic, centrifugal, or impact-drive mechanisms.
- Easily fabricated by small shops.

Undesirable features of power-driven applicator.

- Intermittent action.
- Two- to three-row machine.
- Liquid-conveying type.
- Complex and delicate mechanism.

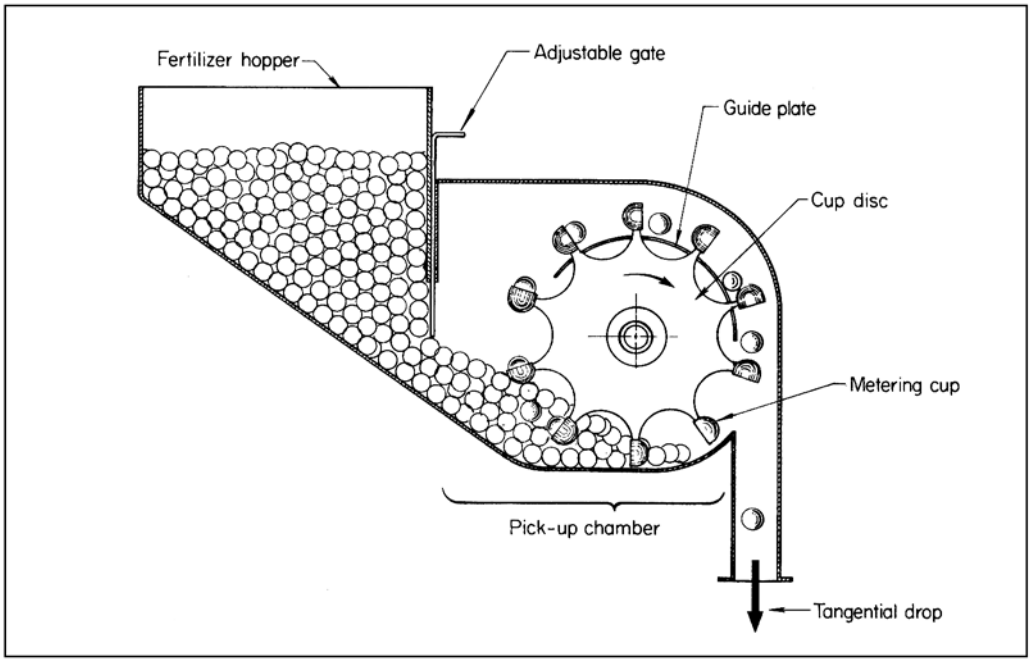
Based on the above specifications, new concepts for manual and powered applicators were proposed.

Cup-type metering mechanism for granular fertilizers. PU with granule sizes ranging from 1.0 to 2.4 mm is the most common fertilizer for rice in Asia. FGU (4.0-5.7 mm) is commercially available in some industrially advanced countries. Recently, some fertilizer companies have experimentally produced USG (11.4 to 16.4 mm) for deep placement in wet rice fields. So there is now a wide range of granular fertilizers available to farmers. Most fertilizer-metering devices depend on granule size and uniformity. With the increasing size variations, a versatile metering mechanism is needed.

Basic metering devices that are not too dependent on granule size include the variable opening with agitator, the indented rolled, the auger feed, and the cup-type feed. Among these, the cup-type feed is the least dependent on granule size and offers the best potential for development.

A cup-type metering device fabricated in the laboratory consists of a hopper and pick-up chamber with a rotating circular disk fitted with 16 semicircular cups on its periphery. Nine, 10 (Fig. 5), and 12 cup disks were used in later designs. An opening with an adjustable gate connects the hopper with the pick-up chamber. The size of the opening controls the fertilizer level in the chamber. As the disk rotates, fertilizer is picked up by the cups and carried until it falls out when the cups reach the top. A semicircular guide plate along the inside diameter of the cups guides the material falling from the cups along the cup circle for tangential delivery.

This arrangement works well with USG. A semicircular cup of 1.6-cm diameter picked up one

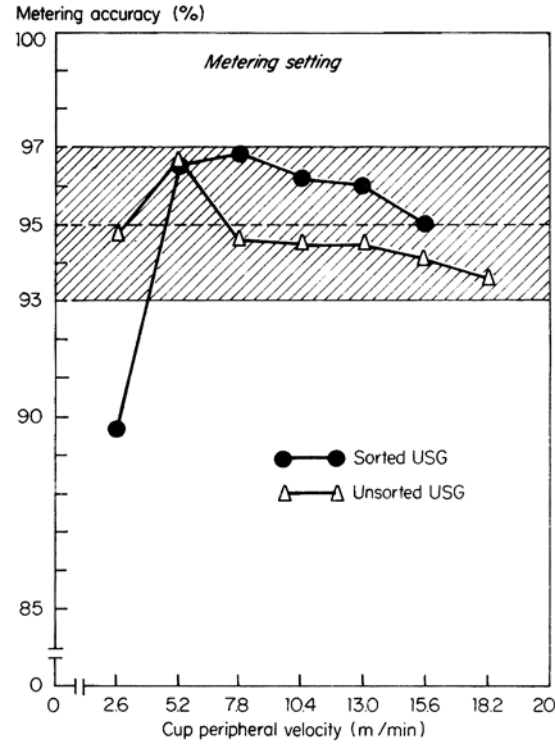


5. Experimental 10-cup metering device with tangential drop. IRRI, 1982.

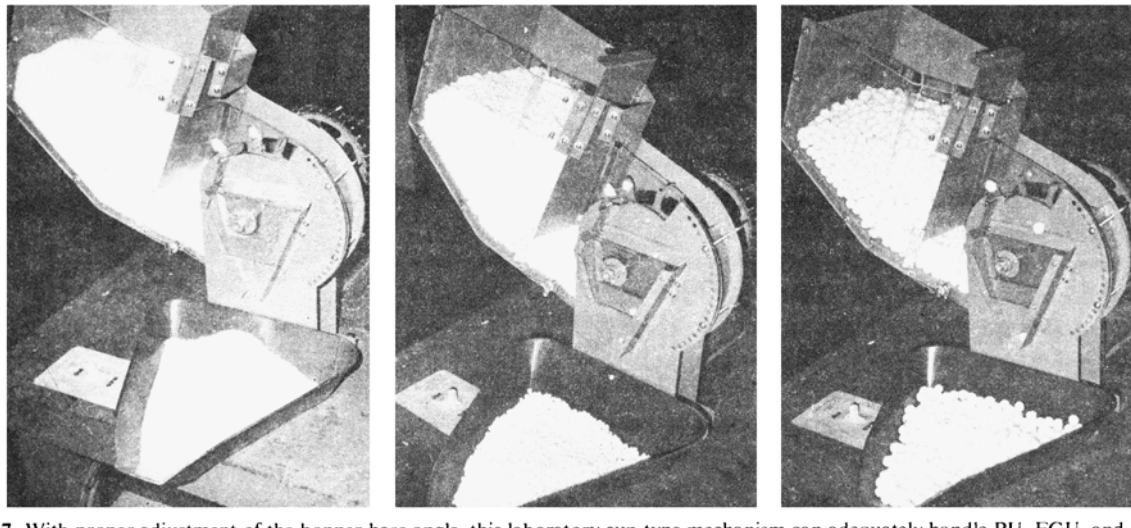
USG at a time as it passed through the chamber. Because of the wide variation in USG shape and size and occasional twin granules, the standard commercial USG material and USG hand-sorted for uniformity were tested. The device had a metering efficiency of 95 ± 2% within the peripheral cup velocity range of 2.6-18.2 m/min when the rate was set for 100%. The device had a more or less consistent metering performance over this range of cup peripheral velocity for both sorted and unsorted USG (Fig. 6). The peripheral drop design however was not suited for PU and FGU.

A funnel-shaped device was installed on a second laboratory unit on the inside of the upper part of the cup pitch circle to catch and deliver material falling from the cups (Fig. 7). The hopper-base angle can be tilted from 25° to 75° from the horizontal at 5° intervals. An adjustable slide gate between the passage connecting the hopper and the pick-up chamber controls the fertilizer level in the chamber.

Preliminary tests indicated that USG and FGU can be metered satisfactorily at hopper-based angles ranging from 35° to 75°, provided the hopper opening is adjusted properly. For PU, the machine performs better at base angles greater than 55°. As the base angle increases, the gate opening must be reduced to maintain the same level of fertilizer in the pick-up chamber. Increasing peripheral velocity tends to increase the amount of double-granule pickup for USG and the amount of PU and FGU per cup. At the higher cup velocity, each cup picks up more of the smaller granules. So, somewhat larger cups may be necessary for



6. Performance of cup-type metering device at different cup peripheral velocities with both sorted and unsorted USG. IRRI, 1982.



7. With proper adjustment of the hopper-base angle, this laboratory cup-type mechanism can adequately handle PU, FGU, and USG. Note the funnel-shaped device for catching and delivering the material. IRRI, 1982.

metering fertilizer with larger granules to deliver the same amount of fertilizer.

Furrow closers for minimizing fertilizer loss in flooded fields. Losses in deep-placed fertilizer in flooded fields are seriously affected by the method of closing the placement furrow, but the reasons are not well understood. Water entering a furrow during placement may quickly dissolve some of the fertilizer; the solution may splash out when the furrow is closed with soil. Furrow closers of different designs have been tried on various IRRI applicators with mixed results.

A study is under way to investigate the impact of furrow closing on fertilizer loss in flooded fields and to compare under carefully controlled laboratory conditions four furrow closers used with IRRI machines. The closures are plain skid, plain skid with inverted U-shaped closure, plain skid with staggered soil-deflecting blades, and plain skid with staggered soil-deflecting blades and with a rear press plate.

About 20 cm of Maahas clay soil was placed in five fabricated laboratory soil bins (4 × 1 × 0.4 m). A tool carrier mounted on two rails on top of the bins moves the furrow openers and closers. An electrically powered cable-drum arrangement pulls the tool carrier with the furrow openers or closers at a uniform walking speed of 1.5 km/h. Strain gauges on each tool mounting beam permit force measurements on each opener or closer under carefully controlled soil and water depths. Weights are added on the closure skids to achieve normal pressures on the soil.

The soil is puddled uniformly and then leveled and settled for 5, 10, and 15 d. Tap water is used to maintain the 5-cm water level in the bin. Water is drained from the bin just before furrow opening. After furrows have been opened in the drained soil, five 0.32-cm diameter tubes are placed at the bottom of each furrow. Each tube connects to a graduated liquid container. The tubes have the same length, but the furrow openings are staggered to permit measurement of percolation rates at five points.

The furrow is then closed with the furrow closers at 1.5 km/h. Then, colored water is released through each tube under a pressure head of 15.4 cm. A graph indicating time required for discharging a known water quantity is plotted for each tube to indicate furrow sealing quality. Emergence points of the colored water may give some clues about how the fertilizer is lost and whether the closed furrow channel under the soil is contiguous or broken. This procedure is being repeated for different soil settling times (5, 10, and 15 d after puddling) and for three different skid ground pressures (7, 11, and 14 g/cm^2).

In a second set of experiments, water is drained from the bins and the furrows are opened. Fertilizer is carefully applied and the furrows closed using one type of furrow closure in each bin. The bins are flooded with 5 cm of water immediately after furrow closure. The concentrations of urea and ammonium^N in the floodwater are measured at 4-h intervals for 5 DAT to study the effect of each type of closure on fertilizer loss. This procedure is being repeated for the three settling times and the three normal skid ground pressures.

Manually operated spring auger granular fertilizer applicator. The two-row spring auger fertilizer applicator, developed last year, was extensively tested in 1982. Major problems encountered with this pull-type machine included inadequate covering, excessive pulling force, and imprecise movement between rows. This machine was redesigned for pushing (Fig. 8).

The curved delivery tubes of the earlier machines, which caused the spring augers to break off after only 8 h of operation, were replaced with straight auger tubes with a 90° bevel sprocket drive. The delivery tube diameter was reduced from 29 to 19

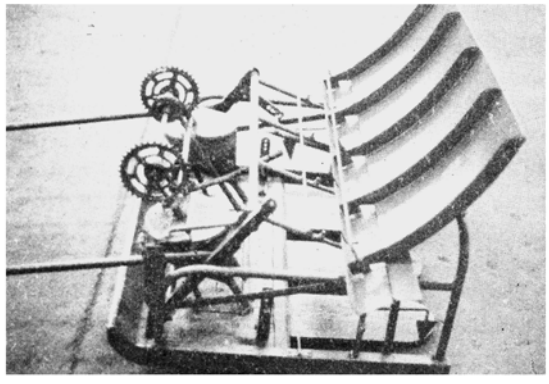


8. The spring auger granular fertilizer applicator was redesigned for pushing which permits better movement control and more effective furrow opening and closing. IRRI, 1982.

cm and the placement depth from 10 to 5 cm by raising the auger at the skid mounting. The auger drive shaft was extended 8 cm into the spring auger at the drive end, preventing PU from flowing through the delivery tubes when the auger was not rotating. The free-floating ground drive wheel was retained because it provided good flotation when fields were soft and reduced the skid load.

To compensate for the reduced flow rate because of the smaller diameter auger, a step-up bevel sprocket transmission was designed with a 15:1 ratio, which permitted a maximum metering rate of 87 kg N/ha. The furrow opener and closures were modified by installing a 15° V-shaped opener and a single soil-deflecting furrow closer. Initial trials have indicated promising results with satisfactory placement at 5-7 cm and reduced pushing force. Urea and ammonium^{N} measurements showed that plots fertilized with the two-row machine performed similarly to plots fertilized with the USG plunger-type applicator. Further tests are under way in farmers' fields.

Prilled fertilizer applicator for IRRI transplanter. In 1982, a PU applicator attachment (Fig. 9) was developed for the IRRI transplanter because PU is the most commercially available fertilizer in Asia. Combining the transplanting and fertilizing operation can minimize labor requirements and may help popularize mechanical transplanting and deep placement of fertilizer. The applicator can simultaneously place PU 5-7 cm deep at a precisely indexed position between two plant hills during transplanting.



9. Prilled fertilizer applicator designed for the IRRI transplanter. IRRI, 1982.

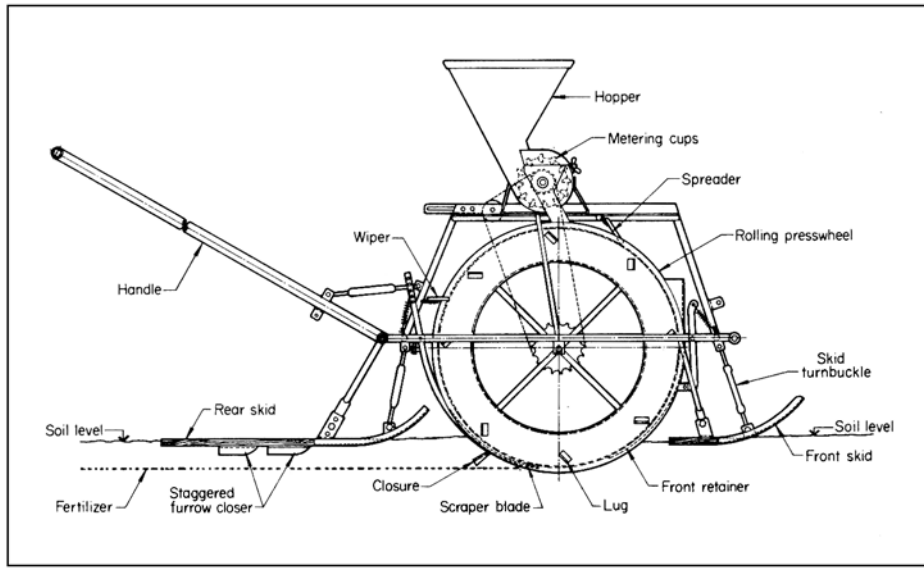
The machine has two fertilizer hoppers with auger-type feed mechanisms mounted on the four-row IRRI transplanter. The auger delivery tubes extend 5 cm below the transplanter skid. Narrow V-shaped furrow openers are attached in front of the auger tubes to reduce soil resistance when the machine is moved. The portion of the transplanter skid at the rear of the auger tube closes the furrows as the machine moves.

Fertilizer is metered and ejected during the downward stroke of the transplanter's handle. The feed auger is driven by a cable wound on a free-wheeling pulley mounted on the auger drive shaft. As the transplanter handle is pushed downward, the cable unwinds and drives the auger shaft. A flat coil spring rewinds the cable back on the auger drive pulley when the transplanter handle is retracted upward. Fertilizer rate is varied by changing the cable attachment point on the picker link, which changes the cable travel for each stroke. Results of initial tests are encouraging and the machine is undergoing further testing.

Rolling presswheel applicator. Force-feed injector and auger-feed applicators for deep placement of fertilizer in wet rice fields are being tested and further developed at IRRI and in the People's Republic of China. However, a rolling presswheel machine is another alternative for force-feeding fertilizer and could offer greater versatility because it can place different granular materials.

The machine has a large-diameter narrow wheel which, by its rolling action, transports fertilizer from the metering mechanism for deep placement into the wet soil (Fig. 10). The main components are a 19-mm wide and 50.8-cm diameter rolling presswheel with a C-shaped grooved rim and a cup-type fertilizer-metering mechanism, which is chain-driven from the wheel axle and mounted on top of the wheel. A scraper blade, mounted in the C-groove at the bottom of the wheel, scrapes clinging fertilizer from the groove and deposits it at the bottom of the wheel furrow.

When the machine was used with PU, excess mud and water clinging to the wheel sometimes wetted and blocked the fertilizer delivery funnel. A rubber wiper installed on the rim groove eliminated the wetting problem. PU sometimes dropped on the rim in heaps; portions that did not adequately cling to the wet rim groove fell in front of the



10. The rolling presswheel fertilizer applicator can offer greater placement versatility. IRRI, 1982.

machine as it moved. A rubber spreader, mounted on the rim in front of the fertilizer delivery point, helped to spread the fertilizer more evenly on the rim and minimized the fertilizer loss.

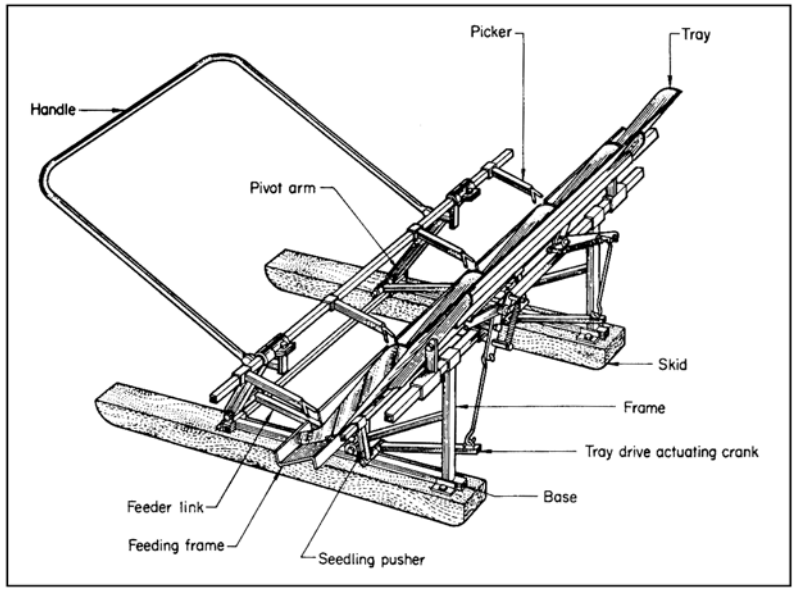
Because of its larger granule size, FGU did not cling to the wheel. A retaining guard mounted at the lower front of the wheel eliminated dropping of the large granules on the soil surface. The front retaining guard was mounted with a spring-loaded arrangement to accommodate various amounts of fertilizer between the rim and the guard.

One skid at the rear of the wheel and one in front were required for the single-row machine. The rear skid had two staggered soil-deflecting blades to push loose soil back into the wheel groove for better sealing of the wheel furrow. The single-row machine weighs 10 kg without fertilizer in the hopper. Pushing the machine was found to be more satisfactory than pulling. A two-row machine is being designed for more stability. Preliminary evaluation of floodwater measurement of urea and ammonium^{N} concentration in fields fertilized with the rolling presswheel indicates that it performs better with FGU than with PU.

Transplanter-mounted liquid chemical injector. The five-row peristaltic pump metering device was mounted on the IRRI transplanter to inject liquid fertilizer and systemic insecticide below the soil surface simultaneously with rice seedling transplanting. The additional force required to operate the transplanter with the mounted injector was determined by installing a compression-tension type of load cell on the transplanter handle. The average pulling force was taken when the operator was pulling the machine at uniform speed with and without the mounted injector. Pulling and transplanting forces were also instantaneous during the normal operation of the machine.

Pulling forces averaged 12 and 10 kg when the transplanter was operated with and without the injector, respectively. Increases of about 1-2 kg of the maximum transplanting force and about 6-8 kg of the maximum pulling force were also recorded. The increased weight of the transplanter with the mounted injector has caused these increases required in pulling and transplanting forces. Field observations showed that the transplanted seedlings in the middle row of the transplanter usually fell along the footprints of the operator. An even-rowed transplanter was therefore designed to avoid the problem.

The design of the four-row transplanter (Fig. 11) will reduce considerably the weight of any mounted fertilizer applicator, because it will only require one applicator for every two rows instead of one for every row.



11. Four-row IRRI transplanter. IRRI, 1982.

Analytical measurement of application power of two-row deep plunger USG applicator. Designed to place USG up to 8 cm deep for straight transplanted rice, the two-row deep plunger can be operated by using one hand on the main frame handle (which drives and guides the machine) and the other on the plunger handle. The machine applies four rows per passing and places the USG in the center for four hills. The operator's path is at the center row and different from the applicator's; thus, the applied granules are not disturbed.

In this trial, the required force to push the machine and the forces involved in operating it were measured using the outlined instrument in Figure 12.

Table 1 shows the results at two different times after transplanting. Figure 13 also shows the instantaneous pulling and pushing forces at the plunger handle of the two-row USG applicator.

With the applicator, a 1-ha field can be fertilized in 1.7 d (13.59 h) using 58 kg N/ha, and 2.6 d (20.8 h) using 87 kg N/ha. The two-row plunger is easier to balance than the single-row applicator.

TWO-STAGE AXIAL-FLOW PUMP

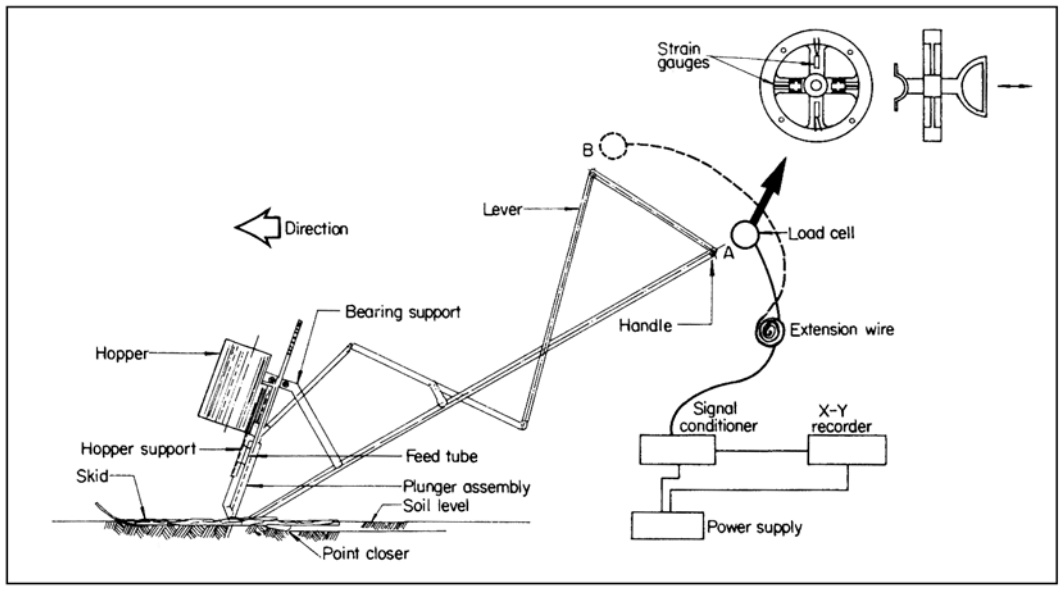
Feedback from the farmers and IRRI industrial extension engineers indicated a need for a high-capacity portable irrigation pump to lift water from 4 to 6 m. Because the existing axial flow pump was designed for lower lifts of only 3 m and at 70% minimum efficiency, it will perform at a drastically reduced efficiency if used for higher lifts.

The new two-stage axial flow pump will operate at the required minimum efficiency when used to lift water 3-6 m. A schematic diagram of the proposed two-stage axial flow pump is in Figure 14.

THRESHING EQUIPMENT

Improved portable axial-flow thresher (TH-6). A project to improve the portable axial-flow thresher was initiated. The improved portable thresher must have a threshing performance comparable to or better than that of the commercially available and locally-made threshers and still be simply constructed and affordable to small farmers. The improvements made on the fabricated prototype (Fig. 15) come from new design ideas and good features already existing on farmers' threshers.

To improve portability, the new prototype can be disassembled into the engine and engine base, the cover and the feeding tray, and the threshing cylinder and the blower. Each of these major assemblies is light enough to be carried to the



12. The load cell is attached to A when the pushing force is measured, then transferred to B when the application forces are measured. Wire is connected from the load cell to a signal conditioner and a recorder. IRRI, 1982.

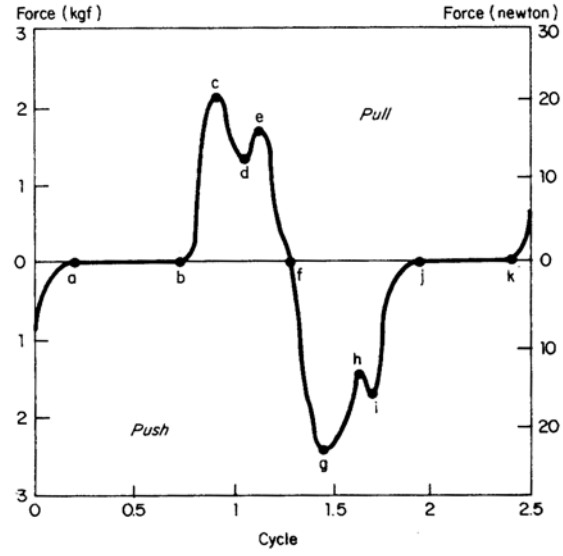
Table 1. Force requirement to operate the two-row deep plunger at two times after transplanting. IRRI, 1982.

Operation	Force (kgf)[a]	
	3 DT	12 DT
Pushing	2.37	3.03
Picking USG	1.71	1.61
Deep-placing	1.61	2.18
Lifting the plunger	1.85	1.79
Actuating USG	1.64	1.75

[a]Soil cone index value: 1.76 kg/cm^2 at 3 DT, 2.28 kg/cm^2 at 12 DT.

threshing site and easily reassembled with bolts. The louvers attached to the cover have been redesigned. The material caught in the first louver is effectively conveyed to the second louver and so on until it reaches the discharge point. The bent corners of the semihexagonal cover help separate loose grains from the straw by interrupting the smooth flow.

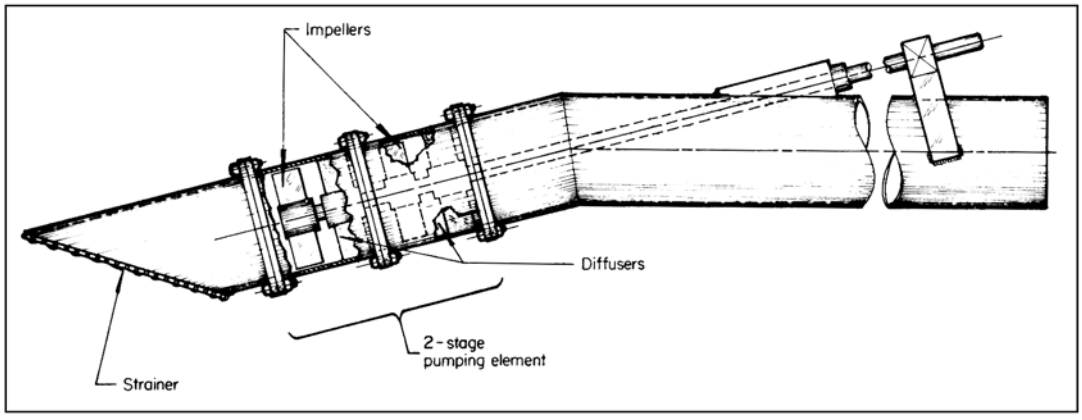
The lower concave is a combination of three round bars alternated with one flat bar, creating an uneven surface for improved threshing efficiency and less separation loss. Adjustable stationary pegs remedied the problem with long-strawed rices encountered in the old design. To accommodate more material at the feeding end, the tray's height



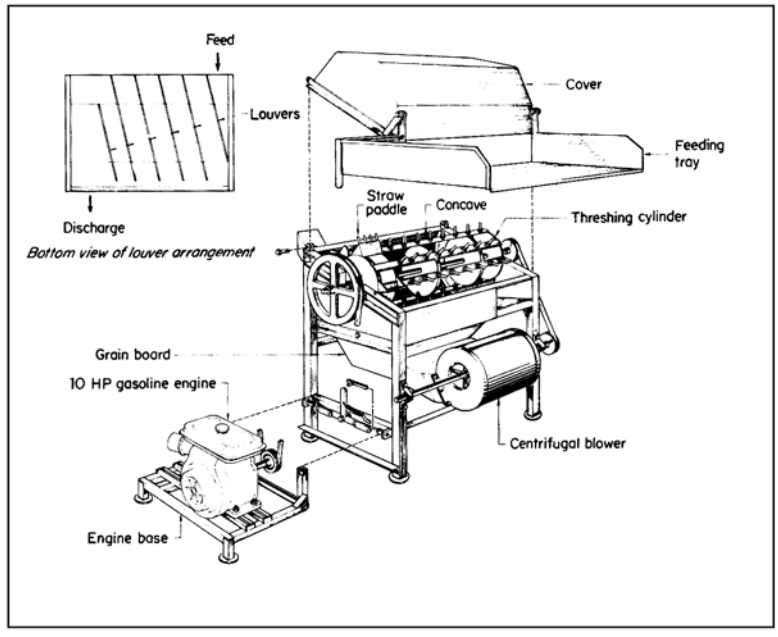
13. Instantaneous pulling and pushing force at the plunger handle of the two-row USG applicator. IRRI, 1982.

and length were increased. The straw paddle tips were provided with short pegs to minimize clogging of straw at the discharge section.

Threshed grains from the lower concave fall through a trough where they are caught with an air stream from the blower. Cleaned grains drop directly to the ground or to any container as light



14. The two-stage axial-flow pump assembly is so constructed to be easily changed from a single-stage to a two-stage pump. IRRI, 1982.



15. Improved IRRI TH6 axial flow thresher. IRRI, 1982.

chaff, unfilled grains, and other impurities are removed by the blower's air stream passing through a grain board. The inclination of the grain board can be adjusted to attain the desired purity.

In prototype tests, the improved portable showed a lower separation loss than that of the original TH-6 design. The extensive threshing action inside the threshing chamber resulted in more broken straws, which decreased the efficiency of cleaning the threshed grains. Air velocity was adjusted by increasing the engine speed. This improved cleaning but caused more grains to be blown out through the grain board.

The improved prototype, the original design, and a manufacturer's model were compared for efficiency in threshing of long and short straws. A 10-hp gasoline engine was mounted on the prototype. On the basis of the comparisons, the lower concave was modified to a two-section concave — one section made of round bars and the other of 12-gauge, 13-mm mesh wire.

Experimental panicle thresher with straw chopper. The IRRI-designed axial flow thresher emits bruised, damaged, and long straws. An experi-

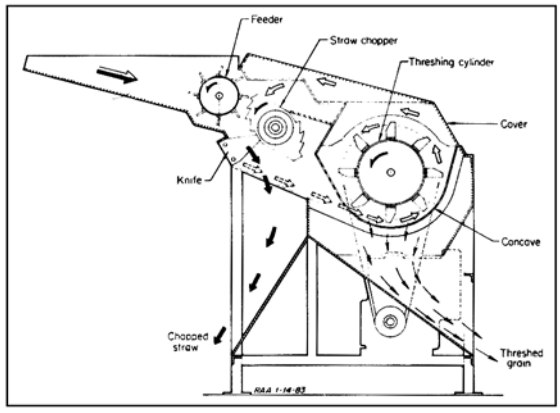
mental thresher was designed to chop straw and spread it back onto the field for soil incorporation during the next land preparation and to satisfy an increasing market for chopped straw.

The machine comprises the threshing unit, the straw chopper, and the feeding unit (Fig. 16). The threshing unit is based on the original axial flow design with some modifications. The peg teeth are made of flat bars instead of round bars or bolts and their frontal surfaces are shaped with logarithmic curve profiles in relation to the cylinder's direction of rotation. Clearance between the cylinder pegs and the concave was reduced to 1.3 cm. The cylinder is designed to operate at peripheral velocity of 14.5 m/s. Instead of a straw paddle, pegs were used to move the straw to the rotary cutter.

The chopping unit has a series of saw tooth blades mounted on a single shaft and twisted counterclockwise during assembly. The cutter is designed to cut straw 6 cm long and to cut the panicles at the feeding side of the threshing chamber. A standard reaper's knife is used as the counterknife. To chop straw effectively, the cutter is designed to operate at a linear speed of 4 m/s.

A feeder operating at 0.72 m/s conveys material to the straw chopper and is designed to protect the operator from the cutting mechanism, orient the straw at a right angle to the cutter, and limit the maximum rate of feeding into the threshing chamber.

The cover is made semihexagonal to assist in separating threshed grains from the straw by interrupting the smooth circular motion. The concave is made of flat bar grills at the feeding side and a 12-mm wire mesh at the separation section. It is also provided with five partitions with a removable cutoff wall allowing visual inspection of the threshed grain from the feeding side to the discharge side.



16. Experimental panicle thresher with straw chopper. IRRI, 1982.

The prototype was tested using a 5-hp gasoline engine. High power was necessary for the chopper to cut straw at a 6-cm length. Cut panicles wrapped around the feeder and chopper shafts, clogging the inlet opening of the threshing chamber. The inlet opening was too narrow to accommodate panicles of various lengths.

Modification and evaluation of the experimental panicle thresher are continuing.

IRRI REAPER PROJECT

1.6-m lightweight reaper. Design improvement and field performance testing on the 1.6-m lightweight reaper continued.

Several material specifications on the main frame, the hitch frame skid, and the gathering header mechanism were changed. For ease of fabrication and maintenance, the extreme-right header starwheel mounting bracket was made similar to the other four mounting brackets. Polyvinyl chloride starwheels with reduced diameter were also added. An adjustable rear skid (Fig. 17), mounted to the hitch to eliminate vibrations when the front skid passes over humps or holes, can easily be lifted when crossing levees. The rear skid was very effective on soft soil and also positively balanced the reaper for cutting evenness.

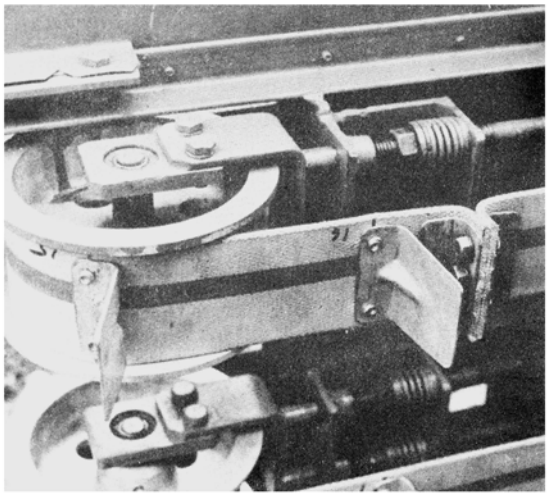
Upper and lower conveyor belts were provided with crest joints (Fig. 18), which improve the strength and life of the belt conveyor joints without obstructing the flow to the discharge end.

The prototype performed well during the tests at IRRI and farmers' fields in Laguna Province, Philippines. During later tests in central Luzon and the Bicol region, metal fatigue on the main frame and damage on the hitch mounting frame were observed. As a result, stronger materials were used on subsequent units and incorporated with the specifications.

1-m reaper. *Modification for a commercial hand tractor.* The CAAMS-IRRI reaper was modified

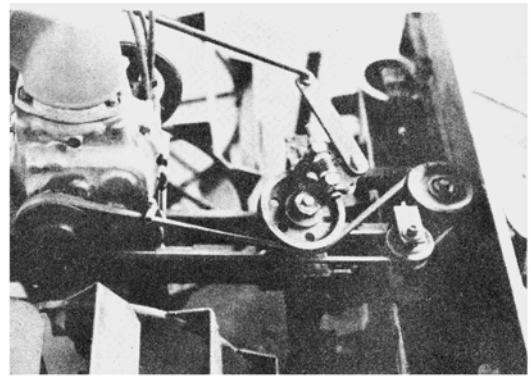


17. The 1.6-m reaper with adjustable rear skid. IRRI, 1982.



18. Crest joints for the upper and lower belt conveyors of the 1.6-m reaper. IRRI, 1982.

so that it could be attached to the Honda hand tractor (model G42). To minimize modification on the hand tractor, the reverse speed of the unit was initially used to drive the reaper. A quarter-turn V-belt (Fig. 19) brought power to the reaper's knife drive shaft and an inclined spring-loaded idler was incorporated into the drive system. An adjustable



19. Quarter-turn V-belt used on the 1-m reaper modified for attachment to a commercial hand tractor. IRRI, 1982.

rear skid, adapted to the built-in counterweight of the tractor, balanced the weight.

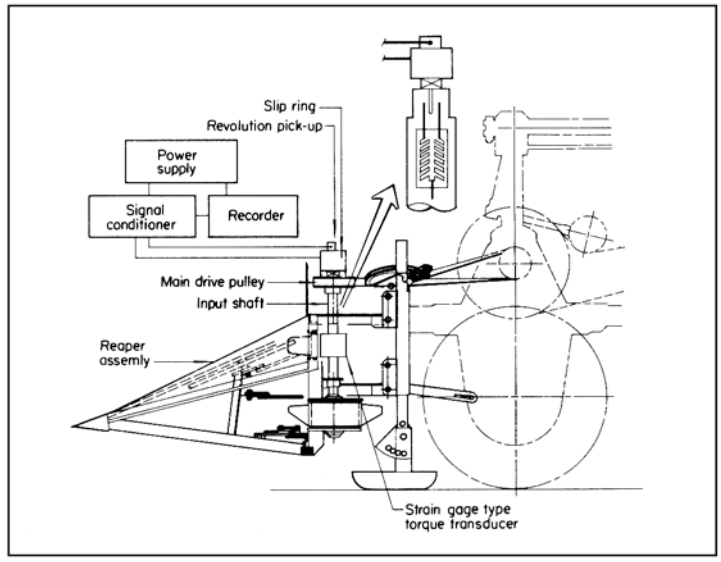
Preliminary tests using reverse speed showed a low field capacity, so forward speed was used with better results. Modifications were made on the tractor by moving the engine and its mounting bracket assembly from the front to the rear. A reaper hitch frame was fabricated to allow belt stretch and wear between the reaper and the tractor.

Using curved pipes, the rear skid was directly mounted underneath the two outermost header pipes. The skid can be easily adjusted by transferring the lockpin to the next drilled holes on the adjustment bracket. A 0.46-m diameter cagewheel was installed. The originally designed reaper drive was used except that the spring-loaded idler was provided with a pivoted bracket that can be engaged and disengaged during reaping. The forward speed ranges from 0.3 to 1.7 m/s using the first or second gear.

Simplified production specifications were drawn to show manufacturers one way of attaching the reaper to the tractor.

Measurement of input power. The power applied on the input shaft of the 1-m reaper was determined during field operation. The power applied to the shaft goes to the conveyor system and cutter bar, and therefore gives a measure of the cutting and conveying power required.

Power was measured with a shaft-mounted torque-strain gauge and generator-type tachometer (Fig. 20). Torque and revolutions-per-minute readings are monitored on a recorder and the



20. Instrument setup for the measurement of input power for 1-m reaper. IRRI, 1982.

power is determined through the relationship

$$P = \frac{T \times N}{9561.7}$$

where P = power in kilowatts (kW)
T = torque in newton-meters (N·m)
N = revolutions per minute (r/min).

Results of the trial at the IRRI farm are in Figure 21. The power required for cutting and conveying the crop averaged 0.42 kW and reached up to 0.51 kW at times.

The measurement method proved very accurate because of the good response of the instruments.

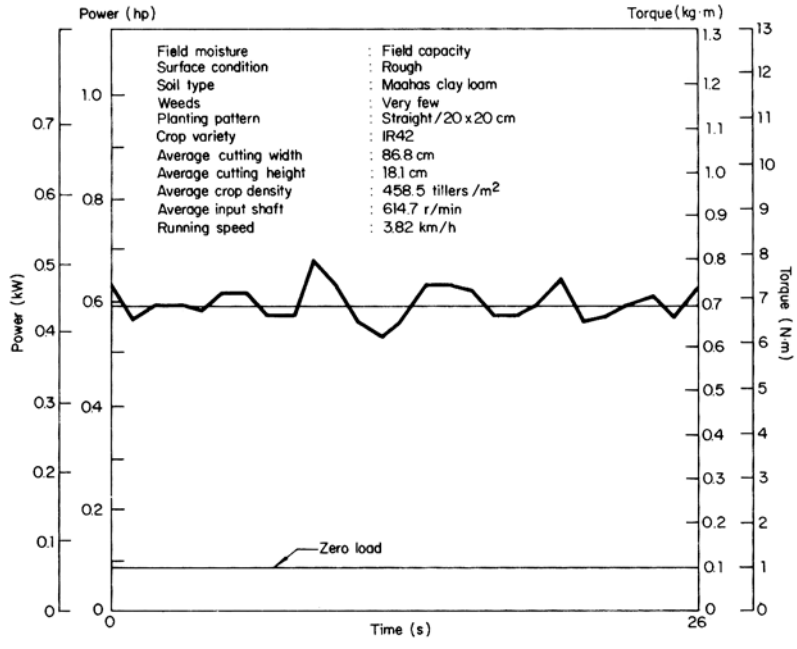
GRAIN DRYING

Heated-floor dryer. Sun-drying is the most common method of drying rice in the tropics. However, because it is not practical when there is rain or heavy clouds, the heated-floor dryer was conceived as a relatively inexpensive and simple technology to complement sun-drying. The basic idea is to heat a covered section of the drying floor to between 60° and 90° C to rapidly get the grain MC down to approximately 18% with minimal fissuring and discoloration. Grain at 18% MC can be stored safely for several weeks until weather conditions permit sun-drying to a more-desired 14% MC.

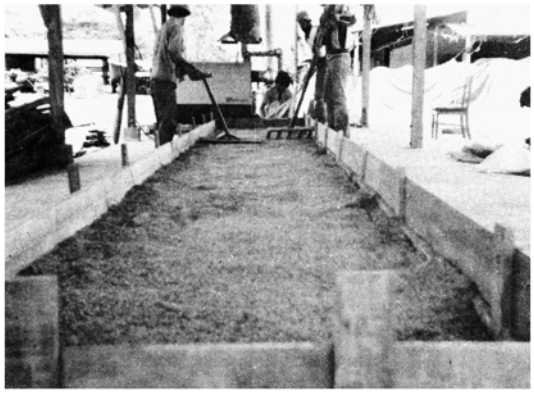
A small experimental unit was made from two steel plates with internal water passages, designed originally as solar collectors for heating water. The water heater was fabricated from a 200-liter oil drum heated underneath by a kerosene burner. An electric pump circulated the hot water from the heater to the drying plate. Probes at various points in the system monitored the drying floor and hot water temperatures.

Tests showed that moist grain can be rapidly dried to 18% MC in less than 1 h when continuously raked over the heated floor at 90° C. In milling tests, the samples sun-dried to 14% MC in this manner showed no appreciable decrease in head rice recovery compared with the traditionally sun-dried samples. There was no significant effect on the drying rate even when the RH of the ambient air was high.

To evaluate capacity and labor-requirement characteristics of the heated-floor dryer, a larger experimental unit was fabricated and installed at the Philippine Packing Corporation rice farm in Musuan, Bukidnon (Fig. 22). This company has been cooperating with IRRI in field-testing machines. The dryer was installed adjacent to the existing sun-drying pavement. A shed protects the grain from rain and serves as shelter for the workers and the dryer. The concrete floor beneath the shelter has two different levels so that the rice being sun-dried on the pavement can be quickly gathered in the event of impending rain, and then



21. Sample power requirement of IRRI 1-m reaper in actual field operation. IRRI, 1982.



22. A larger experimental unit of the heated floor dryer installed at PPC Rice Farm, Musuan, Bukidnon.

raked up toward the slightly raised portion of the floor and dumped unto the lower portion where the drying plates are.

Each drying plate consists of two 16-gauge iron sheets, 1,220 × 2,240 mm, with a 6-mm gap between them. Flat bars, 6 × 20 mm, are welded between the plates to provide the gap and zigzag passage for the hot water flow. Wooden supports keep the plates off the concrete floor to minimize heat loss.

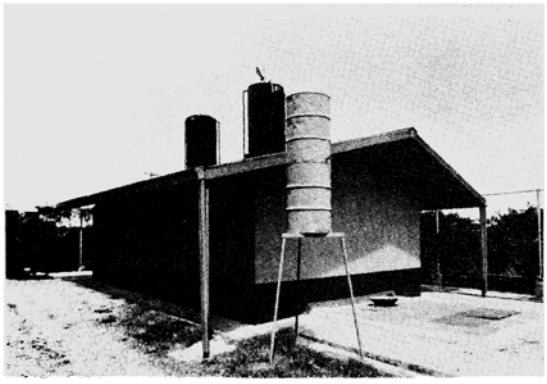
Inlet and outlet pipe nipples are welded on the lower plate and connected to the main pipe lines with flexible hose. A truck engine water pump driven by a 1-hp electric motor circulates the hot water from the heater to the drying plates and back. Probes at various points determine the temperatures of each plate, the incoming and outgoing hot water, and the water in the heater.

A barrel-type boiler, used as the water heater, has a draft regulator for efficient burning of wood, rice hulls, straw, and other agricultural wastes and for controlling the water temperature.

Initial tests have been conducted and results are being analyzed to determine the technical and economic feasibility of this technology.

Warehouse grain dryer. The warehouse grain dryer (Fig. 23) is being designed to utilize nonconventional energy sources such as rice hulls and other agricultural wastes. It consists of a furnace, drying chamber, and two wind machines.

The drying chamber is divided into a predrying area for holding wet materials before being loaded into the drying bin and the main drying chamber. Vertical trays hold the rice and are positioned around the main drying chamber. The dryer has an estimated capacity of 3-6 t of rice daily. Design improvements underway will improve loading and unloading of materials to and from the holding bin,



23. The warehouse grain dryer with two vortex wind machines burns a variety of agricultural waste products. IRRI, 1982.

reduce construction costs, and increase heat utilization efficiency.

The center tube furnace, made from fire brick fabricated from rice hull ash, will efficiently burn any kind of agricultural waste such as rice hulls, sawdust, corncobs, coconut husks and shells, and similar materials. It has primary and secondary air inlets, a center mold, and a T-chimney. The T-chimney gives maximum ventilation for complete combustion. In tests, burning efficiency was 90% when the fuel used had a 16% MC or less. The furnace can also be used for a circulatory water heating system.

Two unique wind machines (Fig. 23) on the roof of the dryer create air movement without an external power source. As the wind strikes the vanes of the towers, internal vortexes of air are formed. The resulting low-pressure area creates upward air movement.

Ways to reduce the cost of construction by using indigenous materials and to reduce the labor required to load and unload rice are being studied. The design of the warehouse dryer is applicable for village or cooperative-level operation.

TESTING AND EVALUATION

Improved portable thresher (TH-6). In 1982, initial comparative tests showed that the manufacturer's model and the improved IRRI TH-6 had aggressive threshing concaves. Heavy breakage of rice straw caused some grain cleaning problems with the simple blower. However, the aggressive concave arrangement resulted in less than a 0.5% separation loss compared with more than a 2% loss with the wire mesh concave.

BD1 and BD2 blower performance. The performances of BD1 (vane-axial) and BD2 (tube-axial) blowers were reviewed in an effort to substitute one blower for use in either the flatbed dryer (BD1) or the vertical batch dryer (BD2).

Tests indicated that the performance characteristics of both blowers were 50% less efficient than the commercially available blowers. The BD2 design is being considered for improvement with particular attention on blade design, shape, angular twist, and pitch.

Preliminary tests on the IRRI wetland (multihopper) seeder for coated seeds. The IRRI wetland multihopper seeder was modified by incorporating an appropriate furrow closer underneath the skid to ensure firm seed placement, particularly for CaO_2-coated seeds. The roller-type metering device is equipped with spikes arranged in a single row protruding from the rubber roller to regulate seeding rate. A rubber scraper affixed on the casing aids in regulating seeding rate.

Tests showed some grinding of the CaO_2 coating and, in some instances, of the seeds. Seeding was found relatively diffused with occasional misses. Mud accumulated by the furrow closer clogged the hopper discharge outlet.

Ongoing development includes 1) analyzing seed flow characteristics of coated, pregerminated, dry or wet seeds; 2) redesigning the metering mechanism to give a uniform and adjustable discharge rate with minimum damage; 3) defining parameters that will check proper seed placement on different soil conditions; and 4) reducing pulling draft.

INDUSTRIAL EXTENSION

The Industrial Extension Network extends to Burma, Egypt, Indonesia, Pakistan, Thailand, India, and the Philippines. The activity in Pakistan has been continuing after the departure of an IRRI-appointed staff member and an engineer will be appointed to India located at Coimbatore. IRRI representatives are located in the other countries.

Burma. Interest in the manual transplanter continues. In 1980, an IRRI-designed transplanter

was introduced and modified to fit Burma's conditions. It is reported that one mechanical transplanter is equivalent to six hand transplanters. The capacity of the machine is 0.25 ha/d. About 1,500 units were fabricated and operated in 1982.

The IRRI-designed reaper-windrower was introduced in 1981. Seven units were fabricated and tested in 1982. Results indicate that a reaper will become a useful machine in Burma.

Indonesia. Industrial extension has been active in West Sumatra, South Sulawesi, South Kalimantan, and West Java.

To test the adaptability of two-wheel power tillers, 10 IRRI-designed units were introduced. Six were given to farmers and four were retained for demonstration by cooperatives. Although only 1 yr of the project has been completed, results were encouraging. The machines have been utilized heavily and repair costs have been minimal. The following are pertinent conclusions:

- The two-wheel tractors have been a profitable investment and show a better advantage over traditional tillage methods than the four-wheel tractor.
- As a result of mechanization, there has been little change in labor requirements on the farm, although there has been some reduction in family labor and a small increase in hired labor.
- There appears to be a large demand for land preparation mechanization because labor in the Luwu area is in short supply.

Philippines. The program concentrated on the introduction or extension of the portable thresher (IRRI TH-6), the 1-m reaper, the PT5 power tiller, and the axial flow pump. These implements were expected to be highly acceptable by small shops, owners, and farmers.

The reaper was introduced during a February workshop attended by 24 cooperators. Ten participants have since successfully fabricated a reaper. Nineteen manufacturers attended a second workshop in August and fabricated their first reaper. In 1982, farmers bought 88 of 161 fabricated units.

The vertical reaper was introduced in 1982; 180 were fabricated — 150 in central Thailand and 30 in the eastern area.

The improved plow is being demonstrated in the northeast where the farmers use buffalo extensively. Twenty plows were fabricated and purchased by the Department of Agriculture for farmer evaluation. Ten were purchased for the Department of Agricultural Extension.

Associated formal training program

IRRI seeks to promote research capability of national agricultural institutions engaged in rice and rice-based cropping systems research through its resident training and educational programs. It offers various types of research training programs and eight different formal training courses which deal primarily on research/production methodology. These include 1- to 2-yr research training in the form of postdoctoral fellowships, MS and Ph D graduate scholarships, and 3- to 12-mo on-the-job training undertaken with the supervision of senior scientists.

RESEARCH TRAINING PROGRAMS

Postdoctoral fellowships. The research-oriented program is closely associated with IRRI's research programs. Postdoctoral fellowships are available to candidates who wish to pursue a specific research problem relevant to their home country in close collaboration with IRRI senior scientists. The topics they work on are also of mutual interest to IRRI. Thus, they complement staff research with their expertise.

Degree programs. The graduate degree programs are very important to national manpower development not only in developing research competence but also in generating leadership for research management. The graduates of this program often become the backbone of rice and rice-based cropping systems in their countries and serve as important linkages in IRRI's collaboration network.

A majority of the MS and Ph D candidates obtain their degrees from the University of the Philippines. However, arrangements are being made with other agricultural universities to enable students to complete their course requirements in universities in their own countries and then come to IRRI to conduct their thesis research. This arrangement has been formalized with the Post-Graduate Institute of Agriculture: University of Sri Lanka for seven MS students and the Central Luzon State University for two MS students.

In 1982, there were 122 scholars taking courses at UPLB. In addition, 27 scholars were conducting thesis research at IRRI after having completed course requirements in universities abroad — 2 from India, 6 Sri Lanka, 2 United Kingdom, 4 West Germany, 3 the Netherlands, and 10 the United States.

Nondegree programs. Requests for on-the-job training increased in 1982, particularly for 3- to 6-mo training in specific research techniques and procedures. Ideally, nondegree candidates should remain at IRRI long enough to conduct a well-planned experiment, analyze the data, and write a report on it.

Tables 1 and 2 show the distribution of 247 fellows and scholars who participated in research-oriented training programs at IRRI. Of these, 16 postdoctoral fellows, 12 doctoral fellows, 22 MS scholars, and 36 nondegree candidates completed their respective training programs at IRRI.

FORMAL TRAINING COURSES

A total of 237 scholars participated in eight regular training courses offered in 1982. In addition, six scholars attended special courses in farm management and entomology of cropping systems. The 2-wk rice production course was offered six times during the year with 77 participants, excluding participants of the regular formal training courses which integrates this course as a basic component of the respective course syllabus. The 2-wk rice production course is open to new staff members of IRRI, field extension workers, and even farmers.

The names and countries of origin of research fellows and scholars who completed their training in 1982 and the titles of the research they pursued at IRRI follow. An asterisk (*) indicates completion of the MS degree; two asterisks (**), completion of the Ph D degree. Absence of these symbols indicate that the projects are ongoing.

Table 1. Distribution by country of IRRI research fellows and scholars by training programs, 1982.

Country	Research-oriented training				Formal training								Special courses[a]	Total
	Post-doctoral fellows	Ph D	MS	Non-degree	GEU	INSFFER	RPTP	CSTP	IPM	IWMT	AEC	Ag Econ		
Philippines	4	4	10	2	3	3	3	5	7	5	11	3	–	60
Bangladesh	3	5	24	4	2	1	2	7	3	3	2	–	–	56
China	2	–	15	11	11	6	–	–	–	–	2	–	–	47
Sri Lanka	1	1	13	3	4	–	6	6	3	3	1	2	1	44
India	12	3	1	5	5	1	8	–	4	2	2	–	–	43
Thailand	2	4	6	–	3	2	–	8	7	2	4	1	3	42
Indonesia	–	1	6	–	3	2	4	4	5	4	4	2	2	37
Burma	–	–	7	6	4	4	–	3	–	2	–	1	–	27
Vietnam	1	1	–	10	2	2	–	2	6	1	–	–	–	25
Pakistan	1	4	8	–	1	1	–	–	–	–	–	1	–	16
Korea	4	5	1	3	–	–	–	1	–	–	1	–	–	15
Malaysia	–	–	–	–	1	2	–	1	4	1	–	1	–	10
Japan	4	1	1	3	–	–	–	–	–	–	–	–	–	9
Nepal	–	1	8	–	–	–	–	–	–	–	–	–	–	9
West Germany	2	4	–	1	–	–	–	–	–	–	–	–	–	7
U.S.A.	1	1	2	1	–	–	–	–	–	–	–	–	–	5
Egypt	–	–	–	1	2	–	–	–	–	–	1	–	–	4
England	1	–	–	2	–	–	–	–	–	–	–	–	–	3
Netherlands	–	2	1	–	–	–	–	–	–	–	–	–	–	3
Cameroon	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Ecuador	–	–	1	–	–	–	–	–	–	–	1	–	–	2
Senegal	–	–	1	1	–	–	–	–	–	–	–	–	–	2
Taiwan	–	–	1	1	–	–	–	–	–	–	–	–	–	2
Brazil	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Belgium	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Canada	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Colombia	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Cuba	–	–	–	1	–	–	–	–	–	–	–	–	–	1
Ghana	–	–	1	–	–	–	–	–	–	–	–	–	–	1
France	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Italy	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Morocco	–	–	–	1	–	–	–	–	–	–	–	–	–	1
Nigeria	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Panama	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Peru	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Upper Volta	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Venezuela	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Somalia	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Total	40	43	108	56	44	24	23	38	39	23	29	11	6	484

[a]Two trainees in Farm Management (July 5-22, 1982) and 4 trainees in Entomology Cropping System Training Course (Dec 6, 1982-Jan 3, 1983).

Table 2. Distribution, by department, of IRRI research fellows and scholars, 1982.

Department	Post-doctoral fellows	Research fellows			Research scholars		Total
		Ph D	MS	Nondegree	MS	Nondegree	
Plant Breeding	3	6	5	5	11	7	37
Agricultural Economics	3	10	3	2	14	1	33
Agronomy	6	3	3	2	12	0	26
Entomology	3	4	2	1	8	5	23
Agricultural Engineering	2	1	1	2	6	0	12
Plant Pathology	4	1	2	4	7	1	19
Multiple Cropping	1	3	5	1	6	0	16
Plant Physiology	7	4	1	3	1	6	22
Water Management	0	5	–	–	2	0	7
Soil Chemistry	5	2	2	1	2	3	15
Soil Microbiology	4	1	1	1	2	1	10
Statistics	–	–	–	0	2	1	3
IRTP	2	–	–	–	1	–	3
OIS	–	1	–	3	1	2	7
Training Office	–	–	–	1	–	–	1
RPTR	–	–	1	–	–	1	2
Chemistry	–	–	2	–	–	2	4
(Abroad)	–	2	–	–	5	–	7
Total	40	43	28	26	80	30	247

RESEARCH SCHOLARS

Agricultural Economics

Abdul Jabber.* Bangladesh. Rice processing in Bangladesh Rice Research Institute pilot project areas, Joydebpur, Bangladesh.

Masjidin Siregar.* Indonesia. Cost and returns of using hand tractors on rice farms in West Java, Indonesia.

Abdus Shahid.* Bangladesh. Aspect of land tenure affecting rice production in Bangladesh.

Bonita Sinclair Nicolas. USA. Some aspects of mechanization at the farm level.

Alida Res. The Netherlands. Role of women in small farm production systems. Philippines.

Tek Thapa. Nepal. Socio-economic constraints to high rice yield in Kapilvastu District, Nepal.

Agricultural Engineering

Habibur Rahman.* Pakistan. AO-l mixed integer programming model for farm machinery selection and crop planning.

T. T. Sharma. India. Field performance evaluation of the IRRI manual rice transplanter.

Agronomy

Zhi-Hong Cao.* China. Effects of placement methods on recovery of applied N (^{15}N labelled urea) in wetland rice.

Amadou Diop.* Senegal. Weed control in broadcast-seeded wetland rice (*Oryzae sativa* L.)

Indira J. Ekanayake.* Sri Lanka. Inheritance of root characters in rice and their relation to drought resistance.

Fwu-Fenn Hou.* Taiwan. Effects of plant growth regulators and herbicides on sprouting, growth, grain yield, and weed community composition of ratoon rice.

Abdul Mazid.* Bangladesh. Evaluation of placement applicators and use of supplementary sources of N to increase fertilizer efficiency in wetland rice.

German B. Rico.* Venezuela. Improved fertilizer technology and varietal exploitation to soil nitrogen use efficiency by wetland rice.

Valerio C. Tanguilig.* Philippines. Comparative response of rice, corn, and soybean to water stress with emphasis on leaf water potential, transpiration, and nutrient uptake.

Entomology

Arifin Kartohardjono.* Indonesia. Integration of some arthropod predators and varietal resistance for the control of the brown planthopper *Nilaparvata lugens* (Stal.)

Information Services

Sylvia Sunarno. Indonesia. An assessment of the

effectiveness of AARD publications among subject matter specialists in Indonesia.

International Rice Testing Program

Noel Simbe.* Sudan. Genetics of response to daylength in rice.

Multiple Cropping

S. B. Naseem.* Bangladesh. Performance of mungbean (*Vigna radiata* L.) as influenced by different seeding techniques under varying cultural practices.

Sheik Mohammad Sattar.* Bangladesh. Effect of the combination of organic and inorganic manures on growth, yield and nitrogen uptake of rice in Lipa City, Philippines.

Plant Breeding

Chi-Ren Chu.* China. Cytogenetical studies on interracial hybrids among aus, bulu, and upland types.

Yong-Bao Pan.* China. Isozyme analysis of interracial hybrids among aus, bulu, and upland types.

Ju-Bao Yang.* China. Cytoplasmic-genetic male sterility and fertility restoration in rice.

Plant Pathology

Ken-Chang Chuke.* China. Pathological and physiological studies of sheath rot of rice caused by *Sarocladium oryzae* (Sawada) W. Gams and Hawksw.

Bharat Upadhyay.* Nepal. Development of functional differentials and identification of sources of resistance to the rice blast fungus *Pyricularia oryzae*: A case study in Nepal.

Atsushi Yoshimura. Japan. Genetic analysis of resistance to bacterial leaf blight of rice.

Plant Physiology

Kazuhiro Suenaga. Japan. Rice callus culture for increasing salt tolerance.

Soil Chemistry

Huai-Man Chen.* China. Cadmium uptake by wetland rice as affected by addition of cadmium, phosphorus and zinc compounds.

RESEARCH FELLOWS

Agricultural Economics

Abraham Huysman. The Netherlands. Risk management of rainfed rice based cropping systems.

Karl Kaiser. West Germany. Fertilizer efficiency evaluation in Luzon, Philippines.

Frederick Wackernagel. USA. Increasing rice production under a cold weather constraint: The demand for cold tolerant varieties.

Agricultural Engineering

Yong Woon Jeon.** South Korea. Design and development of a multi-purpose dryer using non-conventional sources of energy.

Agronomy

Jae Chul Chun.** South Korea. Autoecology and ecotypic differentiation of *Echinochloa colona* (L.) Link.

P. A. Sarkar. India. Study on competitive ability of different rice (*Oryza sativa* L.) cultivars with weeds under transplanted conditions.

Entomology

Chalerm Sindhusake.** Thailand. Degree of resistance of rice varieties for control of the yellow stem borer *Scirpophaga incertulas* (Walker).

Jung-Tsung Wu. China. Resistance of wild rice to the brown planthopper *Nilaparvata lugens*.

Information Services

Somasekharappa Gowdar. India. Training needs of information services in agricultural research and educational organization in Asia: a 9-country survey.

Irrigation Water Management

Le Ngoc Sen. Vietnam. The influence of water and agronomic management packages on chemical changes in acid sulphate soils and their effects on the growth and yield of rice.

Multiple Cropping

Jorge Jonas.** Panama. Soil productivity assessment on alluvial and plain land systems of the Cagayan Valley, Philippines.

Plant Breeding

Wen-Hsun Chang. China. Components of growth duration in Chinese varieties.

Yung-Wen Chien. China. Studies on the Asian wild taxa on *Oryza*.

Brahiman Bhakta Mathema.** Nepal. Genetic analysis of resistance to whitebacked planthopper *Sogatella furcifera* (Horvath) in some rice varieties.

Abdul Azis Miah.** Bangladesh. Studies on the inheritance of callus induction ability through anther culture and evaluation of dihaploid lines in rice.

Shou-Yun Shi. China. Techniques of seed production in hybrid rice.

Plant Physiology

Chun-Ye He. China. Rice cell suspension culture for increasing salt tolerance.

Neel K. Shrivastava. India. Fraction 1-protein of rice and distant hybrids with rice.

Soil Microbiology

Kazuyuki Inubushi. Japan. Dynamics of biomass-nitrogen in flooded soils.

POSTDOCTORAL FELLOWS

Agronomy

Dalpat C. Bhandari. India. Ecological studies on weeds as affected by hydrology, control measures, and cropping systems.

Sukhdev S. Hundal. India. Soil physical edaphology studies in rice-based cropping systems.

D. Gamini Keerthisinghe. Sri Lanka. The role of non-exchangeable ammonium in wetland rice soils.

Tawachai Na-Nagara. Thailand. Simultaneous diffusion and mass flow of nitrate nitrogen to corn roots.

S. V. R. Shetty. India. Influence of alternate management techniques on weed growth and yields of mungbean planted after rice.

Entomology

Weerawoth Katanyukul. Thailand. The effect of cropping patterns on insect pests and natural enemies.

Multiple Cropping

Md. Zahidul Hoque. Bangladesh. On-farm cropping systems research and development in Asia.

Plant Breeding

V. Sivasubramanian. India. Genetic analysis of resistance to bacterial blight in some rice varieties.

Hak Soo Suh. South Korea. Genetic analysis of resistance of blast in some rice varieties.

Plant Pathology

Marco Badino. Italy. Screening for resistance in rice varieties to the rice blast disease using tissue culture techniques and the rice blast toxin.

Plant Physiology

R. Radhakrishnan. India. Studies on deepwater rice physiology.

Nautsugu Uchida. Japan. RuBP carboxylase activity in rice varieties.

Soil Chemistry

H. U. Neue. West Germany. Organic matter decomposition: (a) turnover of carbon, (2) gaseous products.

Soil Microbiology

Gero Benckiser. West Germany. Microbiological studies of iron toxicity of wetland rice.

Ian Grant. United Kingdom. Algae-grazer relationship of floodwater ecosystem.

Jadish K. Ladha. India. Immunological identification of N_2-fixing bacteria and *Anabaena azollae*.

OTHERS

Agricultural Economics

Madura Swaminathan. India. Study on the credit behavior of farm families in Nueva Ecija.

Chemistry

A. K. Ariyaratne. Sri Lanka. Grain quality and evaluation.

Le Huu Hieu. Vietnam. Quality characteristics of some Vietnamese rice varieties.

Entomology

Rafael Carbonell Meneses. Cuba. General entomology.

Govinda Charan Ghosh. India. Taxonomy and techniques for population studies on planthoppers and leafhoppers.

Prem Chandra Srivastava. India. Taxonomy and techniques for population studies on planthoppers and leafhoppers.

Nguyen Cong Thuat. Vietnam. Screening for resistance to rice insects.

Information Services

W. S. A. D. Jayatilaka. Sri Lanka. Graphic arts.

Razia Sultana. Bangladesh. Graphic arts.

S. Sundaramurthy. Sri Lanka. Media production.
H. R. Talukdar. Bangladesh. Media production.

Multiple Cropping

Vilma Garrity. Philippines. Comparison of the rolling injector planter and existing seeding techniques in establishing mungbean after rice.

Plant Breeding

Ha Quang Lap. Vietnam. Management of rice genetic resources.

Jen-Fan Ming. Taiwan. Breeding for disease and insect resistance.

Mar Mar Myint. Burma. Grain quality analysis of breeding lines.

Soe Myint. Burma. Grain quality analysis of breeding lines.

Khin Nu Wai. Burma. Grain quality analysis of breeding lines.

Long-Pin Yuan. China. Hybrid rice.

Plant Pathology

Ta Minh Soan. Vietnam. Isolation and multiplication of isolates and testing of *Xanthomonas oryzae* and *X. oryzicola*.

Abou Zarif Zeid. Egypt. Observation on blast reaction in nursery and production of spores of *Pyricularia oryzae* and *Helminthosporium oryzae*.

Plant Physiology

Manimekalai Gurunathan. India. Plant cell and tissue culture.

Don Jin Kim. South Korea. Korea-IRRI collaborative project on rice cold tolerance.

Doo Wook Kim. South Korea. Study of anther culture in rice and somatic cell culture of rice seed.

Mai Van Quyen. Vietnam. Effect of seedling ages on aluminum tolerance.

Soil Chemistry

Mantengue Diack. Senegal. Nitrogen supplying power of three acid sulfate soils.

Le Van Tiem. Vietnam. Chemical analysis of acid sulfate soils.

Dinh Van Tinh. Vietnam. Amelioration of an acid sulfate soil from Malinao, Albay.

TRAINING PROGRAM FOR ECONOMICS IN AGRICULTURAL RESEARCH
(1 Feb-31 Mar)

Burma

U Thein Oo, junior research officer, Agriculture Corporation, No. 74, Shwedagon Pagoda, Rangoon

Indonesia

Erwidodo, research assistant, Center for Agro-Economics Research, Department of Agriculture, Jalan Ir. Juanda 20 Bogor

Agus Pakpakan, researcher, Center of Agro-Economic Research, Department of Agriculture, 20 Jalan Ir. H. Juanda, Bogor

Malaysia

Wan Zainun Hj. Wan Ahmad, research officer, Malaysian Agricultural Research and Development Institute, Serdang, Selangor

Pakistan

Muhammad Manzoor Ali, national coordinator (Social Sciences), Cooperative Constraints Research Program, Pakistan Agricultural Research Council, Islamabad

Philippines

Rita Manguiat-Fabro, science research specialist I, Philippine Council for Agriculture and Resources Research Development, Los Baños, Laguna

Editha P. Morata, researcher, Agriculture Division, Zamboanga del Sur Development Project (PADAP), Pagadian City

Virgilio T. Villancio, research assistant, Multiple Cropping Section, Department of Agronomy, University of the Philippines at Los Baños, College, Laguna

Sri Lanka

Athauda Mudiyanselage Jayatilaka, economic assistant, Economics Division, Department of Agriculture, Peradeniya

Punchy Bandaratnayaka Kumburegama, economic assistant, Economics Division, Department of Agriculture, Peradeniya

Thailand

Nida Sainumtip, research assistant, Statistics Section, Planning Division, Department of Agriculture, Bangkok

GENETIC EVALUATION AND UTILIZATION
(8 Feb-28 May)

Bangladesh

Hafiz Uddin Ahmed, scientific officer, Plant Pathology, Bangladesh Rice Research Institute, Joydebpur, Dacca

Sarkar Haran Chandra, scientific officer, Plant Breeding, Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

Aung Yin, deputy farm manager, Lungyaw Farm Kyauk Se

Aye Thein Maung, agricultural inspector, Central Farm, Mandalay Agricultural Corporation

Kyi Tun, junior research officer, Agricultural Research Institute, Yezin, Pyinmana

China

Yi-Yi Chen, assistant fellow, Hubei Academy of Agricultural Sciences, Wuhan

Yu-Hua Lin, assistant fellow, Sichuan Academy of Agricultural Sciences, Chengdu

Bai-Qin Qiu, assistant fellow, Zhejiang Academy of Agricultural Sciences, Rice Research Institute, Zhejiang

Hong-Wen Si, research assistant, The Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, Beijing

Jian-Ming She, assistant fellow, Jiangsu Academy of Agricultural Sciences, Jiangsu

Ji-Rong Tian, assistant fellow, Hunan Academy of Agricultural Sciences, Changsha

Wang Qiang, assistant entomologist, Institute of Plant Protection, Jiangsu Academy of Agricultural Research Sciences, Jiangsu

Tiu-Ru Zheng, assistant fellow, Fujian Academy of Agricultural Sciences, Fuzhou, Fujian

India

Marella Nagaraju, scientist (Breeding), Division of Plant Breeding and Genetics, Central Rice Research Institute, Cuttack (Orissa)

Kasturi Satyanarayana, scientist (Plant Pathology), All India Coordinated Rice Improvement Project, Rajendranagar, Hyderabad-500030, A.P.

Indonesia

Rahmat Suhadi, research assistant, Division of Plant Physiology, Central Research Institute for Food Crops (CRIFC), Bogor

Ade Santika, research assistant, Plant Breeding Department, Central Institute for Food Crops, Bogor

Amril B., plant pathologist, Sukarami Research Institute for Food Crops, Padang

Philippines

Thelma F. Padolina, chemist, Bureau of Plant Industry, Muñoz Rice Research and Training Center, Muñoz, Nueva Ecija

Lucina R. Pondias, horticulturist, Bureau of Plant Industry, Iloilo City

Sri Lanka

B. D. Pathinayake, research officer, Central Rice Breeding Station, Batalagoda

S. W. Abeysekera, research officer, Rice Research Station, Ambalantota

Thailand

Chartchai Sirinupong, agriculturist, Rice Division, Department of Agriculture, Nakhon-si-Thammarat, Rice Experiment Station, Nakhon-si, Thammarat

Boonluck Seetanun, agronomist, Rice Division, Department of Agriculture, Bangkhen, Bangkok

Vietnam

Hoang Van Phan, plant breeder (Research Staff), Genetic and Plant Breeding Department, National Institute of Agricultural Sciences, Hanoi

GENETIC EVALUATION AND UTILIZATION COURSE
(16 Aug-3 Dec)

Brazil

Silvino A. Neto, researcher in Plant Breeding, Pesagro-Rio, Caixa Postal 131, 28100 Campos-RJ

Burma

Tin Myint, inspector (Plant Breeding Section), Rice Division, Agricultural Research Institute, Yezin, Pyinmana

Cameroon

Samuel B. C. Wanki, chief of production and research coordinator of International Rice Testing Program, Upper Nun Valley Development Authority, P.O. Box 25, NDOP, United Republic of Cameroon

China

Hu Fen, research assistant in Meteorology, Agricultural Meteorology, CAAS, P.O. Box 275 (66), Peking

Zhi-Hua Zhu, research assistant in Crop Germplasm, The Institute of Crop Germplasm Resources, CAAS, Beijing

Rong-Jie Zhao, plant pathologist, Institute of Plant Protection, CAAS, Malianwa, Beijing

Egypt

Abdel S. E. Draz, senior research assistant in Plant Breeding, Sakha Agricultural Station, Kafr-El-Sheik, A.R. Egypt

Talaat W. Ghobrial, senior research assistant in Plant Breeding, Sakha Research Station, Kafr-El-Sheik, A.R. Egypt

India

R. Satyanarayana, scientist S-1, Department of Genetics and Plant Breeding, CRRI, Cuttack 753006 (Orissa)

Bhal C. Shukla, junior entomologist, Zonal Agricultural Research Station, College of Agriculture, Raipur 492006 (M.P.)

D. P. Mishra, assistant rice breeder, cum assistant professor, Rajendra Agricultural University, Agricultural Research Institute, Mithapur Patna-800001, Bihar

Malaysia

Faizah Md. Shariff, research assistant in Plant Breeding, Plant Science Branch, MARDI, P.O. Box 2301, G.P.O., Kuala Lumpur

Pakistan

Noor Md. Burdi, assistant rice botanist, Rice Research Institute, Dokri

Philippines

Ana P. Mutya, agronomist, Bicol Experiment Station, San Agustin, Pili, Camarines Sur

Sri Lanka

Maddumage Padmasiri, agronomist, Regional Agricultural Research Station, Bombuwela, Kalutar

D. B. Wickremasinghe, research officer in Soil Chemistry, Central Rice Breeding Station, Batalagoda, Ibbagamuwa

Thailand

Prateep Pintanon, research assistant in Plant Breeding, Sanpatong Rice Experiment Station, Sanpatong, Chiangmai

Upper Volta

Moussa Sie, plant breeder, C.E.R.C.I., P.O. Box 540, Bobo-Dioulasso

Vietnam

Pham Duc Hung, agronomist, Food Crops Research Institute, Gia Loc, Hai Hung

INTERNATIONAL NETWORK ON SOIL FERTILITY AND FERTILIZER EVALUATION FOR RICE
(8 Feb-28 May)

Bangladesh

Md. Shamsur Rahman, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

U Win Naing, junior deputy assistant general manager, Agriculture Corporation, Rangoon

U Aung Than, junior officer, Agriculture Corporation, Extension Headquarters, 72-74 Shwedagon Road, Rangoon

U Myint Thein, junior deputy assistant general manager, Fertilizer Marketing and Distribution Project, Procurement and Distribution, Agriculture Corporation, No. 42, Strand Road, Rangoon

U Thein Win, deputy assistant general manager, Bio-Fertilizer Section (Extension), Agriculture Corporation, Rangoon

China

Yong-Ming Gu, primary researcher, Soils and Fertilizer Research Institute, Shanghai Academy of Agricultural Sciences, Shanghai

Li Li, lecturer, Zhejiang Academy of Agricultural Sciences, Hanzhou

Jia-Kang Li, assistant researcher, Soils and Fertilizer Research Institute, Chinese Academy of Agricultural Sciences, Beijing

Long-Fei Tang, technician, Fujian Academy of Agricultural Sciences, Beijing

Mu-Xiang Zeng, researcher, Soils and Fertilizer Research Institute, Chinese Academy of Agricultural Sciences, Beijing

Zou Jin, assistant professor, Jiangsu Academy of Agricultural Sciences, Nanking

India

Bhanu Prakash Govil, zonal agronomist, IFFCO, Zonal Office, 28 Lowther Road, George Town Allahabad 211002, U.P.

Indonesia

Batim Taslim Gumala, agronomy staff member, Central Research Institute for Food Crops, Merdeka 99, Bogor

Agus Sofyan, assistant researcher, Fertility Division, Center for Soil Research, Jl. Juanda 98, Bogor

Malaysia

Mohd. Ramlan Suhood, agriculture assistant, Yunit Sains Tanah dan Analisa Jabatan Pertanian Negeri, Kuala Trengganu, Trengganu

Amid Bin Takzim, agriculture assistant, Soil and Analytical Services, Agriculture Department, Telok Chengai, Alor Setar Kedah

Pakistan

Shaikh Aijaz Ahmed, agricultural chemist, Rice Research Institute, Dokri

Philippines

Luis C. Abulencia, senior soil technologist, Ministry of Agriculture, Soil Services Division, Butuan City, Agusan del Norte

Celso R. Bersabe, soil technologist II, Bureau of Soils, Taft Avenue, Manila

Jesusa E. Fabrigas, senior soil technologist, Ministry of Agriculture, Soil Services Division, Region 6, Iloilo City

Thailand

Oraphan Rirermsoonthorn, agriculture technician, Nakhonsrithammarat Rice Experiment Station, Nakhonsrithammarat

Walaiporn Uttarapong, agriculture technician, Chainat Rice Experiment Station, Chainat

Vietnam

Nguyen Van Chien, researcher, Institute of Soils and Fertilizer, Hanoi

Phan Thi Xuan, vice head, Department of Chemical Fertilizer, Institute of Soils and Fertilizer, Hanoi

5-MONTH RICE PRODUCTION TRAINING PROGRAM

(5 Apr-27 Aug)

Bangladesh

Md. Khairul Bashar, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Bazlur Rahman, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

India

Kanhu Charan Biswal, agronomist, Department of Agriculture, Koraput, Jeypore 764001, Orissa

Bijoy Kumar Borthakur, rice pathologist, Rice Research Station, Titabor-785630, Assam

Asim Kumar Mitra, senior lecturer, Gram Sevak Training Centre, Chinsurah, Hoogly, West Bengal

Durgan Rangaswamy Iyengar Parthasarathy, deputy director of Agriculture (Agronomy), T&V System, Thanjavur, Tamil Nadu

Saraf Naga Raju, agricultural officer, P.O. Mudegere, Chikmagalur District, Karnataka

Abidur Rohman, entomologist, Rice Research Station, Titabor, Assam

Debendranath Sarma, district level subject matter specialist, Jorhat, Assam

Narendralal Chimanlal Shah, subject matter specialist (paddy), District Panchayat Bhadra, Ahmedabad-Crujarat State

Indonesia

Nurlaila Hasbullah, assistant researcher (Agronomy), Banjarmasin Research Institute for Food Crops, Jl. Mayjen Sutoyo S, No. 1134 A, Banjarmasin

Nurul Aida Akhmad Minggu, assistant researcher (Agronomy), Banjarmasin Research Institute for Food Crops, Jl. Mayjen Sutoyo S, No. 1134 A, Banjarmasin

Jan Alfrits Sorongan, subject matter specialist, Food Crop Extension Service of North Sulawesi Province, Jln. E. Gagola Manado, North Sulawesi

Nano Suharno, chief, Economic Agricultural Section, Agricultural Service Kuningan Regency, Jenderal Sudirman 86, Kuningan, West Java

Philippines

Quirino L. Asuncion, agronomist I, BPI, Ilagan Experiment Station, Ilagan, Isabela

Manuel D. Ching, research assistant, Bureau of Plant Industry, San Andres, Malate, Manila

Leonora B. Nalitan, plant laboratory aide, Bureau of Plant Industry, MES, Bual, Midsayap, North Cotabato

Sri Lanka

Selvarajah Balendra, research assistant, Regional Research Centre, Kilinochchi

Galaboda Ralalage Dharmasena, agriculture instructor, Government Farm, Wariyapola

Palle Gedara Dewayalage Gunatilaka, agriculture instructor, Central Rice Breeding Station, Batalagoda Ibbagamuwa

Higuralawedikkara Archchillaye Pangnadasa, agriculture instructor, Agriculture Office, Monaragala

Jayasingha M.U.W.B. Rambukwella, agriculture instructor, Government Seed Paddy Farm, Polonnaruwa

Kannangara Pathirannahelage, Baratha Sunilchandra, agriculture instructor, Agriculture Office, Kantale, Trincomale District

5-MONTH CROPPING SYSTEMS TRAINING PROGRAM
(27 Sep 1982-18 Feb 1983)

Bangladesh

Muhammad Nurul Alam, scientific officer, Bangladesh Agricultural Research Institute, Joydebpur, Dacca

Ferdaus Azad, extension officer, D.N.D. Irrigation Project, B.W.D.B., P.O. Sarulia, Dacca

Md. Tazirul Islam, extension officer, G. K. Project (Khustia Unit), B.W.D.B., Sreepur, Jessore

Hossain Khan Liaquat, extension officer, G. K. Project, B.W.D.B., Khustia

Muhammad Abdul Quayum, scientific officer, BRRI Regional Station, Sonagazi, Noakhali

Md. Nowsher Ali Sarder, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Jalal Uddin Ahmed, scientific officer, Department of Agronomy, Bangladesh Agricultural University, Mymensingh

Burma

U Aung Kyi, township manager, Agriculture Corporation, Syriam, Rangoon Division

U Myo Wai, township manager, Agriculture Corporation, Bassein (East) Township

U San Yin, township manager, Agriculture Corporation, Tharrawaddy

Indonesia

Surya Lesmana, agricultural officer, Regional Agricultural Office, Sumatra No. 2 Road, Bandung, West Java

Iman Subagiyo, subject matter specialist, Department of Agriculture, Imam Bonjoc 48, Kendari, S. E. Sulawesi

Suherman, staff, Agronomy and Extension/Training, Sub-Project of Cilutung Watershed Management and Development Center, Jln. Rayabarat, TILP 28, Majalengka, West Java

Didi Sumardi, extension officer, Food Crops Agriculture Office, Jln. Jendral Sudirman 86, Kuningan, West Java

Korea

Young Soon Kim, agricultural junior researcher,

Kyeong Buk Office of Rural Development, 200 Dong Ho Dong, Daegu City

Malaysia

Siti Zubaidah Bt. Mohd. Rashid, agricultural officer, Pilot Project Office, Muda Agricultural Development Authority, RPM 8, Jalan Lumba Kuda, Alor Satar, Kedah

Philippines

Aniceto L. Aliman, site leader (Sr. FMT), Farming System Development Project-Eastern Visayas, SRMU Gandara, Samar

Andres B. Diamsay, Jr., soil technologist, Ministry of Agriculture, Soils Services, Nueva Ecija

Jocelyn J. Dicen, research assistant, Multiple Cropping Section, Department of Agronomy, U.P. at Los Baños, College, Laguna

Pelagio P. Lavapie IV, agronomist III — FTS study leader, Bicol Experiment Station, San Agustin, Pili, Camarines Sur

Thelma M. Lambio, research assistant (agronomist), Dr. Manuel L. Roxas Memorial Experiment Station, BPI, Marauay, Lipa City

Somalia

Nur Hagi Dere H., agronomic research officer, C.A.R.S., Algoi, Somalia

Sri Lanka

Veluppillai Gunasingham, agricultural experimental officer, Regional Research Center, Department of Agriculture, Kilinochchi

Welipitiya Gurunanselage Dayarathna, subject matter officer, District Agricultural Office, Puttalam, N.W.P.

Nihal Karalliyadde, farm manager/agricultural instructor, District Agriculture Training Centre, Galpalama, Kandapola

Kasturi Arachchige Mettananda, research officer, Agriculture Research Station, Mahailluppallama

Murugesapillai-Namasivayam, subject matter officer, District Agricultural Office, Amparai

Chandrawansa Nillegoda, agricultural instructor/farm manager, Agricultural Farm, P.O. Box 16, Gannoruwa, Peradeniya

Thailand

Vichien Bumroongsri, entomologist, Department of Agriculture, Bangkhen, Bangkok

Chuancheun Diowwilai, agronomist, Farming Systems Research Institute, Pochakorn Building, Department of Agriculture, Bangkhen, Bangkok

Cherdsuk Pavanavichian, subject matter specialist (rice), Department of Agricultural Extension, Bangkhen, Bangkok

Rirngjitr Promsatit, subject matter specialist, Provincial Agricultural Extension Office, Department of Agricultural Extension, Cholburi Province

Sawaeng Rimpranam, subject matter specialist, Nakornratsima Province, Agricultural Extension Office, Nakornratsima Province

Julmanee Susana, subject matter specialist, Provincial Agricultural Extension Office, Muaeng District, Ubolratchathanee Province

Pakorn U-Thaiphun, agronomist, Farming Systems Research Institute, Department of Agriculture, Bangkhen, Bangkok

Phat Vibooncharoenphol, agronomist, Farming Systems Research Institute, Department of Agriculture, Bangkok

Vietnam

Mai Van Thiet, agronomist, The National Insitute of Agricultural Sciences, Thanhtri, Hanoi

Nguyen Trong Thinh, chief, Research Group, The National Institute of Agricultural Sciences, Thanhtri, Hanoi

INTEGRATED PEST MANAGEMENT COURSE
(6 Sep-17 Dec)

Bangladesh

Md. Shamsul Islam Akanda, scientific officer, Plant Pathology Division, Bangladesh Rice Research Institute, Joydebpur, Dacca

Nazrul Islam, assistant entomologist, Directorate of Plant Protection, Ministry of Agriculture, Dacca

Kaiser Khan, technical assistant, Directorate of Plant Protection, Ministry of Agriculture, Dacca

India

Prasanna Kumar Das, biological control officer,

Central Rice Research Institute, Cuttack

Shankar Nath Shukla, scientist, Division of Plant Pathology, Central Rice Research Institute, Cuttack

Anil Kumar Singh, senior scientist, Department of Entomology, Rajendra Agricultural University, Bihar, Pusa, Samastipur

Atin Ghosh, junior virologist, All India Coordinated Rice Improvement Project, Rajendranagar, Hyderabad

Indonesia

Ismail Abumas'ud, subject matter specialist, Perumahan Pemda 24/B, Padang Harapan, Bengkulu

Wijaya Karyadhara Sanusi, chief, Production Section, Agricultural Extension Service, Kabupaten Kuningan, Jawabarat

Ir Mi'un, subject matter specialist, Jalan Jenderal Sudirman, Sungai Penuh

Sudradjat, Staff of Food Crop Protection Subdivision, Food Crop Extension Service, West Java Province

Soekirno, Staff of Field Pest Control Division, Directorate of Food Crop Protection, Tanaman Pangan, Jl. Ragunan, Pasarminggu, Jakarta, Selatan

Malaysia

Mohd. Yusuf A. Rahman, agricultural assistant, National Extension Project, Department of Agriculture, Semenanjung

Mohammad bin Mohd. Salleh, research officer, MARDI, Bumbong Lima, Kepala Batas, Seberang, Perai

Supki bin Hj. Ahmad, Crop Protection Branch, MARDI, P.O. Box 202, Serdang

Mazlan Saadon, Crop Protection Branch, Department of Agriculture, Jalan Gallagher, Kuala Lumpur

Philippines

Candelario Quicoy, multiple cropping field supervisor, Ministry of Agriculture, Zamboanga Del Sur Development Project, P.O. Box 01, Pagadian City, Zamboanga Del Sur

Vicente Garnica, Jr., entomologist, Multiple Cropping Project, Betinan Research Station, San Miguel, Pagadian City

Agapito de la Paz, supervising plant entomologist, Crop Protection Division, Bureau of Plant Industry, 192 San Andres, Malate, Manila

Reynaldo B. Salamat, plant entomologist II, Regional Crop Protection Center, Balinsasayao, Abuyog, Leyte

Rafael Cabalquinto, OIC, Regional Crop Protection Center, Region 7, Bureau of Plant Industry, Mandaue City

Paulino Matamis, plant pest control technologist, Bureau of Plant Industry, Ilagan, Isabela

Aurora Santiago, integrated pest control regional project leader, Ministry of Agriculture, Region No. 3, San Fernando, Pampanga

Sri Lanka

P. M. Wijeratne Banda, agricultural research officer, Agricultural Research Station, Maha Illuppallama

Dharmawansa Alonar Mudali Maheepala, subject matter officer, Plant Protection, Department of Agriculture, Peradeniya

Demata Pitiye Ralalage Nimal Edirisinghe, subject matter officer, Plant Protection, Department of Agriculture, Peradeniya

Thailand

Charn Mongkon, plant pathologist, Rice Diseases Branch, Plant Pathology and Microbiology Division, Bangkhen, Bangkok 10900

Tawee Sangtong, weed scientist, Weed Science Branch, Technical Division, Department of Agriculture, Bangkhen, Bangkok

Suniyon Taprab, agricultural technician, Rice Division, Department of Agriculture, Bangkhen, Bangkok

Sermsakdi Hongnark, zoologist, Agricultural Zoology Branch, Entomology and Zoology Division, Department of Agriculture, Bangkhen, Bangkok 9

Nipha Chansrisommai, entomologist, Insect Pest and Rice Branch, Entomology and Zoology Division, Department of Agricultural Extension, Bangkhen, Bangkok 10900

Prasit Sornthum, entomologist, Plant Protection

Service Division, Department of Agricultural Extension, Bangkhen, Bangkok 10900

Manit Ruacha, regional plant protection specialist, Central Regional Agricultural Extension Office, Amphur Muang, Chainat 17000

Vietnam

Dao Xuan Cuong, pest control officer, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

Duong Van Thieu, pest control officer, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

Pham Ti Nhat, pest control officer, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

Bui Van Dam, plant quarantine inspector, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

Luong Thi Xuan Phuong, surveillance diagnostic and forecasting officer, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

Dao Trong Anh, pest control officer, Plant Protection Department, Ministry of Agriculture, 189b Tay son, Dong da, Hanoi

IRRIGATION WATER MANAGEMFNT TRAINING
(26 Jul-3 Sep)

Bangladesh

Shah Ahmed Ali Khan, deputy chief agronomist, Bangladesh Water Development Board, G. K. Colony, Kushtia

Abdus Sattar, executive engineer, Sailkupa Water Development Division, Sailkupa, Jessore

Md. Abdul Wazed, executive engineer, Chuadanga Water Development Division, G. K. Project, Chuadanga, Kushtia

Burma

U Ko Gyi, executive engineer, Ministry of Agriculture and Forest, Irrigation Department, 19/27 Strand Road, Rangoon

U Aung Than, executive engineer, Ministry of Agriculture and Forest, Irrigation Department, 19/27 Strand Road, Rangoon

India

Tapan Dutta, agronomist (irrigation), Department of Agronomy, Assam Agricultural University, Jorhat, 785013, Assam

Narayan Sahoo, scientist - 1 (Water and Soil Engineering), Engineering Division, CRRI, Cuttack 6, Pin 753006, Orissa

Indonesia

Darman T. Z., subject matter specialist, Dinas Pertanian Tanaman Pangan tk 1. Sumatra, Selatan, Palembang

Sugeng Susetya Partoutomo, subject matter specialist (agronomist), Dinas Pertanian Tanaman Pangan Propinsi, South of Kalimantan, Banjarbaru

Nono Sudiyono, operation and maintenance engineer, Irrigation Design Unit-Resources Division, Dinas Pekerjaan Umum Propinsi Daerah Tingkat 1, Bagina Pengairan, Jalan Indra 901, Bengkulu

Soedjarwo, operation and maintenance deputy, Kali Progo Irrigation Project, Jl. Solo, Km. 6, Yogya

Malaysia

Chia Wei Seng, executive engineer, Drainage and Irrigation Department, Bahagian Kedua, Sri Aman, Sarawak

Philippines

Jesusimo S. Mariano, hydrology engineer, NIA-UPRIIS, District 1, Central Luzon State University, Muñoz, Nueva Ecija

Olympio B. Penetrante, Jr., officer-in-charge, Zone 1, PRIS Area, NIA-UPRIIS, District 11, Talavera, Nueva Ecija

Salvacion Samaniego, soil technologist 1, NIA-LCPIS, Libmanan, Camarines Sur

Robert C. Suguitan, supervising engineer, NIA-UPRIIS, Engineering and Operations Division, Cabanatuan City

Felizardo Tabo, irrigation engineer, NIA-LCPIS, Libmanan, Camarines Sur

Sri Lanka

Madurapperuma Achchillage Gunawardena, chief field research investigator, Agrarian Research

and Training Institute, P.O. Box 1522, 114 Wijerama Mawatha, Colombo-7

Muttucumaru-Sivapatham, agricultural extension officer, Soil Conservation Division, Royal Botanical Gardens, Peradeniya

Warnakulasuriya Don Leonard Stanley, research officer (water management), Department of Agriculture, Peradeniya

Thailand

Jesda Kaewkulaya, lecturer and head, Department of Irrigation Engineering, Faculty of Engineering, Kasetsart University, Kamphaeng Saen Campus, Nakornpathom

Md. Enayet Ullah, research associate, Asian Institute of Technology, Bangkok, P.O. Box 2754

Vietnam

Nguyen Duy Tinh, scientist, National Institute of Agricultural Sciences, Hanoi

2-WEEK AGRICULTURAL ENGINEERING COURSE
(7-18 Jun)

India

Karunanithi Rajamanickam, associate professor, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore 641003

Manian Rangasamy, associate professor, Department of Farm Machinery, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore 641003

Indonesia

Ahmad Denny D. Suan, c/o Mechanization Section, Agriculture Extension Service, South Kalimantan

Said Zaidir, staff, Directorate of Food Crops, Komplex Wisma Tani No. 9, RT 0012/01 Ragunan, Jakarta

Latin America

Marcelo Fernando Espinosa, vice head, Mechanical Engineering and Machine Design, Escuela Superior Politecnica del Litoral (ESPOL), P.O. Box 5863, Guayaquil, Ecuador

Philippines

Joseph H. Lopez, senior agricultural engineer, AMTEC, Los Baños, Laguna

Carlos S. Macabenta, agronomist I, Bureau of Plant Industry, Gandara Seed Farms, Sapinit, San Jorge, Samar

Ferdinand Z. Caylao, project development analyst III, Small Business Advisory Center, Ministry of Trade and Industry, San Fernando, Pampanga

Rolando Jumento, project development analyst II, Small Business Advisory Center, Ministry of Trade and Industry, Manila

Huberto W. Paderanga, project development analyst I, Small Business Advisory Center, Region IV, Ministry of Trade and Industry, Manila

Sri Lanka

Ramanayake Pathirannahelage Mahindapala, deputy project manager (agricultural officer), Farm Mechanization Training Centre, Department of Agriculture, Anuradhapura

Thailand

Charoon Komcomphunt, assistant chief, Workshop and Service Section, Agricultural Engineering Division, Department of Agriculture, Ministry of Agriculture and Cooperative, Bangkok

Boonsom Suwanaruk, agricultural engineer P.C. 5, Agricultural Engineering Division, Department of Agriculture, Bangkok

Cherawat Munkit, agricultural engineer, Farm Mechanization, Department of Agricultural Extension, Bangkhen, Bangkok

ENTOMOLOGY CROPPING SYSTEMS NETWORK
(6 Dec 1982-3 Jan 1983)

Indonesia

I. Wayan Laba, research staff, Bogor Research Institute for Food Crops, Jl. Kapten Muslihat 9, Bogor

Tata Rasta Omoy, researcher (entomology), Lembang Research Institute for Horticulture, Lembang

Thailand

Manochai Keerati-Kasikorn, lecturer in entomology, Department of Entomology and Plant Pathology, Faculty of Agriculture, Khon Kaen University, Khon Kaen

Thamnoon Bhudhasamai, entomologist, Rice Insect Branch, Entomology and Zoology Division, Department of Agriculture, Bangkok 10900

2-WEEK AGRICULTURAL ENGINEERING COURSE
(6-17 Dec)

Bangladesh

Md. Humayun Khander Kabir, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Syedul Islam, scientific officer, Agricultural Engineering Division, Bangladesh Rice Research Institute, Joydebpur, Dacca

China

Xiaolun Shi, assistant engineer, Chinese Academy of Agricultural Mechanization Sciences, Beijing

Yao Jun, assistant engineer, Chinese Academy of Agricultural Mechanization Sciences, Beijing

Egypt

Moustafa Ahmed Shehata, white rice laboratory specialist, Rice Marketing Co., Rice Technology Training Center, Post Bag Hagar El Nawatia, Alexandria

Indonesia

Made Dasnaya, staff, Sub Directorate of Farm Machineries Development, Directorate of Food Crops, Jakarta

Mappa Effendy Hamdani, chief, Mechanization Section, Food Crops Agricultural Extension Service, South Sulawesi

Korea

Hyum Young Suck, agricultural extension specialist, Weonseong County Rural Guidance Office, Weonju City, Kangweon Province

Philippines

Herminia L. Comia, project specialist, Farm System Development Corporation, Rudgen Building, 17 Shaw Blvd., Pasig, Metro Manila

Farlie E. Daguro, engineer, Bureau of Plant Industry, Malate, Manila

Ruben V. Perez, operations supervisor, Kaisa Fabrication Machine Shop, Apokon, Tagum, Davao

Pedro A. Malaluan, research aide, Agricultural Engineering Division, Bureau of Plant Industry, Malate, Manila

Ildefonso G. Ventura, junior mechanical engineer, Bureau of Plant Industry, San Andres Street, Malate, Manila

Thailand

Setsamut Tansakun, assistant manager, Setthakitkarnchang Manufacturer, 471 Rob Muang Road, Amphoe Muang, Korat

FARM MANAGER'S COURSE
(5-22 Jul)

Sri Lanka

Senanayaka Pathirannahelage Dharmawardana, agricultural instructor/farm manager, Agricultural Research Station, Mahailluppallama

Thailand

Wittaya Pliandecha, technician, Bangkhen Rice Experiment Station, Bangkhen, Bangkok 9

International activities

COLLABORATIVE RESEARCH

The working relationship between many national programs and IRRI has evolved from one of technical assistance to genuine collaboration. The number of national programs with which IRRI holds formal annual meetings to plan research and training collaboration has increased substantially, particularly in the last few years. Since the first formal collaborative meeting between Korean and IRRI scientists and administrators in 1977, similar discussions on research and training collaboration have been held with seven national programs — China, Cuba, India, Indonesia, Japan, Korea, and Vietnam. In each case, the collaborative effort has been focused on a limited number of research areas. For example, the collaborative effort with Korea is focused on rice blast disease and tolerance for low temperature. The current collaborative effort with Indonesian scientists emphasizes upland rice, hybrid rice, brown planthopper, rice tungro virus, and irrigation water management. Discussions pertaining to research and training collaboration are also held with scientists from Bangladesh, Pakistan, Sri Lanka, and Thailand. In response to specific needs and problems, IRRI and national program scientists collaborate in areas other than those in which they had formally agreed to do collaborative research.

COOPERATIVE COUNTRY PROJECTS

In 1982, IRRI had cooperative country projects in Indonesia, Bangladesh, Thailand, the Philippines, Burma, and Egypt.

Indonesia. The Agency for Agricultural Research and Development (AARD) has a corps of rice scientists who have assumed leadership for and are implementing a well-planned and coordinated national rice research program. From a team of six scientists 2 years ago, IRRI now has only two scientists in residence in Indonesia. This in no way implies any diminution of the working relationship between AARD and IRRI scientists; in fact, the relationship has become collaborative. Every year for the last 3 years, Indonesian and IRRI scientists and administrators have met to discuss and develop work plans for research collaboration on problem areas of mutual interest.

A cropping systems specialist continues to help in planning and implementing a strong multidisciplinary nationwide coordinated research and training program on rice-based cropping systems.

An agricultural engineer is assigned in Indonesia to provide assistance to mechanization under way in rural areas of Indonesia. His efforts include contacting manufacturers to assist them with the manufacture of IRRI-type machines and equipment for rice production. Assistance is also given in the redesign or the modification of machines for rice production. Field days are held to illustrate what could be accomplished by utilizing various mechanization sources.

Bangladesh. The cooperative research and training program with the Bangladesh Rice Research Institute (IRRI) continues to be funded by a consortium of donors — the Ford Foundation and the governments of Australia, Canada, and the United States. A very significant achievement of the cooperative project is the training, up to the Ph D level, of young rice scientists, many of whom lead multidisciplinary task forces assigned to investigate priority problem areas affecting rice production.

Four IRRI scientists — a research systems specialist and IRRI representative, a rice production specialist, a rice breeder (deepwater rice), and an agricultural economist — are in Bangladesh.

In fulfilling its overall objective, the cooperative project continues to assist in the development of BRRI until all parties concerned reach a consensus regarding a change in the working relationship between BRRI and IRRI.

Burma. Three IRRI scientists — a rice breeder, a cropping systems agronomist, and an agricultural engineer — are assigned to the Burma-IRRI cooperative rice research and training program. The project is based at the Agricultural Research Institute (ARI) in Yezin, with test sites in the major rice-growing areas of the country. Burmese scientists who have undergone short-term and graduate

degree training have returned to Burma and have assumed leadership or greater involvement, or both, in ARI's rice research programs.

Thailand. Thailand is one of the sites for the small-farm machinery industrial extension project, the objective of which is to conduct studies to determine the potential of IRRI-designed machines, to determine their performance in selected sites, and to provide technical assistance to manufacturers. It is also the base for IRRI's research on deepwater rice, conducted collaboratively with the Ministry of Agriculture of Thailand. An agronomist and an entomologist supported from IRRI's core funds worked at the Huntra Research Station with Thai deepwater research scientists.

Philippines. An IRRI scientist is assigned to a cooperative project with the Ministry of Agriculture (MA) with emphasis on technology transfer. The mechanism for facilitating the transfer of production technology that has been initiated is a workshop involving MA officials (regional directors, research managers, and research coordinators) and IRRI scientists and administrators. The workshop gives the MA officials and regional staff the opportunity to identify and discuss the most pressing production problems in their regions to be "matched" with the promising technology IRRI scientists believe should be evaluated in the area. An agricultural engineer also works with MA personnel in an industrial extension project similar to that in Thailand.

Egypt. The primary objective of the cooperative project is to increase the rice research and training capabilities of the Arab Republic of Egypt. IRRI participates in the project with the University of California, Davis; the University of Arkansas; and the Egyptian Ministry of Agriculture. IRRI's responsibilities are in the research component of the project, specifically the rice breeding program, the applied research program, and the mechanization program.

To date, the most significant achievement of the project is the adoption of the Mabrouk 4 (meaning "congratulations for producing 4 t of rice per feddan") rice production program. The package of technology for the program was the result of applied research trials that were subsequently evaluated in pilot production programs.

REGIONAL PROGRAMS

Liaison scientists stationed at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, and at the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia, link IRRI with Africa and Latin America. They visit national rice programs within their respective regions to assist in identifying problems limiting rice research. They assist IRRI in organizing and coordinating workshops such as the Upland Rice Workshop held at Bouake, Ivory Coast, in October 1982, and monitoring tours such as the August tour of production systems, commercial constraints, and research activities in Jamaica, Haiti, and Dominican Republic. In addition, they work as members of the rice programs of IITA and CIAT and assist those institutes and IRRI in relations with the national governments in Africa and Latin America.

INTERNATIONAL RESEARCH NETWORKS

IRRI continues to serve as a catalyst in the planning and implementation of four research networks (Table 1).

Table 1. International networks coordinated by IRRI, 1982.

Network	Participating countries	Region	Cooperating scientists
International Rice Testing Program (IRTP)	57	Worldwide	765
Cropping Systems Network	10	Asia	[a]
International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)	15	Asia, Africa	51
Agricultural Machinery Network	8	Asia, Latin America	19

[a]Not available.

Table 2. IRRI-sponsored or cosponsored workshops and conferences, 1982.

Event	Date	Location	Participants
ORD (Korea)-IRRI joint planning session on blast and cold tolerance	25-29 Jan	IRRI	20
IRRI-MAFF (Japan) planning workshop	1-2 Mar	IRRI	23
Workshop on varietal improvement of upland crops for intensive cropping	15-17 Apr	IRRI	50
International rice research conference	19-24 Apr	IRRI	147
International workshop and training course on nitrogen management	26 Apr-3 May	Fuzhou, China	56
Symposium on organic matter and rice	27 Sep-1 Oct	IRRI	80
Upland rice conference	10-15 Oct	Ivory Coast	120
Chemrawn II (International conference on chemistry and world food supplies: the new frontiers)	6-9 Dec	Manila	588
Post CHEMRAWN workshops			
IDRC meeting	10-11 Dec	IRRI	10
ICDUP meeting (Board meeting of the International Council for Development of Underutilized Plants)	10-11 Dec	IRRI	8
BOSTID meeting (NAS Board on Science and Technology for International Development)	12-15 Dec	IRRI	52
ACSTD meeting (Integrated Application of Emerging and Traditional Technologies for Development)	13-15 Dec	IRRI	23

IRRI CONFERENCES

A number of conferences and workshops held at IRRI headquarters and elsewhere in 1982 attracted more than 1,300 participants (Table 2). Nearly 600 participated in the IRRI-cosponsored second major conference on Chemistry and World Food Supplies (CHEMRAWN II) in Manila.

Information resources, experimental farm, and service laboratories

LIBRARY AND DOCUMENTATION CENTER

Bibliographies. The 1981 Supplement to the *International Bibliography of Rice Research* was published in 1982. It is the second computerized supplement jointly produced by the Library and the Statistics Department. It contains 6,759 references to scientific rice literature, most of which appeared in journals in 1981. 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 175 rice literature translations, mostly from Chinese to English. It has an author index and a keyword index. Bibliography supplements 1976-1981 have already been fed into the computer system. Computer retrieval of rice information will be instituted soon.

The 1982 supplement to *Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute* lists 91 titles, bringing the overall collection of theses and dissertations to 1,243.

All new bibliographies were sent to agricultural libraries and documentation centers of the rice-producing regions. Most citations included are available at IRRI.

References and circulations. Within IRRI, the number of books and journals and other library materials borrowed during 1982 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 were also received. Assistance in library organization and management and in the selection and acquisition of agricultural materials was also sought. Requests for short specific-subject bibliographies, mostly from Bangladesh, India, Thailand, and Malaysia, increased notably.

Library holdings. The additional 3,037 monographs (books, pamphlets, and reprints) increased the overall monographic collection to 62,422. Some 144 serial titles were added through subscriptions, exchanges, and donations. Maps, translations, and microfilms were also added.

Other library activities. To keep the scientists informed of the latest publications on rice, tables of contents of newly received journals continued to be routed within IRRI and to the Bangladesh Rice Research Institute; the Central Research Institute for Food Crops, Indonesia; and the West African Rice Development Association, Liberia.

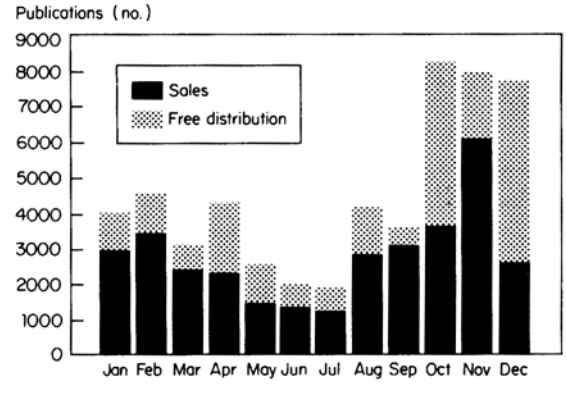
The Library continued to purchase books for IRRI research scholars and other training participants.

INFORMATION SERVICES DEPARTMENT

The Information Services Department distributed about 54,000 copies of major publications during 1982. About 25% were given free, mostly to key Third World libraries, and the remainder sold (Fig. 1).

Major publications. Seventeen publications released in 1982 were:

- *Rice tissue culture planning conference*
- *Evolution of the gene rotation concept for rice blast control*
- *Drought resistance in crops with emphasis on rice*



1. Information Services Department publication distribution. IRRI 1982.

- *Proceedings of the 1981 international deepwater rice workshop*
- *Landless workers and rice farmers: peasant subclasses under agrarian reform in two Philippine villages*
- *Report of a workshop on cropping systems research in Asia*
- *Evaluating technology for new farming systems: Case studies from Philippine rice farms*
- *Rice research in the 1980s*
- *Rice research strategies for the future*
- *A global experiment in agricultural development*
- *An adventure in applied research: A history of the International Rice Research Institute*
- *Report of a workshop on the role of anthropologists and other social scientists in interdisciplinary teams developing improved food production technology*
- *Japan's role in tropical rice research*
- *A plan for IRRI's third decade*
- *Research highlights for 1981*
- *World food day, 16 October 1982*
- *Integrated application of emerging and traditional technologies for development*

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 1981* were published. Fifteen issues of the *IRRI Research Paper Series* were published:

No. 71 The development and diffusion of rice varieties in Indonesia

No. 72 Levels of resistance of rice varieties to biotypes of the BPH, *Nilaparvata lugens*, in South and Southeast Asia

No. 73 Growing season analyses for rainfed wetland fields

No. 74 San Bartolome: beyond the green revolution

No. 75 Pathotypes of *Xanthomonas campestris* pv. *oryzae* in Asia

No. 76 Focusing field research on future constraints to rice production

No. 77 An international survey of methods used for evaluation of cooking and eating quality of milled rice

No. 78 Research on algae, blue-green algae, and phototrophic nitrogen fixation at the International Rice Research Institute (1961-81), summarization, problems, and prospects

No. 79 Seed-derived callus culture for selecting salt-tolerant rices

No. 80 Economic limitations to increasing shallow rainfed rice productivity in Bicol, Philippines

No. 81 Irrigation system management research and selected methodological issues

No. 82 Interdisciplinary challenges and opportunities in international agricultural research

No. 83 Comparative analysis of cropping systems: an exploratory study of 14 rainfed sites in the Philippines

No. 84 Rapid generation advance of rice at IRRI

No. 85 Physicochemical characterization of iron-toxic soils in some Asian countries

Book exhibitions. IRRI and the China National Publications Import and Export Corporation cosponsored the first International Agricultural Research Center (IARC) Book Exhibition in China in May 1982. About 500 books, periodicals, slide sets, and films published by the IARCs were displayed at 10-d exhibitions in Beijing, Ch'angsha, and Sian. After the exhibition, the educational materials were rotated in New Book Show Rooms across China.

IRRI exhibited 220 major books, audiotutorial modules, and periodicals at the 1982 Frankfurt Book Fair.

Copublication. *A farmer's primer on growing rice* is being copublished in 24 languages. The revision of *Field problems of tropical rice* is being translated, in advance of the release of the English edition, into 10 languages (the original *Field problems* was copublished in 12 languages).

Audiotutorial modules. The 61-module audiotutorial series (sets of color slides, cassette tapes, booklets on rice training and research) was completed in 1982, and work was started on a 36-module series on rice-based cropping systems.

EXPERIMENTAL FARM

The new wetland area near the end of block 200 was fully developed and a third rice crop harvested. The area is temporarily being used in the seed

production program. During development, there was some soil movement. As soon as the plant growth shows uniformity, the whole area will be assigned to the Plant Breeding Department.

Three plots for deepwater rice experiments were constructed in block C and are now in operation. The area selected was the unused irrigation water reservoir in C24-C26.

In the dryland area, the turnover of more unplanted fields to the Experimental Farm by various departments resulted in more income for IRRI, better weed control, and improved field appearance.

A new deepwell for delivering irrigation water low in boron content was constructed in block F. It will also help augment the irrigation water supply for blocks F, G, J, K, and L. Extra water will be delivered to the college reservoirs in blocks C and D to supply water to some experimental plots in blocks B, C, D, and E.

The department offered a 3-wk course in experiment station operation and management to two trainees from Thailand and Sri Lanka.

A concrete bridge across the Maitim River was constructed to connect the old and new wetland rice farms.

About 203.8 ha were prepared and planted on the wetland farm during the 1982 WS and DS. The area was 42.7 ha larger than that planted in the 1981 growing season.

About 119 ha were plowed, harrowed, or rotovated on the dryland farm — about 20 ha more than in 1981. Sixteen hectares, compared with 5 ha in 1981, were prepared and planted by the Experimental Farm. As in the previous years, the Multiple Cropping Department planted the largest area followed by the Agronomy, Rice Production Training and Research, Experimental Farm, Plant Breeding, Entomology, and Plant Pathology Departments, and the International Rice Testing Program.

About 20.2 ha were planted for seed multiplication of IR36, IR42, IR56, IR841, IR342-299, and IR9751-71-3-2 during the WS, and of IR54, IR841, and IR13429-109-2-2-1 during the DS. About 71.5 t of rice seed and 24.9 t of rice for milling were produced on the IRRI farm.

Because of the larger area planted, about 166 t of fertilizer valued at $36,304 were used on the experimental farm. The amount was 10 t more than that used in 1981. The price of fertilizer increased as follows: ammonium sulfate by 20%, urea by 22.8%, solophos by 50.9%, 14-14-14 by 13.3%, and muriate of potash by 1.8%. Ammonium sulfate accounted for 56.1% of the total consumption followed by urea, 16.3%; solophos, 13.3%; 14-14-14, 10.9%; and muriate of potash, 3.4%.

The insecticide and tenac sticker expenditure was $60,224.25, less than in 1981. There were no serious pest outbreaks. A pest monitoring group determined when to spray for insect control to greatly reduce chemical use.

About $15,635 was spent on weed control. Greater use of the mower along roadways and ditches resulted in considerable savings. Contract labor cost $238,857.

The 1982 farm income of $29,679 was derived from the sale of rice for seed, rice for milling, milled rice, green maize, dried flint maize, sorghum, and rice bran.

Rats killed totaled 42,817. Sustained baiting was maintained using warfarin, tomorin, ratoxin, liphadione, ratak, and talon. Dogs were used at times to detect the presence of rats in burrows, which saved time in digging and flame-throwing operations. Rat fences were continuously maintained; the use of electric barriers was continued.

ANALYTICAL SERVICE LABORATORIES

Chemical Analysis Laboratory. There were 139,247 analyses made on 65,030 soil, plant, and solution samples. Table 1 shows the 6-yr trend.

Mass Spectrometer Laboratory. The laboratory analyzed the N^{15}-N^{14} ratio in 4,191 soil and plant samples. Table 2 shows the 2-yr breakdown.

Radioisotope Laboratory. A total of 3,050 samples containing C^{14} were accepted for radioactivity measurements (Table 3).

PESTICIDE RESIDUE LABORATORY

Four hundred and thirty-two soil samples were analyzed for butachlor for the Agronomy Department and 64 rice leaf samples for MIPC for the Entomology Department. The laboratory also analyzed 25 samples for sugars submitted by the Plant Pathology Department.

Table 1. Output of the Chemical Analysis Laboratory, 1977-1982.

Year	Samples (no.)				Analyses (no.)			
	Soil	Plant	Water	Total	Soil	Plant	Water	Total
1977	4 542	24 865	–	29 407	16 169	42 604	–	58 773
1978	7 304	28 242	–	35 546	28 642	46 156	–	74 798
1979	9 312	23 297	2 024	34 633	46 873	34 838	4 048	85 759
1980	5 514	35 315	23 418	64 247	27 957	44 131	25 970	98 058
1981	3 558	41 207	17 402	62 167	21 536	79 098	44 494	145 128
1982	2 702	44 385	17 943	65 030	20 453	84 316	34 478	139 247

Table 2. Number of samples run in the Mass Spectrometer Laboratory. IRRI, 1981-82.

Year	Samples (no.)			
	Soil	Plant	Floodwater	Total
1981	918	1378	352	2648
1982	4067	124	–	4191

Table 3. Number of samples analyzed in the Radioisotope Laboratory. IRRI, 1982.

	Samples (no.)		
	Liquid scintillation counter	Vibrating reed electrometer	Total
Soil	454	–	454
Plant	123	–	123
Water	1259	629	1888
Gases	390	195	585
Total	2226	824	3050

The Chemistry Department submitted 60 samples for quantitative analysis of aldononitrile derivatives of neutral sugars of bran, germ, and milled-rice cell walls, and 253 samples for analysis of insect resistance factors in the rice plant. The Entomology Department submitted 136 extracts from pheromone traps in the field for synthetic pheromone persistence studies.

PHYTOTRON

Thirty-eight research projects of the Agricultural Engineering, Agronomy, Entomology, Plant Breeding, Plant Pathology, Plant Physiology, and Soil Microbiology Departments used the Phytotron facilities in 1982. The glasshouse room had the highest occupancy (94%), followed by the artificially lighted cabinet (93%). Occupancy of other environmental rooms ranged from 46% to 83%. About 50% of the space in the cold room was used for the storage of RGA bulk rice materials in 1982.

Maintenance service was performed on the air-conditioning system and its supporting equipment of all glasshouse rooms and growth cabinets in November. The controllers, recorders, and sensors were calibrated and tested for proper operation. All facilities were given a dry run to ensure standard performance.

Publications and seminars

PUBLICATIONS

Administration

Greenland, D. J. 1982. Chemistry and the soil environment — surfaces and sorption processes. Pages 99-110 *in* Frontiers of chemistry. Pergamom Press, Oxford.

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Swaminathan, M. S. 1982. Improving the productivity of rice-based farming systems: the challenges ahead. Pages 1-15 *in* International Rice Research Institute. Rice research in the 1980s. Los Baños, Laguna, Philippines.

Swaminathan, M. S. 1982. Science and integrated rural development. Concept Publishing House, New Delhi. 354 p.

Agricultural Economics

Flinn, J. C., and G. L. Denning. 1982. Interdisciplinary challenges and opportunities in international agricultural research. IRRI Res. Pap. Ser. 82. 19 p.

Flinn, J. C., S. K. Jayasuriya, and E. Labadan. 1982. Evaluating cropping patterns in a whole-farm framework. Pages 669-694 *in* International Rice Research Institute. Report of a workshop on cropping systems research in Asia. Los Baños, Laguna, Philippines.

Flinn, J. C., and K. Kalirajan. 1982. Supply responsiveness of rice farmers in Laguna, Philippines. Aust. J. Agric. Econ. 26(1):39-48.

Herdt, R. W. 1982. Focusing field research on future constraints to rice production. IRRI Res. Pap. Ser. 76. 18 p.

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SEMINARS

The seminars held at IRRI during 1982 are grouped as Thursday seminars, Saturday seminars, and special seminars. The Saturday seminars report ongoing IRRI researches. Unless otherwise stated, the speakers were staff members.

Thursday seminars

IRRI's training and professional advancement programs. Dr. M. D. Pathak.

Utilization of rice straw for paper making. Dr. W. S. Tiosic, president and chairman of the Board, People's Pulp and Paper Mills, Inc., Manila.

Diving the WW II shipwrecks of Truk Lagoon, Carolines. Dr. T. R. Hargrove.

Cropping systems entomology: accomplishments and future directions. Dr. J. A. Litsinger.

Weed control in rainfed cropping systems: some experiences in ICRISAT. Dr. S. V. R. Shetty, postdoctoral fellow, Agronomy Department.

Edible tropical plants or Asian vegetables including wild plants. Ms. S. Yoshida, IRRI Staff Housing.

White line mosaic, a new disease of corn. Dr. C. Boothroyd, advisor, National Crop Protection Center, University of the Philippines at Los Baños.

The scheme of biology — a unifying concept. Dr. H. H. Hagerman, visiting communication specialist, Rice Production Training and Research.

Vertebrae pest research at IRRI — an update. Mr. L. Fiedler, biologist, National Crop Protection Center, University of the Philippines at Los Baños.

Present and future status of research on wheat in the Philippines. Dr. T. Masajo, postdoctoral fellow, International Rice Testing Program.

IRRI cropping systems and research in Solana. Mr. Rolando Torres.

Development of applicators for fertilizer deep placement. Dr. B. J. Cochran, visiting scientist, Agricultural Engineering Department.

The secret of effective office management: tips to bosses and secretaries. Ms. E. Yalong.

The potential of the potato in a rice-oriented Asia. Dr. Peter Vander Zaag, regional representative, International Potato Center (CIP), c/o Philippine Council for Agriculture and Resources Research Development.

Factors influencing growth and nitrogen fixation of Azolla. Dr. Tung Heng Fong, senior postdoctoral fellow, Soil Microbiology Department.

Grain legumes in cropping systems in India. Dr. R. K. Pandey, senior research fellow, Cropping Systems Program.

The rices of IRRI. Dr. T. R. Hargrove.

Iron toxicity: a soil microbiological view. Dr. G. Benckiser, postdoctoral fellow, Soil Microbiology Department.

General concept of rice yield losses caused by insect pests. Dr. O. Mochida.

Water stress and sterility in rice. Dr. J. C. O'Toole.

Nitrogen-fixing diazotroph isolated from *Saccharum spontanium* roots enhanced growth of rice and corn. Dr. M. Umali-Garcia, assistant professor, College of Forestry, University of the Philippines at Los Baños.

Quantitative evaluation of agrotechnology transfer. Dr. F. B. Cady, visiting scientist, IRRI.

IARC book exhibition and co-publishing in China. Dr. T. R. Hargrove.

Some thoughts on rice disease research. Dr. T. W. Mew.

Irrigation projects — typical problem areas in planning and execution. Mr. A. Seki, irrigation engineer, Irrigation Division II, Asian Development Bank, Manila.

Land classification in a tropical river basin using LANDFAT and ancillary data. Dr. R. A. Morris.

What did a new rice technology do to population? Dr. M. Kikuchi.

Properties of rice starch in relation to varietal differences in processing characteristics of rice grain. Dr. B. O. Juliano.

Do's and dont's on the IRRI farm. Mr. F. V. Ramos.

INTSORMIL — the title XII sorghum/millet program. Dr. J. W. Maranville, visiting scientist, Institute of Plant Breeding, University of the Philippines at Los Baños.

Diseases of cropping systems research. Dr. E. C. Price.

Some alternate concepts for deep fertilizer applicator. Dr. A. U. Khan, consultant, Agricultural Engineering Department.

Genetics of rice bacterial resistance. Mr. Atsushi Yoshimura, research fellow, Plant Pathology Department.

Application of tissue- and culture-induced mutagenesis to crop improvement. Dr. S. Yoshida.

Algae as food in the Philippines. Dr. Milagrosa Martinez, assistant professor, Department of Botany, University of the Philippines at Los Baños.

Biochemical response of plants to mechanical wounding, fungal infection and insectival infestation. Prof. Emeritus Dr. Ikuzo Uritani, Department of Agricultural Chemistry, Faculty of Agriculture, Nagoya University, Furu-Cho, Chikusa, Nagoya, Japan.

Saturday seminars

Hybrids and composites in the varietal improvement for rainfed lowland rice. Dr. R. C. Chaudhary, senior research fellow, Plant Breeding Department, IRRI.

Field performance evaluation of the manual IRRI rice transplanter. Mr. T. R. Sharma, research scholar, Agricultural Engineering Department, IRRI.

^{15}N dilution to assess nitrogen fixation in association with rice. Mr. Wilbur Ventura and Dr. Iwao Watanabe.

Consumer preference and properties of raw and cooked milled rice (cooperative study between IRRI and IHE-UPLB until 1980). Ms. A. del Mundo, assistant professor, Institute of Human Ecology, University of the Philippines at Los Baños.

Submergence tolerance in rice and its inheritance. Dr. H. K. Mohanty, senior research fellow, Plant Breeding Department.

Availability of blue-green algal nitrogen to the rice plant. Ms. A. Tirol.

Dinitrogen-fixing *Pseudomonas* associated with wetland rice. Mr. W. L. Barraquio and Dr. I. Watanabe.

Role of natural enemies in population suppression and pest management of green rice leafhoppers. Dr. F. O. Cariño, postdoctoral fellow, Entomology Department.

Morphological variations among three biotypes of the rice brown planthopper, *Nilaparvata lugens* (Stal), in the Philippines. Dr. R. C. Saxena.

Whitebacked planthopper, *Sogatella furcifera* (Horvath), problem on rice in Asia. Dr. O. Mochida.

Improving the reproductive drought resistance of rice. Dr. D. P. Garrity, Dr. J. C. O'Toole, Mr. R. T. Cruz, and Mr. R. P. Novero.

Tolerance to the brown planthopper in rice varieties. Dr. N. Panda, postdoctoral fellow, Entomology Department.

Aeroponic culture techniques for screening root characteristics of rice germplasm. Ms. G. C. Loresto.

Comparison tests of seeders (planters) and their suitability for small scale farmers. Mr. E. Henke, research associate, Agricultural Engineering Department.

A mixed 0-1 integer programming model for farm machinery selection and crop planning. Mr. Habib Ur-Rehman, research scholar, Agricultural Engineering Department.

The environment and the rice culture in the Cagayan Valley. Dr. H. Furukawa, senior research fellow, Multiple Cropping Department.

Adaptation of soybeans to prerice and postrice environments. Dr. R. Clements, postdoctoral fellow, Multiple Cropping Department.

The role of nonexchangeable ammonium in nitrogen dynamics in wetland rice soils. Dr. G. Keerthisinghe, postdoctoral fellow, Agronomy Department.

The world of Alang-Alang: a qualitative review of research and development in the Asian Cropping Systems Network. Dr. M. Z. Hoque, postdoctoral fellow, Multiple Cropping Department.

Design and development of a multi-purpose dryer using non-conventional sources of energy. Mr. Yong Woon Jeon, research fellow, Agricultural Engineering Department.

Residual effects of fertilizer nitrogen in a rice-rice cropping sequence. Mr. Rogelio Magbanua.

Toxins of *Xanthomonas campestris* pv. *oryzae*. Dr. G. P. Singh, postdoctoral fellow, Plant Pathology Department.

Studies on the resistance of IR34 to tungro. Mr. R. Cabunagan.

Influence of soil microorganisms on the survival of the rice sheath blight pathogen. Ms. A. Rosales.

Chemical control of blast, sheath blight, and bakanae diseases of rice. Mr. J. Bandong.

Weed control in dry-seeded wetland rice. Mr. D. Navarez.

Response of rice to water stress. I. The role of osmotic adjustment in leaf rolling and tissue death. II. Sensitivity of meiosis during pollen development. Ms. E. B. Yambao, Ms. O. S. Namuco, and Dr. J. C. O'Toole.

Review of the current research on the role of ammonia volatilization as a nitrogen loss mechanism in wetland rice topdressed with urea. Dr. I. R. P. Fillery, Dr. S. K. De Datta, Ms. E. Flordelis, Ms. C. Menguito, Mr. E. Castillo, and Ms. M. del Rosario.

Synchrony of rice cultivation and the dynamics of pest populations. Dr. M. Loevinson, research fellow, Entomology Department.

Activities of the International Association for Cereal Chemistry (ICC) Study Group 21B "Test methods for rice-cooking properties." Dr. B. O. Juliano.

Improving irrigation system infrastructure at the tertiary level to increase rice production: an Indonesian case. Mr. W. F. Purba, research scholar, Irrigation and Water Management Department, and Dr. S. I. Bhuiyan.

Improving the water allocation-distribution method in a pump irrigation system. Mr. A. Galang, Mr. D. Tabbal, Dr. S. I. Bhuiyan; Ms. S. Samaniego, soil technologist, Mr. F. S. Tabo, irrigation engineer, and Mr. P. D. Favenir, acting irrigation superintendent, National Irrigation Administration.

Community irrigation: indigenous solutions to management of water resources. Dr. R. Y. Siy, partial research fellow, Irrigation and Water Management Department, and Dr. A. C. Early.

Collaborative irrigation system management research results from the Upper Pampanga Integrated Irrigation System. Dr. A. C. Early, Mr. T. B. Moya, Mr. D. M. Cablayan, Mr. B. C. Gilles, Mr. B. Valera, Ms. G. G. Soltes, Mr. M. M. Alagcon, and Ms. M. Y. H. Sipin.

Mechanization and cropping intensification. Dr. S. K. Jayasuriya, cropping systems network economist, Dr. A. Te, postdoctoral fellow, Agricultural Economics Department, and Dr. R. W. Herdt.

Rice production constraints research in Pakistan. Dr. J. C. Flinn.

Changes in labor use and labor contracts for rice farming in Laguna, Philippines. Ms. F. B. Gascon, Ms. L. M. Bambo, Dr. M. Kikuchi, and Dr. R. W. Herdt.

Performance of salt-tolerant rices in saline soils in the Philippines. Mr. R. Y. Reyes.

Improving the fertility of rice soils by straw and water management. Ms. A. B. Capati.

Amelioration of peat soils for wetland rice. Ms. C. C. Quijano.

The rapid generation advance (RGA) facilities at IRRI. Mr. G. Pateña.

Induction and selection of salt tolerant mutant rice by tissue culture. Dr. M. Ogawa, postdoctoral fellow, Plant Physiology Department.

Nutritional disorders of rice in acid soils from the Philippines and Thailand. Ms. V. Coronel.

Effect of water stress on grain filling in rice. Dr. M. S. Rahman, postdoctoral fellow, Plant Physiology Department.

Special seminars

Experience of a 200-ha rice garden. Mr. A. Baclig, superintendent, PPC Rice Farm, Bukidnon, Philippines.

Use of protoplasts for plant genetic manipulations. Prof. E. C. Cocking, head, Department of Botany, School of Biological Sciences, University of Nottingham, England.

Green energy project in Japan. Dr. Y. Takahashi, IRRI representative in Japan and formerly director, Department of Physiology and Genetics, National Institute of Agricultural Sciences, Japan.

Classification and evaluation of rices by Ifugao seed selectors. Dr. Harold C. Conklin, Department of Anthropology, Yale University, New Haven, Connecticut.

Brazilian agricultural research. Dr. Victor Palma, head, Planning and Methods Department, Brazilian Agricultural Research Corporation (EMBRAFA), Brasilia, D.F., Brazil.

Perspectives in biotechnology. Dr. M. S. Swaminathan.

Nuclear male sterility in wheat and its use in composite crosses and in hybrid production. Dr. C. J. Driscoll, Waite Professor in Agronomy, University of Adelaide, Waite Agricultural Research Institute, Australia.

'*Chipco andolan*': A predominantly women's movement to safeguard wise use of forests. Mr. Chandi Prasad Bhatt, 1982 Ramon Magsaysay Foundation Awardee for Community Leadership.

Soil physics in crop growth models. Dr. F. D. Whisler, visiting scientist, Multiple Cropping Department.

The influence of tillage for wetland rice on some physical properties of soils. Dr. N. C. Keersebilck, project leader, Belgian Bilateral Cooperation Project, Gadjah Mada University, Yogyakarta, Indonesia.

Soils and development in highland New Guinea. Dr. Colin Pain, soil scientist/geomorphologist, University of New South Wales, Sydney, Australia.

Immunological techniques for the identification and ecological study of N_2-fixing microorganisms associated with rice plants. I. Heterotrophic bacteria. II. Symbiotic blue-green algae, *Anabaena azollae* from *Azolla*, Dr. J. K. Ladha.

Adaptation of the IRRI-CAAMS reaper in Pakistan. Dr. Zia Ur-Rahman, director, Agricultural Machinery Division, Pakistan Agricultural Research Council, Pakistan.

Professional communication between UPLB and IRRI researchers. Ms. Alice Flinn, IRRI Staff Housing.
Soybean resistance to bean fly. Dr. Dale M. Norris, professor of Entomology, University of Wisconsin-Madison.
Emerging economic scenario in Asia. Mr. Masao Fujioka, president, Asian Development Bank, Manila.

Finances

The Institute received $24,977,201.86 during 1982.

The United States Agency for International Development (USAID) gave $7,775,671.77 — $5,900,000 for core operations; $36,000 to assist in the implementation of the Philippine national and regional applied research and extension programs in rice and rice-based cropping systems; $621,495.53 for industrial extension of small-scale agricultural equipment developed at IRRI; and $6,391.41 for training costs of Razia Soltana and Metengue Diack.

USAID also released $1,211,784.83 for continuing contracts:

- $112,749.98 for a contract between IRRI and the Government of Sri Lanka for assistance in implementing rice and cropping systems research projects with funds provided by USAID loan.
- $157,203.07 for a contract between the Arab Republic of Egypt and the Regents of the University of California and IRRI for a technical assistance relationship for increased production and improved quality of rice in Egypt through the development and adoption of improved agricultural practices and varieties of rice.
- $22,516.82 for the services of an industrial engineer for the small-scale agricultural equipment extension project of the Government of Indonesia.
- $52,056.08 for technical services and equipment to conduct a demonstration program in Luwu (Indonesia) project area, of the IRRI-designed and Indonesian-manufactured hand tractor and accessories.
- $449,205.94 for supporting a 3.5-year project for accelerated development and use of improved rice technology in Indonesia.
- $183,132.93 for collaborative rice research in Pakistan.
- $111,770.01 for a project on consequences of mechanization on small farms.
- $70,000 for the water management applied research and training in connection with the memorandum of agreement between the Bicol River Basin Development Program, IRRI; the National Irrigation Administration and the Joint Project Implementation Letter No. 15 of 26 Jan 1981.
- $53,150 to support setting up of a Nutritional Evaluation Laboratory as a regional center for research on the nutritional value of high-protein cereals and legumes and weaning foods of children.

The Japanese Government gave $3,400,000 for partial support of the GEU program including expenses of germplasm collection and maintenance; for partial support of Soil and Crop Management Program; and for partial support of Control and Management of Rice Pests.

The Ministry of Overseas Development, United Kingdom gave $1,102,320 for the core program.

The Canadian International Development Agency gave $1,208,250 for core operations; $527,464.86 for cooperation between the Bangladesh Rice Research Institute and IRRI; and $406,255.81 for cooperative research on rice, rice-based cropping systems, and development of machines for small-scale farming between the Government of Burma and IRRI.

The International Development Research Center (IDRC), Canada, gave $297,039.48. Of that $112,438.26 was part of a 3-year grant for cropping systems outreach in South and Southeast Asia; $156,023 for the IRRI/UPLB cooperative research project on varietal improvement of dryland legume crops for rice-based cropping systems; $8,435 as part of a 4-year grant to support a multiple cropping research project at the Bangladesh Rice Research Institute; $20,000 to enable Dr. M. Sahidul Hoque to undertake postdoctoral studies at IRRI; and $143.22 towards the training cost of Mr. Amadou Makhtar Diop.

The European Economic Community gave $2,010,311.51 for water management, scholarships for candidates from developing countries, and partial support of the GEU program.

The Australian Government gave $1,107,229.56 of which $655,140 was for core operations, including travel of Australian scientists; $406,713.46 for expansion of technical assistance and collaborative relationships with the Bangladesh Rice Research

Institute; and $45,376.10 in support of the consultancy study concerning the International Board for Soil Resources Management.

The Federal Republic of Germany gave $530,660 for core operations; $207,650 towards the project on the effects of organic matter on paddy soils; $5,795.99 for support of a visiting scientist in soil microbiology; and $20,730 to support the International Board for Soils Resources Management.

The International Development Association gave $1,230,000 for core operations and capital expenditures.

The United Nations Development Programme released $1,637,200 of which $1,540,200 was for the International Rice Testing and Improvement Program; $12,000 toward annual meetings of the Rice Testing Program and Biological Nitrogen Fixation components of the project; and $85,000 to undertake expanded research on rice-weather relationship.

The International Fund for Agricultural Development gave $1,600,000 for research on rice-based cropping systems.

The Government of India gave $115,445 for the core program.

The Government of Denmark gave $126,063.66 for the core program.

The Government of the Philippines gave $250,000 for the core program.

The Government of Sweden gave $256,572.53 for the core program.

The Government of New Zealand gave $18,477.50 for the core program.

The Government of Spain gave $25,000 for the core program.

The Government of Belgium gave $136,454.29 for the core program and $20,992.97 for the collaborative research with FLKU (Fakulteit der Landhovwwetenschappen Katholieke Universiteit Leuven).

The Swiss Federal Council, represented by the Swiss Development Corporation, gave $136,800 to support the studies of nitrogen fertilizers used for rice.

Since February 1978, a contract between IRRI and the International Fertilizer Development Center has supported a joint project on the fate and efficiency of nitrogen fertilizers in lowland rice. IFDC reimbursed IRRI $33,481.53.

Since 1980, a contract between IRRI and the International Food Policy Research Institute (IFPRI) has supported a major collaborative research on rice policy in Southeast Asia. IFPRI reimbursed IRRI $51,931.58.

The Ford Foundation gave $263,300 — $150,000 for core operations and capital expenditures; $100,000 in support of rice research and development in Bangladesh; $12,000 for fellowships of Asian students; and $1,300 for a workshop in socioeconomic constraints.

The Rockefeller Foundation gave $154,177.35 — $150,000 for core operations and capital needs; $2,177.35 toward expenses of a postdoctoral appointee; and $2,000 as an outright and restricted contribution for the cordial reception accorded to RF fellows.

Other donors were:

- Office of Rural Development, Korea, seed multiplication program and cooperative research program $70,000.00
- Philippine Council for Agriculture and Resources Research, cooperative applied research on rainfed rice $42,994.29
- National Food and Agriculture Council, strengthening the settlement program to carry out agrarian reform policies and programs $15,374.08
- Ministry of Agriculture, implementation of the Philippine national and regional applied research and extension program in rice and rice-based cropping systems $40,698.80
- International Board for Plant Genetic Resources, field collection of indigenous rice germplasm in South and Southeast Asia $11,000.00
- Imperial Chemical Industries, research grant $5,000.00
- Stauffer Chemical Company, weed control $3,000.00
- Ciba-Geigy, agrochemical research $3,000.00
- Monsanto, herbicide research $3,020.12
- American Cyanamid Overseas Corporation, weed control and

insect control $2,000.00
- Hoechst, AG, research work at IRRI $4,545.45
- American Chemical Society, International Conference on Chemistry and World Food Supplies (Chemrawn II) $65,910.00
- SKWTrostberg Aktiengesellschaft, soil fertility research $6,000.00
- Montedison, herbicide and pesticide research $6,000.00
- KenoGard, entomology research $1,000.00
- FMC International, entomological research $3,000.00
- International Potash Institute and Potash and Phosphate Institute, soil fertility research $14,383.73
- UNESCO
  - Travel grant to enable Dr. Clodualdo Maningat to carry out a cooperative research program at Grain Science, Kansas State University $2,500.00
  - Travel grant to enable Mrs. Rhodora Romero to work in the laboratory of the Centre Nacional de Recherche Scientifique (CNRS) in Gif-Sur-Yvette on "Rice Microspore Culture" $2,700.00
- Food and Agriculture Organization of the United Nations:
  - Support of the 2d Integrated Pest Management Course from September 6 to December 12, 1982 ..... $16,300.00
  - Assist in conducting a rice monitoring program $2,500.00
  - To cover expenses for analyzing data on crop losses due to seeds $1,000.00

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- International Potash Institute and Potash and Phosphate Institute, soil fertility research $14,383.73

Staff changes

January

Dr. James A. Litsinger, entomologist, completed a 1-yr sabbatical leave at the University of Hawaii.

Mr. Charles J. Moss resigned as agricultural engineer, IRRI/Egypt Rice Project.

February

Dr. David J. MacKill of International Crop Research Institute for the Semi-Arid Tropics joined the Plant Breeding Department as associate plant breeder.

Dr. Leonard R. Oldeman of the World Meteorological Organization began a 1-yr assignment as visiting scientist, Multiple Cropping Department.

Dr. Mun Hue Heu resigned as plant breeder, Plant Breeding Department.

Dr. Jeff R. Simpson, Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, completed a short-term assignment as visiting scientist, Soil Chemistry Department.

Mr. Henry M. Beachell resigned as plant breeder, AID-492-1310 (Indonesia).

Dr. Keh-Chi Ling, plant pathologist, passed away.

March

Dr. Robert E. Huke of Dartmouth College completed a short-term assignment as visiting scientist, Agricultural Economics Department.

April

Dr. M. S. Swaminathan joined the IRRI staff as Director General.

Mr. Paul A. Cooper, a private consultant and formerly with USAID, began a 2-yr assignment as consultant, Administration (Director General's Office).

Mr. Walter G. Rockwood resigned as editor to join USAID, Washington, D.C.

Mr. Jack B. Duff, associate agricultural economist, completed a 1-yr sabbatical leave at the University of California, Davis.

May

Dr. John C. O'Toole, agronomist, completed a 1-yr sabbatical leave at the University of California, Davis.

Dr. Derk HilleRisLambers, plant breeder, IRRI cooperative projects with the Ministry of Agriculture and Cooperatives in Thailand, completed a 1-yr assignment as visiting scientist, Plant Breeding Department.

Dr. Keith Moody, agronomist, began a 1-yr sabbatical leave at the Weed Research Organization.

Dr. Victor A. Dyck resigned as entomologist to return to Canada.

Dr. Walter L. Griffeth resigned as crop production specialist, Rice Production Training and Research Department.

June

Dr. Benito S. Vergara, plant physiologist, completed a 1-yr sabbatical leave at the University of California, Davis.

Ms. Lina M. Vergara, librarian, completed a 1-yr sabbatical leave at the University of California, Davis.

Dr. Ray B. Diamond of the International Fertilizer Development Centre, began a 1-yr assignment as visiting scientist, Agronomy Department.

Dr. Jerry W. Maranville of the University of Nebraska began a 1-yr assignment as visiting scientist on the Joint IRRI/Institute of Plant Breeding (UPLB) Collaborative Project.

Dr. Igmidio T. Corpuz left the IRRI staff as agronomist; AID-492-1310 (Indonesia) was terminated.

Dr. James R. Hooper left the IRRI staff as associate agronomist; AID-492-1310 (Indonesia) was terminated.

Mr. Hugh T. Murphy, director for administration, began a 6-mo sabbatical leave at Harvard University.

Dr. Elvis A. Heinrichs, entomologist, began a 6-mo sabbatical leave at the University of Nebraska.

July

Dr. Tom W. Mew, plant pathologist, completed a 1-yr sabbatical leave at the North Carolina State University.

Dr. Richard A. Morris, agronomist, completed a 1-yr sabbatical leave at IBM de Mexico, S.A.

Dr. Edwin C. Price, agricultural economist, completed a 1-yr sabbatical leave at Yale University.

Dr. Derk HilleRisLambers rejoined the IRRI staff as plant breeder, Plant Breeding Department.

Mr. Edwin A. Tout formerly of the University of Arizona joined the Information Services Department as associate editor.

Dr. Frank D. Whisler of Mississippi State University began a 1-yr assignment as visiting scientist, Multiple Cropping Department.

Dr. LaRue Pollard of the Iowa State University completed a 1-yr assignment as visiting science editor, Information Services Department.

Dr. Billy Cochran of Louisiana State University completed a 1-yr assignment as visiting agricultural engineer, Agricultural Engineering Department.

Dr. Phillip E. Church of USAID/Bangladesh completed a 1-yr assignment as visiting associate agricultural economist, Agricultural Economics Department.

August

Dr. Kwanchai A. Gomez, statistician, completed a 1-yr sabbatical leave at the Food Research Institute, Stanford University.

Mr. Orlando G. Santos, associate farm superintendent, completed a 1-yr sabbatical leave at the Bowling Green State University.

Dr. Dennis P. Garrity joined the IRRI staff as associate agronomist, International Rice Testing Program Department.

Dr. Amir U. Khan, formerly with the IRRI/PARC Collaborative Project in Pakistan, transferred to IRRI as consultant on agricultural engineering matters, Agricultural Engineering Department.

Dr. Foster Cady of Cornell University began a 1-mo assignment as consultant, International Rice Testing Program Department.

Dr. Paul Webster of Wye College began a short-term assignment as consultant, Agricultural Engineering Department.

Dr. James S. Townsend resigned as agricultural engineer with the IRRI/Burma Collaborative Project.

September

Dr. Heinz-Ulrich Neue of the University of Hamburg joined the Soil Chemistry Department as associate soil chemist.

Dr. H. Hibino of the Institute of Plant Virus Research, Japan, joined the Plant Pathology Department as plant pathologist.

Dr. John M. Bonman of The Rockefeller Foundation, Thailand, joined the Plant Pathology Department as associate plant pathologist.

Mr. Eugene P. Hettel of Iowa State University began a 1-yr assignment as visiting associate editor, Information Services Department.

Dr. Tsugufumi Ogawa of the Tropical Agricultural Research Center began a 2-yr assignment as visiting scientist, Plant Breeding Department.

Dr. Tsuyoshi Yamamoto of Tropical Agricultural Research Center began a 2-yr assignment as visiting scientist, Plant Pathology Department, and 3- to 5-mo assignments in Japan.

Dr. Foster Cady of Cornell University completed a 1-mo assignment as consultant, International Rice Testing Program Department.

Dr. Paul Webster of Wye College completed a short-term assignment as consultant, Agricultural Engineering Department.

October

Mr. Marvin M. Parker of USAID-Manila joined the IRRI staff as agricultural engineer, IRRI/Egypt Rice Project.

Mr. Vernon E. Ross resigned as rice production specialist, IRRI/Egypt Rice Project.

Dr. Leo D. Haws resigned as crop production specialist.

Dr. Johnny W. Pendleton resigned as agronomist to return to the University of Wisconsin, Madison.

November

Dr. Danny R. Minnick, formerly professor of entomology, University of Florida, joined IRRI as training specialist, Rice Production Training and Research.

Dr. Jagdish K. Ladha, former postdoctoral fellow, joined the Soil Microbiology Department as associate soil microbiologist.

Mr. Marvin L. Nafziger, associate agricultural engineer, left for an extended sick leave up to 31 Mar 1983.

December

Mr. Hugh T. Murphy, director for administration, completed a 6-mo sabbatical leave at Harvard University.

Dr. Robert E. Huke, professor of geography, Dartmouth College, began a 3-mo assignment as visiting scientist.

Dr. Neil C. Turner, principal research scientist of CSIRO, Australia, began a 6-mo assignment as visiting scientist, Agronomy Department.

Dr. S. K. W. Jayasuriya resigned as associate agricultural economist to join the Australian National University.

Crop weather

The 1982 weather at IRRI, Los Baños (14° 19'N; 121° 15'E), was characterized by a short 3-mo WS (July-September), which was preceded by below-normal rainfall in May and June and followed by below-normal rainfall in October and November (Table 1). The total rainfall was 1,479 mm — 560 mm below the normal. Rainfall was recorded on 188 d; an extreme 24-h rainfall occurred on 8 Sep (116 mm) and 9 Sep (162 mm).

The maximum temperatures at the wetland site ranged from 27.1° C in January to 33.0° C in May and June (Table 2). Those at the dryland site were about 2° C higher during the DS (January-June). The minimum temperatures at the wetland site ranged from 21.0° C in January to 24.2° C in May; those at the dryland site were about 1° C lower during the DS.

Vapor pressure deficits at noon were highest in May and June (21.6 mbar in the wetland and 26.3 mbar in the dryland) and lowest in January in the wetland (12.2 mbar) and in December in the dryland (14.1 mbar).

Total radiation fluctuated from an average 320 cal/cm^2 per day) in January to 475 cal/m^2 per day in March. During the short WS, radiation values dropped to 350 cal/cm^2 per day with extreme low values during the first 10 d of September (210 cal/cm^2 per day).

Wind speed was reasonably constant throughout the year, although slightly higher during the first part of the DS. In the dryland, the average annual wind speed was 1.9 m/s; in the wetland, 1.4 m/s.

Evaporation rates, related to the combined effects of radiation, air temperature, vapor pressure deficit, and wind speed, were lowest in November and December (107 mm/mo in the wetland and 114 mm/mo in the dryland) and highest from March through June averaging 162 mm/mo in the wetland and 197 mm/mo in the dryland. The annual evaporation was about 250 mm higher in the dryland.

Twenty-one tropical disturbances were recorded within the Philippines' area of responsibility. Most of them did not affect the IRRI farm, although on 10 occasions warning signals were hoisted over the southern Tagalog provinces. Tropical storm Emang (12-16 Jul) caused heavy rainfall (over 140 mm in 2 d). Typhoon Ruping (5-11 Sep) crossed 60 km south of IRRI and brought more than 270 mm rainfall in 2 d with a maximum intensity of 50 mm in 2 h on 9 Sep.

Table 1. Rainfall, total radiation, and sunshine duration. IRRI, 1982.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Rainfall (mm)	16	15	24	40	51	85	345	205	444	55	78	121	1479
25-yr av (mm)	41	19	30	34	194	243	262	272	264	238	272	170	2040
Sunshine (h)	5.7	6.0	8.1	7.8	6.9	6.2	3.6	3.6	3.4	5.8	5.8	4.9	
Radiation (cal/cm^2 per day)	320	365	475	455	430	400	330	365	325	370	335	300	

Table 2. Monthly weather data at the wetland and dryland sites. IRRI, 1982.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
						Wetland site							
Max temp (°C)	27.1	28.2	30.3	31.8	33.0	33.0	30.6	30.8	30.2	30.3	30.0	29.4	
Min temp (°C)	21.0	21.3	22.4	23.5	24.2	24.1	23.7	23.6	23.4	23.3	23.2	23.1	
Min relative humidity (%)	66	65	60	59	57	57	65	67	70	64	66	64	
Max vapor pressure deficit (mbar)	12.2	13.4	17.3	19.3	21.6	21.6	15.4	14.7	12.9	15.4	14.4	14.7	
Wind speed (m/s)	1.7	1.6	1.7	1.3	1.2	1.5	1.6	1.4	1.3	1.2	1.3	1.4	
Evaporation (mm)	116	114	172	158	166	154	135	134	114	127	107	108	1605
						Dryland site							
Max temp (°C)	29.4	30.9	33.4	33.8	34.5	34.2	31.0	31.0	30.4	31.3	30.1	29.6	
Min temp (°C)	20.4	20.6	21.6	22.7	23.6	23.6	23.2	23.1	23.1	23.0	23.0	22.7	
Min relative humidity (%)	60	57	50	53	51	52	55	68	67	59	65	66	
Max vapor pressure deficit (mbar)	16.4	19.2	25.7	24.7	26.8	25.8	15.3	14.4	14.1	18.7	14.9	14.1	
Wind speed (m/s)	2.3	2.2	2.2	1.7	1.8	2.1	2.1	1.8	1.8	1.6	1.5	1.7	
Evaporation (mm)	152	155	223	196	192	178	132	139	118	142	114	114	1855

- *Research Highlights*
- *Genetic Evaluation and Utilization (GEU) Program*
- *Control and Management of Rice Pests*
- *Irrigation Water Management*
- *Soil and Crop Management*
- *Climatic Environment and Rice*
- *Constraints on Rice Yields*
- *Consequences of New Rice Technology*
- *Cropping Systems Program*
- *Machinery Development and Testing*