INTERNATIONAL RICE RESEARCH INSTITUTE

ANNUAL REPORT FOR 1980

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ANNUAL REPORT FOR 1980

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†On project appointment.
††On part-time basis.
†††On emergency appointment.

About this report

This 19th annual report includes research reported during 1980. The department or departments that performed the research are identified in italics below the topic heading. For example:

YIELD PERFORMANCE AND NITROGEN RESPONSE OF RICE VARIETIES AND SELECTIONS
Agronomy 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 Pathology and Plant Breeding Departments cooperate in the project SOURCES OF RESISTANCE. Because the Plant Pathology Department bears responsibility for one phase of that work, its name follows the heading:

Identification and evaluation *(Plant Pathology).*

This report makes reference to three fundamental types of rice culture. Dryland (upland) culture means rice grown without irrigation in unbunded fields. Rainfed paddy 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, IR32 × IR34 is written IR32/IR34. The sequence of crosses is indicated by the number of slant bars. (IR32 × IR34) × TKM6 is written IR32/IR34//TKM6. 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 due 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.

Names and terms often repeated within sections are abbreviated, e.g. BPH (brown planthopper), GLH (green leafhopper), DT (days after transplanting), DAT (days after treatment), etc. Such abbreviations are spelled out when first used.

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.

Research highlights

"What about the other three?"

That was the question in our *Research Highlights for 1975.* We asked the question because a look at the 10 years of intensive rice research that had followed the release of IR8 pointed to those with irrigation — only one in four rice farmers — as the main beneficiaries of the new rice technology.

Even though the "other three" with no irrigation had not been completely shut out (the fact is they benefited from a spillover of technology that was workable in rainfed fields), IRRI started to focus its research in 1975 more on problems of the rainfed rice farmer: his rain-dependent less-certain water supply, and poorer soils. Because the risk of crop failure is higher for the rainfed farmer, he has less easy access to credit and the inputs needed to increase rice production.

What have we achieved for him in the last 5 years?

It is clear, most of all to the scientist, that there can be no yearly "breakthroughs" in rice research. There have been and there will continue to be, however, outstanding new rices released to farmers, some of which allow the disadvantaged rainfed farmer to double, even triple, his rice production per hectare.

Among the varieties developed since 1975, which help the rainfed farmer to cope better with his adverse environment, we can point to:

- IR36, the rice now most widely grown by the Philippine rice farmers, most of whom do not enjoy assured irrigation. IR36 (IR2071-625-1) was named and released by the Philippine Seed Board in 1976. Its early maturity and multiple pest resistance made it an easy favorite of farmers in both irrigated and rainfed areas. To the rainfed farmers IR36 brought the chance to grow a crop in the short period when good rains were certain. If the rains failed for short periods, IR36 could stand moisture stress and then bounce back when rains returned. IR36 — with its good harvests from both irrigated and rainfed fields — was a mainstay in putting Philippine rice production at the point of exportable surplus in 1979, and enabling it to continue exporting subsequently.
- IR42, named in the Philippines in 1977, has been outstanding on farms with adverse soils. IR42 (IR2071-586-5-6-3) gives high yields in fields with low nitrogen fertility, has moderate tolerance for zinc and phosphorus deficiencies, and resists most of the major rice pests (Table 1). Many farmers among "the other three" of 1975 got in IR42 a rice that could double their yields. One IRRI soil scientist called IR42 "the answer to the poor rice farmer's prayers."
- IR52, named in 1980 in the Philippines, has good drought resistance and all the other desirable characteristics of the modern IR varieties. IR52 (IR5853-118-5) was first reported in *Research Highlights for 1976* for its "excellent vegetative vigor"; later (in 1977) as "drought resistant with potential for rainfed and irrigated" areas, and (in 1979) for "consistently high resistance to drought" over 3 years of tests.
- RD17 and RD19, released in 1979 by Thailand's Department of Agriculture for farmers in areas with medium-deep water (0.5-1 m depth). These first high yielding modern varieties developed specially for flood-prone areas were the

Table 1. The resistance of IR42 to pests and other adverse conditions contrasts markedly with that of IR8, released 11 years earlier.[a]

Adverse factor	IR8	IR42
Diseases		
Blast	MR	R
Bacterial blight	S	MR
Grassy stunt	S	R
Tungro	S	R
Ragged stunt	S	R
Insects		
Green leafhopper	R	MR
Brown planthopper	S	R
Stem borer	MS	MR
Nutrient deficiencies		
Nitrogen	MS	R
Phosphorus	MR	MR
Zinc	S	MR
Iron	S	MR
Soil toxicities		
Salinity	MR	MR
Alkalinity	S	MR
Iron toxicity	S	MR
Boron toxicity	MR	MR
Peat soil problems	MS	MR
Drought	S	MR
Submergence	S	MR

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

product of a Thailand-IRRI Collaborative Deepwater Rice Project. Their full impact is yet to be felt, but there are indications elsewhere in this report of their potential — they were the only rices to survive in a Philippine area subjected to deep flooding in 1980 and yields of RD19 were exceptionally high in deepwater fertilizer trials at IRRI.

- Varieties and lines with drought resistance and good yield in dryland fields. IR43 yielded 4.6 t/ha in a Filipino dryland farmer's field during the 1980 wet season; IR5931-110-1 had yields of 3.9 t/ha in the same field. Both rices held high ratings in 10 trials in 5 countries for the 1980 International Upland Rice Yield Nursery of the International Rice Testing Program. A sister line to IR43 was released as IR1529 in several African and Latin American countries.
- IR cold-tolerant lines with yields higher than 6 t/ha. IR15889-32-1 yielded 7.9 t/ha in Korean cold tolerance tests. Several IR9202 lines had yields in the 5-7 t/ha range in cold areas of Korea and the Philippines.
- Several with tolerance for adverse soil conditions — salinity, alkalinity, iron toxicity, and boron, phosphorus, and zinc deficiency. A growing list of IR varieties and lines shows these tolerances.

We do not cite the rices we note here as ones that will always give spectacular yields in fields with adverse conditions. Farmers who plant these rices, however, have an assurance of some yield in bad years and of high yield in good years. Contrast that with their previous expectation of crop failure in bad years and only low yields in their better years.

With the development of the new varieties, there has also been substantial progress in developing new cropping practices, and farmers in some rainfed areas now grow two rice crops where before they grew only one. Such farmers are found in areas of the Philippines, Sri Lanka, India, and Indonesia. A dry-seeded first crop gets off to a rapid start with the early rains. Using an early-maturing rice like IR36, a crop is ready for harvest within 4 months and a second crop can be transplanted while there is still plenty of water to complete its growth. Use of new drought-resistant varieties helps reduce risks in areas where rainfall is uncertain. In many areas farmers are getting their second rice crop off the fields in time to grow mungbean or another dryland crop on the residual moisture — three crops a year in a rainfed field!

Progress beyond varieties

We believe that it may well be time to start talking about the potential to hit "two out of three" rather than the "three out of four" that are missed by the new rice technology. Table 2 supports that belief.

Better life for more farmers

The technology that allows farmers to produce two or three crops where one was grown before — and do it without irrigation — has had dramatic effects on the incomes of many Asian farmers. In collaboration with national scientists, such intensification of rice cropping is being widely studied throughout Asia through the Asian Cropping Systems Network.

These developments of improved varieties for nonirrigated farms and of methods to intensify crop production in rainfed areas represent real achievements — ones that have already contributed significantly to a better life for many farmers among "the other three."

There has also been progress in other research areas that will make an impact on

Table 2. Human support capacity of rice area in South and Southeast Asia, by character of cultivation in 1980.[a] Rices such as IR36, IR42, IR43, IR50, IR52, and RD17 and RD19 provide higher and more stable yield for farmers in the rainfed and dryland areas.

Rice land type	Area (000 ha)	Mean yield (t/ha)	Support capacity (no. of persons)
Deepwater (> 1 m)	5,308	1.0	24,150,000
Irrigated	28,984	3 8	497,720,000
Shallow rainfed (0-30 cm)	30,248	1.8	247,930,000
Intermediate rainfed (30 cm-1 m)	11,547	1.2	63,100,000
Dryland	11,558	0.9	46,230,000
Total	87,645		879,130,000

[a]Adapted from a table prepared by Dr. R. E. Huke, IRRI visiting scientist, 1980

Table 3. These promising improved varieties and lines from the Genetic Evaluation Utilization program were identified as tolerant of different stresses through worldwide testing in the International Rice Testing Program, 1980.

Excess or deficit moisture	
Rainfed dryland	IR43, IR45, IR9669 Sel., IR2061-522-6-9, IR3839-1, IR36
Rainfed wetland	IR46, IR52, IR4819-77-3-2, IR4829-89-2
Medium deepwater[a]	RD17, RD19
Problem soils	
Alkalinity	IR43, IR46, IR2053-436-1-2, IR4227-28-3-2, IR9846-256-3
Salinity	IR42, IR4595-4-1-15, IR2307-247-2-2-3, IR2153-26-3, IR4630-22-3-3-2, IR4563-52-1
Temperature	
Cold	IR8866-30-1-4, IR3941-25-1, IR13045-182-5, IR15924-265-3
Hot	IR2006-P12-12-2-2, IR1561-228-3-3

[a]From the Thailand-IRRI Collaborative Deepwater Project.

the lives of the less as well as the more advantaged farmers:

- Tissue and cell culture techniques were greatly improved in our laboratories in 1980. These techniques afford the possibility for further rapid advances in the development of varieties with salinity tolerance, disease and insect resistance, and other desirable characteristics. Through embryo culture we can revive irreplaceable stocks that have lost vitality.
- Continued screening of the world germplasm collection has identified new sources of tolerance for drought, flooding, low and high temperatures, and adverse soil conditions. Use of these materials in breeding programs provide hope for better rice worldwide (Table 3).
- More efficient ways of using nitrogen fertilizers have been identified. Work on biological fixation, especially on the association of the water fern Azolla with nitrogen fixing Anabaena, has shown that there is a great potential for increasing rice yields for the small farmer who may not use nitrogen fertilizer, and for saving money for the fertilizer user who buys less to get high yields.

Genetic evaluation and utilization (GEU) program

Genetic resources program

Plant Breeding Department

FIELD COLLECTION

Implementation of a systematic field collection program in major rice-producing countries in South and Southeast Asia continued. A grant by the International Board for Plant Genetic Resources (IBPGR) to assist collaborative efforts enabled the national collection centers in Bangladesh, Burma, India, Indonesia, Nepal, Sri Lanka, and Thailand to expand their collection efforts, to improve seed storage facilities, to hold training courses, and to ship samples to IRRI.

An IRRI staff member joined field collectors in Indonesia during the main rice cropping season and canvassed five major islands of Nusa Tenggara: Timor, Sumba, Flores, Lombok, and Sumbara. A total of 304 varieties was collected. This direct participation in collection activities ensured fresh rice seed from previously unexplored areas and facilitated:

- the identification of ecoedaphic environments peculiar to the area visited,
- the training of local extension and research staff on methods of collection,
- the recording of characteristics of varieties in the field and their specific uses or special features, and
- a recording of the types of crop culture practiced in the remote areas and the development of a picture of the varietal diversity of local rices.

Table 1 summarizes collection activities in Asian countries from 1971 through 1980.

INSTITUTIONAL EXCHANGES

Many institutions of the world continued to deposit duplicate samples of their collections at IRRI. During 1980, IRRI received a total of 5,152 samples. The major donors were:

- Indian institutions such as Gujarat Agricultural University, M. P. Rice Research Institute, All-India Coordinated Rice Improvement Project, ICAR Research Complex at Shillong, Bihar State Agricultural Research Institute, Indian Agricultural Research Institute, Regional Rice Research Station at Kapurthala, and N. D. University of Agriculture and Technology: total of 665 samples.
- Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) France: 1,001 samples collected from Cameroon, Ivory Coast, Malagasy, Mali, Senegal, Tanzania, Chad.
- International Institute of Tropical Agriculture (IITA), Nigeria: 581 samples from various parts of West Africa.
- Malaysian Agricultural Research and Development Institute (MARDI), Malaysia: 382 local rices.
- Rice Division of Thailand: 210 local rices.
- Bangladesh Rice Research Institute: 139 transplanted aman and boro rices.
- Agricultural Science Research Institute of Vietnam: 134 local rices.
- Maros Branch of the Central Research Institute for Agriculture, Indonesia: 83 local varieties.

During 1980, IRRI requested and subsequently received 115 samples to replace the accessions that were no longer available because of either expired viability or destruction by pests in the fields.

The International Rice Testing Program at IRRI turned over 926 entries from different nurseries for preservation.

IRRI continued to provide computer-printed accession lists and characterization data to major national genetic resources centers and other international agricultural research centers upon their request.

Table 1. Indigenous rice varieties collected with IRRI's direct or indirect participation in 14 collaborating Asian countries, 1971-80.

Country	Years	Indigenous varieties collected (no.) with IRRI's direct participation	Indigenous varieties collected (no.) with IRRI's indirect participation
Bangladesh	1973-80	2,451	2,793
Bhutan	1975-76	—	121
Burma	1973-74, 1976, 1980	225	406
India	1976, 1978-80	—	4,828[a]
Indonesia	1972-76, 1978-80	5,103	4,633
Kampuchea	1973	280	—
Laos	1972-73	—	899
Malaysia	1973-79	—	972
Nepal	1971-72, 1979-80	—	968
Pakistan	1972-73, 1976, 1979	—	772
Philippines	1973-76, 1977-80	510	1,971
Sri Lanka	1972, 1975-76, 1978-80	1,675	550
Thailand	1973, 1975-76, 1978-80	—	2,524
Vietnam	1972-75	108	650
	Total	10,352	22,086

[a]Partial estimate based on seed samples received by IRRI

SEED INCREASE, REJUVENATION, AND DISTRIBUTION

Field space used for seed increase, characterization, and rejuvenation during different plantings amounted to 12 ha. During the year 7,988 plots were planted for initial seed multiplication, 11,647 for systematic characterization, and 6,000 for rejuvenation. The total number of plots exceeded that in 1979 by 5,000.

In November, 2,248 plots were planted for initial seed increase of strongly photoperiod-sensitive accessions. About 1,000 short rows were also grown for seed increase of exotic varieties, mutants, genetic testers, *O. glaberrima* strains, and wild species in different plantings.

The supply of seeds to rice researchers continued to be a principal service of the germplasm bank: 4,142 rice samples of Asian and African rices, wild taxa, and genetic testers were furnished to 198 researchers in many countries. Within IRRI 29,734 samples of Asian rices and 733 samples of other species and genetic testers were provided to GEU scientists (Table 2). Although the total number of seed samples distributed was about average for the last 2 years, the number of requests has shown a steady increase during the last decade.

With information furnished by field collectors and workers in national programs, 8,025 samples reputedly tolerant of one or more specialized problems had been assembled. An extra cycle of seed increase was often needed to provide sufficient seed for evaluation. The following special types were offered to various IRRI GEU scientists for evaluation: 86 for tolerance for adverse soils, 15 for insect and virus resistance, 352 for drought testing, 150 for cold tolerance tests, and 7 progenies of intergeneric crosses for various tests.

INVENTORY, CHARACTERIZATION, AND DATA PROCESSING

At the end of 1980, the IRRI germplasm bank had 53,431 registered accessions of *O. sativa*, 2,278 accessions of *O. glaberrima*, 961 populations of wild species or taxa, and 772 genetic testers and mutants (Table 2). Of the *O. sativa* accessions, 40,768 have been characterized for all morpho-agronomic characters; another 7,347 have been completely characterized in the field, but laboratory measurements on 8 remaining items have not been recorded. Among the *O. glaberrima* populations, 785 have been completely characterized. About 364 strains of wild taxa have been characterized. Computerized programs have been developed for the three rice categories.

Table 2. Progress of the IRRI Genetic Resources Program in the preservation and distribution of seed of *Oryza sativa* cultivars, 1973-80.

Year	Distinct accessions in germplasm bank (no.)	Samples distributed[a] (no.)	
		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[b]	29,734 (337)	3,659 (156)

[a]Numbers in parentheses indicate the number of seed requests processed. [b]About 3,167 recently received seed samples are yet to be registered; 6,986 duplicate accessions and 4,428 nonviable seed samples were removed from the registry during 1973-80.

LONG-TERM AND MEDIUM-TERM SEED PACKING AND STORAGE

A new system of seed drying and packing was perfected for safe seed preservation in subfreezing long-term storage (-10° C, 25-35% relative humidity [RH]). Another set of packed seeds was placed in medium-term storage (2-3° C, 35-45% RH), and a third set was deposited in the National Seed Storage Laboratory of the United States.

By drying seed at a moderate temperature (38° C) and feeding dehumidified and chilled air (12° C, 8% RH) into drying ovens, the seeds were quickly dried to 6% moisture content with a minimum effect of heating on seed longevity. The cooled seeds were packed in aluminum cans under partial vacuum.

During the year 2,745 accessions were canned and stored under the new process. Eight cans were placed in the medium-term storeroom and two cans were put in the long-term room.

The process and volume of packing seed for medium- and long-term storage were handicapped because:

- many samples contained a mixture of different types;
- many accessions were unadapted, or susceptible to local pests, and seed yields were low; and

- thorough seed cleaning and roguing were needed to remove diseased or poorly developed seeds and to reduce varietal mixtures in the harvested crop. This operation has further decreased the quantity of seed available for canning.

MONITORING VIABILITY OF STORED SEED

Monitoring of the viability of 3 control varieties kept at 8-9% moisture content inside glass jars and held in a medium-term storeroom (2° C ± 1° C) since March 1963 continued. The viability of 2 tropical varieties (Siam 29 and Peta) has remained at about 96% since the start of the experiment, but that of a temperate-zone variety (Chianan 8) has declined to 23%.

Among thousands of accessions kept in the short-term storeroom (20° ± 1° C, 50-60% RH), 3-year-old seeds varied greatly in their viability. The indica and javanica varieties kept their viability above 80%, but Chinese varieties of the Keng type have lost theirs.

The results confirm the importance of including different varietal types as control varieties of stored seeds harvested from different seasons. In medium- and long-term storage, several control varieties are used for each crop of conserved seed.

TRAINING OF GENETIC STOCK OFFICERS

An IRRI staff member held a 2-week training course on rice germplasm collection and conservation at the Agricultural Research Institute, Yezin, Burma, in May. He also trained field collectors in Indonesia.

Eight GEU trainees received training on various aspects of genetic conservation. Two breeders in national programs spent 3 months each on genetic resources management.

INTERNATIONAL AND INTERINSTITUTIONAL COLLABORATION

IRRI continued to serve as the principal depository for the base collection of the world's rice. Institutes in Brazil, China, Colombia, Cuba, India, Malaysia, and Thailand, as well as the IITA, IRAT, and IBPGR, sent thousands of their samples for preservation at IRRI. IRRI staff members advised national centers of Bangladesh, China, Fiji, India, Indonesia, Mexico, and Thailand plus the Centro Agronomico Tropical de Investigaciones y Enseñanza (Costa Rica) and the IITA (Nigeria) on the construction or improvement of seed storage facilities.

A systematic exchange of accession lists and characterized data with major national genetic resources centers, the IITA and IRAT, was continued for the *O. sativa* and *O. glaberrima* accessions. Such exchanges reduce redundancy in conserved stocks and minimize the possibility of overlooking accessions that carry identical names but have different ecogenetic origin.

Genetic evaluation and utilization (GEU) program

Agronomic characteristics

Agronomy, Plant Breeding, and Plant Physiology Departments

YIELD PERFORMANCE AND NITROGEN RESPONSE OF RICE VARIETIES AND SELECTIONS
Agronomy Department

Irrigated rice. Promising breeding lines and named IR varieties were evaluated at IRRI, at Philippine Bureau of Plant Industry (BPI) stations, and on farms in Laguna province.

IRRI. Table 1 shows the performance of some of the IR varieties and some promising selections at different nitrogen levels. During the dry season, a new breeding line — IR13423-17-1-2-1 — and IR44 yielded more than 7 t/ha at 150 kg N/ha, outyielding all other entries. IR17491-5-4-3-3 yielded 6.4 t/ha at 60 kg N/ha, almost 7 t/ha at 90 kg N/ha and with 4.2 t/ha outyielded all other entries in plots without fertilizer nitrogen. IR15318-2-2-2-2, IR36, IR42, IR46, and IR48 gave high nitrogen responses at 90 and 120 kg N/ha.

During the wet season, IR52 outyielded all other varieties and lines at 60 and 90 kg N/ha. IR42, IR19743-25-2-2, IR19746-28-2-2-3, and IR15538-338-1-2-3 gave grain yields of almost 4.5 t/ha at 60 and 90 kg N/ha.

BPI stations. Eight IR varieties and 10 promising breeding lines were evaluated at the BPI stations in Maligaya, Bicol, and Visayas (Tables 2-9).

During the dry season, the highest yield of 8.5 t/ha was obtained at Maligaya from IR52 at 180 kg N/ha. IR48, IR50, IR19661-131-1-2, IR19743-25-2-2, and IR13429-196-1-2-1 also yielded well. At 150 kg N/ha IR42 gave the highest yield of 8.1 t/ha. Most new breeding lines respondèd well to high rates of applied nitrogen in the dry season.

In Bicol, IR15318-2-2-2 and IR9129-209-2-2-2 responded well to 60-90 kg applied nitrogen/ha. They also outyielded the other entries in plots without fertilizer nitrogen.

In the Visayas, yield responses to applied nitrogen were rather low because of inadequate irrigation. IR15318-2-2-2, IR42, and IR54 yielded almost 6.0 t/ha at 120 kg N/ha. At zero fertilizer nitrogen, IR42 and IR15318-2-2-2 had similar yields of more than 4.0 t/ha, whereas other varieties and lines had maximum yields of similar magnitude at 120 kg N/ha.

At Maligaya and Bicol, wet season yield responses to applied nitrogen were low because of heavy rainfall and typhoons during the later stage of the rice crop; hence, lodging was heavy in plots with high fertilizer nitrogen. IR42 and IR54, however, yielded about 4.0 t/ha at zero fertilizer nitro-

Table 1. Yield of IRRI varieties and promising lines at 5 levels of nitrogen[a] in irrigated plots at IRRI, 1980.

Variety or line	Dry season						Wet season					
		Yield[b] (t/ha)						Yield[b] (t/ha)				
	Maturity (days)	0 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha	Maturity (days)	0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha
IR8	130	0.7	1.9	1.8	1.9	2.9	134	1.2	1.5	1.6	1.8	1.8
IR20	121	2.2	3.9	3.9	5.0	4.4	124	2.4	2.8	3.7	3.6	3.7
IR36	112	3.3	6.3	6.1	6.4	6.6	106	2.9	3.5	3.9	4.4	4.3
IR42	133	3.4	4.8	5.0	6.5	6.7	134	3.1	3.7	4.5	4.4	3.8
IR44	128	2.7	5.2	6.0	7.3	7.3	134	2.7	3.4	3.6	3.8	3.6
IR46	121	3.8	5.8	6.0	6.3	6.3	—	—	—	—	—	—
IR48	130	2.8	6.0	6.4	6.6	6.7	134	2.8	3.4	4.0	3.7	3.8
IR50	111	3.5	5.6	6.2	6.2	6.5	104	2.8	3.4	3.9	4.1	4.3
IR52	116	2.8	5.3	6.2	6.3	6.7	87	3.3	4.0	4.6	4.6	4.6
IR54	122	3.8	5.5	6.5	6.3	6.6	124	3.0	3.5	3.8	3.8	2.8
IR9129-209-2-2-2-3	112	2.7	4.9	5.9	6.5	6.9	105	2.8	3.5	3.8	4.4	4.1
IR13423-17-1-2-1	124	3.2	5.3	6.7	7.2	7.2	128	3.1	4.1	4.4	4.0	4.0
IR13429-109-2-2-1	111	2.9	4.9	5.6	6.1	6.1	111	3.2	3.3	3.9	4.1	4.1
IR13429-196-1-20	107	2.8	5.4	5.8	6.0	6.2	110	3.3	3.8	4.1	4.4	4.5
IR13525-43-2-3-1	107	3.0	5.2	5.6	6.0	6.1	118	3.3	4.1	4.1	4.8	4.6
IR13540-56-3-2-1	115	2.8	5.5	6.3	6.4	7.1	124	3.0	4.1	3.5	4.4	4.6
IR15318-2-2-2-2	125	3.4	5.9	6.8	6.9	6.6	124	2.9	4.7	3.6	4.1	4.0
IR19661-131-1-2	126	2.6	4.9	6.5	6.4	6.6	132	2.9	3.7	3.6	3.9	4.0
IR19729-5-1-1	101	2.5	5.0	5.3	5.4	5.6	132	3.1	3.6	3.1	3.7	3.5
IR19743-25-2-2	109	2.9	5.7	6.0	6.2	6.6	100	2.9	3.8	4.0	4.5	4.2
IR19746-28-2-2-3	103	2.7	5.5	5.8	5.9	6.1	98	2.9	3.7	4.5	4.7	4.2
Peta (traditional check)	136	2.3	3.6	4.2	4.0	3.6	138	1.7	1.4	1.2	1.5	1.6

[a]Av of 3 replications Each treatment includes 30 kg N/ha topdressed at panicle initiation in the dry season and 10 kg N/ha topdressed at panicle initiation in the wet season. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.6 t/ha, LSD (1%) = 0.8 t/ha.

Table 2. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Maligaya Rice Research and Training Center, Philippines, 1980 dry season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha	180 kg N/ha
IR8	136	3 1	5.1	6.5	6.2	6.8	6.3
IR20	119	3 2	5.8	7.1	6.7	6 8	6.8
IR36	111	3.5	5 9	6.7	6.0	7 4	6.5
IR42	133	3.7	5.8	7.9	6 9	8.1	7.1
IR48	136	3.7	6.0	6.6	6.9	7.7	7.6
IR50	110	3.0	5.9	7.1	6.6	6.9	7.6
IR52	119	3 3	5.6	7.0	7.7	7.5	8.5
IR54	129	3.2	6 0	7.3	7.7	7.6	7.2
IR9129-209-2-2-2	111	2.7	5.3	6.5	8.0	7.1	7.2
IR13429-109-2-2-1	111	3.3	5.5	6.6	6.1	7.0	6 8
IR13429-196-1-2-1	111	3.5	5 8	6.4	6.3	7.4	7.4
IR13525-43-3-2-1	111	3.3	5.3	5.7	7.2	7.6	6.8
IR15314-30-3-1-3	129	2 8	4.0	5.5	5.8	6.2	6.4
IR15318-2-2-2	108	3.2	4.4	5.8	5.8	6.3	7.2
IR19661-131-1-2	129	3.6	6.2	6.2	7.4	7.9	7.7
IR19743-25-2-2	109	3.4	5.7	6.6	7.0	6.9	7.5
IR19746-28-2-2	109	3.6	6.3	7 3	6.9	7.0	7.0
Peta (traditional check)	136	3.3	4.8	5.5	5.4	4 6	3.6

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 30 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 1.1 t/ha, LSD (1%) = 1.4 t/ha.

Table 3. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Bicol Rice and Corn Experiment Station, Philippines, 1980 dry season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha	180 kg N/ha
IR8	125	2.6	3.6	3.1	2.3	3.6	1.6
IR20	114	2.7	5.1	6.5	5.1	5.4	5.2
IR36	109	3 0	5.5	6 0	5.6	4.5	5 4
IR42	125	3 3	5.5	5 7	4.2	4.6	5.0
IR48	125	3.8	4.9	5 3	4.8	4.8	5.5
IR50	109	3.6	5.4	6.4	5.3	5.4	5.7
IR52	112	3.6	6.1	6.1	5.5	5.7	4.7
IR54	118	3.5	5.7	5.6.	5.3	5.7	5.1
IR9129-209-2-2-2	106	3.2	5.0	5.8	6.6	6.1	5.9
IR13429-109-2-2-1	108	3.3	4.6	5.5	5.3	4.7	5.5
IR13429-196-1-2-1	108	3.6	5.4	5.9	6.1	5.7	4.8
IR13525-43-3-2-1	109	3.7	6 3	5.6	5.6	5.1	4.9
IR15314-30-3-1-3	124	3.3	3.9	4.8	5.0	4.7	5.0
IR15318-2-2-2	124	4.5	6.4	6.4	6.6	5.3	3.7
IR19661-131-1-2	122	4.4	5.8	6.7	6.2	6.5	6.0
IR19743-25-2-2	104	4.0	4.4	5.1	5.3	5.6	6.3
IR19746-28-2-2	103	3.7	5.7	5.2	4.5	4.9	5.6
Peta (traditional check)	132	3.5	2.8	3.8	2.8	2.8	1.5

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 30 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 1.2 t/ha, LSD (1%) = 1.9 t/ha.

gen. IR19661-131-1-2 and IR13423-10-2-3 produced grain yields of 5 t/ha despite the adverse weather conditions at ripening stage of the crop.

Farmer's field. Six varieties and two promising breeding lines were evaluated for yield in the dry season, and four varieties and four breeding lines were tested during the wet season (Table 10). All except IR8 showed a positive response to increasing rates of fertilizer nitrogen. IR54 produced the highest yield of 7.0 t/ha at 100 kg N, followed by IR42 and IR52. These two varieties yielded well without any added fertilizer nitrogen, and gave yields of over 4.0 t/ha.

During the wet season, IR36 yielded almost 6.0 t/ha with 40 kg N/ha. IR42, IR13429-196-1-2, and IR19661-131-1-2 yielded well at the same nitrogen

Table 4. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Visayas Rice Experiment Station, Philippines, 1980 dry season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha	180 kg N/ha
IR8	129	3.5	3.8	4.5	4.8	4.7	4.2
IR20	119	3.5	3.8	5.3	4.3	3.7	3.4
IR36	109	2.6	3.9	4.4	4.8	4.4	4.2
IR42	131	4.4	4.7	5.1	5.5	5.6	4.9
IR48	132	3.7	4.8	5.2	5.1	5.0	4.8
IR50	109	3.3	5.0	5.3	5.0	4.6	4.0
IR52	116	3.2	4.1	4.4	5.0	4.5	4.0
IR54	119	3.4	4.6	5.2	6.1	5.7	5.6
IR9129-209-2-2-2	109	3.3	3.9	4.3	4.8	4.3	4.2
IR13429-109-2-2-1	107	2.9	4.3	4.3	3.8	3.7	3.4
IR13429-196-1-2-1	109	2.7	3.5	4.2	4.5	4.2	3.6
IR13525-43-3-2-1	116	2.6	4.0	5.2	4.3	4.3	4.1
IR15314-30-3-1-3	119	3.2	3.9	4.0	4.6	4.2	4.0
IR15318-2-2-2	127	4.1	4.8	5.1	5.6	5.5	5.4
IR19743-25-2-2	109	3.4	4.4	4.5	4.4	4.1	3.8
IR19746-28-2-2	104	3.2	4.3	4.5	4.4	4.2	3.8
Peta (traditional check)	134	3.3	4.2	4.3	4.1	3.8	3.4

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 30 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.9 t/ha, LSD (1%) = 1.2 t/ha.

Table 5. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Maligaya Rice Research and Training Center, Bicol Rice and Corn Experiment Station, and Visayas Rice Experiment Station, Philippines, 1980 dry season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha	180 kg N/ha
IR8	130	3.1	4.2	4.7	4.4	5.0	4.1
IR20	117	3.2	5.0	6.3	5.4	5.3	5.1
IR36	110	3.0	5.1	5.7	5.5	5.4	5.3
IR42	130	3.8	5.3	6.3	5.5	6.1	5.7
IR48	131	3.7	5.2	5.7	5.6	5.9	6.0
IR50	109	3.3	5.4	6.3	5.6	5.6	5.8
IR52	116	3.4	5.3	5.8	6.0	5.9	5.7
IR54	122	3.4	5.4	6.0	6.3	6.4	6.0
IR9129-209-2-2-2	109	3.1	4.7	5.6	6.5	5.8	5.8
IR13429-109-2-2-1	109	3.2	4.8	5.5	5.1	5.1	5.2
IR13429-196-1-2-1	109	3.3	4.9	5.5	5.7	5.8	5.3
IR13525-43-3-2-1	112	3.2	5.2	5.5	5.7	5.6	5.3
IR15314-30-3-1-3	124	3.1	3.9	4.8	5.1	5.0	5.2
IR15318-2-2-2	120	3.9	5.2	5.8	6.0	5.7	5.4
IR19661-131-1-2	125	3.8	5.7	6.2	6.4	6.7	6.3
IR19743-25-2-2	107	3.6	4.8	5.4	5.6	5.5	5.9
IR19746-28-2-2	105	3.5	5.4	5.7	5.3	5.3	5.4
Peta (traditional check)	134	3.4	4.1	4.5	3.7	3.8	3.0

[a]Av of 3 replications and 3 sites. Each treatment, except 0 kg N/ha, includes 30 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.8 t/ha, LSD (1%) = 1.0 t/ha.

level.

Rainfed wetland rice. Four varieties and eight breeding lines were tested at IRRI in rainfed wetland fields. Four varieties and four breeding lines were evaluated in a farmer's field for their suitability for rainfed rice culture.

IRRI. The breeding lines IR9217-58-2-2 and IR14632-22-3 yielded 4.5 t/ha at 60 kg N/ha. IR42, IR46, and IR48 gave similar yields. Increasing nitrogen from 60 to 120 kg/ha did not increase the yields of most varieties and lines (Table 11).

Farmer's field. IR48 gave the highest yield (5.0 t/ha) at 80 kg N/ha. At the same N level, IR42 and IR14632-22-3 yielded 4.2 t/ha and 4.4 t/ha. At 40

Table 6. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Maligaya Rice Research and Training Center, Philippines, 1980 wet season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha
IR8	122	2.9	3.9	3.7	4.1	3.9	3.2
IR20	122	3.5	3.7	3.4	3.6	3.2	2.2
IR36	109	3.8	4.1	4.3	4.7	4.0	4.2
IR42	130	3.9	4.9	4.9	5.2	4.5	5.3
IR50	108	3.7	4.6	4.4	5.1	3.9	3.1
IR54	122	3.9	5.0	4.6	5.0	4.0	3.9
IR9129-209-2-2-2	102	3.3	4.2	4.4	4.8	4.2	4.5
IR9752-71-3-2	97	3.1	3.7	4.1	4.3	4.3	4.2
IR13423-10-2-3	122	3.8	5.0	5.0	4.7	4.3	3.2
IR13429-109-2-2-1	108	3.8	4.4	4.2	4.1	3.4	3.3
IR13429-196-1-20	108	3.6	4.5	4.3	4.7	5.3	4.2
IR13429-299-2-1-3	109	3.7	4.0	4.2	4.7	4.2	3.4
IR13525-43-2-3-1	118	3.5	4.5	4.4	2.7	3.8	2.6
IR17494-32-1-1-3	126	3.8	4.8	4.6	4.7	4.5	3.4
IR19661-131-1-2	126	3.7	4.6	4.9	5.5	5.1	3.4
IR19735-5-2-3-2	97	3.2	3.7	3.6	4.0	3.8	4.1
IR19743-25-2-2	97	3.3	4.4	3.9	4.1	4.3	3.9
Peta (traditional check)	130	2.9	3.0	2.9	2.1	2.1	2.2
Mean		3.5	4.3	4.2	4.3	4.1	3.7

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation [b]For comparing variety means at the same N-rate, LSD (5%) = 0.8 t/ha, LSD (1%) = 1.4 t/ha.

Table 7. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Bicol Rice and Corn Experiment Station, Philippines, 1980 wet season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha
IR8	117	2.0	2.5	2.6	2.5	2.2	2.1
IR20	118	2.6	4.6	3.2	3.2	3.1	2.4
IR36	105	3.7	4.5	5.0	4.4	3.5	2.7
IR42	121	2.7	3.3	3.5	2.7	3.8	2.6
IR50	102	4.2	4.9	4.9	4.5	3.9	3.1
IR54	113	4.2	5.0	3.6	2.7	3.0	2.0
IR9129-209-2-2-2	98	3.1	4.8	5.3	3.4	3.4	4.1
IR9752-71-3-2	95	3.2	4.1	5.0	4.1	4.1	4.2
IR13423-10-2-3	117	4.2	4.4	4.1	3.8	3.3	2.3
IR13429-109-2-2-1	103	3.4	4.1	4.8	3.4	3.5	3.1
IR13429-196-1-20	102	3.7	4.8	4.4	3.6	2.7	3.9
IR13429-299-2-1-3	103	3.8	5.0	4.0	4.3	4.5	4.2
IR13525-43-2-3-1	112	4.2	4.7	4.8	3.8	2.8	2.3
IR17494-32-1-1-3	123	4.2	4.2	3.9	2.7	2.6	2.4
IR19661-131-1-2	117	4.0	5.2	4.7	3.1	3.3	2.8
IR19735-5-2-3-2	95	3.7	4.1	4.8	4.8	4.1	3.9
IR19743-25-2-2	96	3.2	4.2	4.2	3.9	3.4	2.9
Peta (traditional check)	134	1.4	1.3	1.3	1.1	0.9	1.3
Mean		3.4	4.2	4.1	3.4	3.2	2.9

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 1.1 t/ha, LSD (1%) = 1.4 t/ha.

kg N/ha, IR48 produced the highest yield of 4.6 t/ha. Increasing the level of applied nitrogen further did not lead to any increases in grain yield. Inadequate rainfall resulted in frequent drying of the field and low yields even at high nitrogen rates (Table 12).

IR42 without fertilizer nitrogen. IR42 was compared with four other modern varieties without fertilizer nitrogen. The data (Fig. 1) from 4 sites over 5 consecutive years (1976-80) raise the possibility of identifying rices that are efficient users of soil nitrogen.

Table 8. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Visayas Rice Experiment Station, Philippines, 1980 wet season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha
IR8	124	3.9	4.6	4.7	4.3	3.8	3.7
IR20	124	4.3	5.0	5.0	4.4	4.2	3.8
IR36	106	3.8	4.9	4.9	5.2	5.2	5.3
IR42	137	3.2	5.1	5.2	4.8	4.4	4.4
IR50	106	4.1	5.0	6.1	5.5	5.5	5.5
IR54	121	4.2	4.6	4.8	4.9	4.6	4.5
IR9129-209-2-2-2	106	4.3	5.0	5.1	4.6	4.4	4.4
IR9752-71-3-2	102	3.0	4.0	4.5	4.6	4.5	4.3
IR13423-10-2-3	124	4.3	4.8	5.1	5.0	4.5	4.1
IR13429-109-2-2-1	106	3.8	4.8	5.0	4.3	4.0	3.8
IR13429-196-1-20	106	3.3	4.0	4.6	4.9	5.2	4.9
IR13429-299-2-1-3	108	3.8	5.2	5.5	5.7	6.5	5.4
IR13525-43-2-3-1	121	4.3	5.2	5.2	5.1	4.8	4.8
IR17494-32-1-1-3-2	124	3.5	4.1	4.8	4.2	4.2	4.3
IR19661-131-1-2	124	3.7	4.2	4.4	5.0	4.8	4.7
IR19735-5-2-3-2	102	3.6	4.1	5.0	5.0	5.0	4.3
IR19743-25-2-2	102	3.5	4.2	4.7	5.1	5.2	4.8
Peta (traditional check)	137	3.5	3.8	3.2	3.2	3.0	2.0
Mean		3.8	4.6	4.9	4.8	4.7	4.4

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.9 t/ha, LSD (1%) = 1.2 t/ha.

Table 9. Yield of IR varieties and promising lines at 6 levels of nitrogen.[a] IRRI-BPI Cooperative Experiment at Maligaya Rice Research and Training Center, Bicol Rice and Corn Experiment Station, and Visayas Rice Experiment Station, Philippines, 1980 wet season.

Variety or line	Maturity (days)	Yield[b] (t/ha) 0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha	150 kg N/ha
IR8	121	2.9	3.7	3.7	3.6	3.3	3.0
IR20	121	3.5	4.4	3.8	3.7	3.5	2.8
IR36	107	3.8	4.5	4.8	4.7	4.2	4.1
IR42	129	3.3	4.4	4.5	4.2	4.2	4.1
IR50	105	4.0	4.8	5.1	5.0	4.4	3.9
IR54	119	4.1	4.9	4.3	4.2	3.9	3.5
IR9129-209-2-2-2	108	3.6	4.6	4.9	4.2	4.0	4.3
IR9752-71-3-2	98	3.1	3.9	4.5	4.4	4.3	4.2
IR13423-10-2-3	121	4.1	4.7	4.7	4.5	4.0	3.2
IR13429-109-2-2-1	106	3.7	4.4	4.7	3.9	3.6	3.4
IR13429-196-1-20	105	3.5	4.4	4.4	4.4	4.4	4.3
IR13429-299-2-1-3	107	3.8	4.7	4.5	4.9	5.1	4.3
IR13525-43-2-3-1	117	4.0	4.8	4.8	3.9	3.8	3.2
IR17494-32-1-1-3	124	3.8	4.4	4.4	3.9	3.7	3.4
IR19661-131-1-2	122	3.8	4.7	4.6	4.5	4.4	3.7
IR19735-5-2-3-2	98	3.5	4.0	4.4	4.6	4.3	4.1
IR19743-25-2-2	98	3.3	4.2	4.3	4.4	4.3	3.9
Peta (traditional check)	134	2.6	2.7	2.5	2.1	2.0	1.8
Mean	113	3.6	4.3	4.4	4.2	4.0	3.7

[a]Av of 3 replications and 3 sites. Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at the same N-rate, LSD (5%) = 0.7 t/ha, LSD (1%) = 0.7 t/ha.

YIELD POTENTIAL OF HYBRID RICE

Plant Breeding and Plant Physiology Departments

Hydrid rice research at IRRI in 1980 explored potentials and problems of this breeding approach. Four replicated yield trials during the wet season used 143 hybrids, their parents, and the commercial varieties IR36 and IR42. The results indicated that even in the tropics there is substantial heterobeltiosis for yield in some specific hybrid combina-

Table 10. Yield of IR varieties and promising lines at 4 levels of nitrogen[a] on an irrigated farm, Laguna, Philippines, 1980 dry and wet seasons.

Variety or line	Dry season					Wet season				
	Maturity (days)	Yield[b] (t/ha)				Maturity (days)	Yield[b] (t/ha)			
		0 kg N/ha	50 kg N/ha	100 kg N/ha	150 kg N/ha		0 kg N/ha	40 kg N/ha	80 kg N/ha	120 kg N/ha
IR8	125	2.5	3 6	4 7	3 9	—	—	—	—	—
IR36	106	3 9	4.4	5 3	6.1	111	3 7	5.6	5.4	5.3
IR42	125	3.4	5 4	5 6	6 6	128	4.2	4 8	4.6	4.9
IR50	105	4.3	5 5	6.0	6.2	111	3 6	4 3	5 2	4.7
IR52	110	4.1	5 5	4 8	6.5	—	—	—	—	—
IR54	110	3.7	4.7	7.0	6.9	123	3 7	3.9	3.7	2.7
IR9752-71-3-2	—	—	—	—	—	133	2.2	3 9	4 7	3 2
IR13429-196-1-2	106	3.4	4.4	4.6	5.7	145	3.6	5.1	5.4	4.8
IR19661-131-2	125	3 4	3.9	3.6	5.6	145	3.9	5 1	3 7	3 7
IR19735-52-3-2	—	—	—	—	—	142	3 1	3.0	3 9	4 0

[a]Av of 3 replications Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation in both seasons [b]For comparing variety means at the same N-rate in the dry season, LSD (5%) = 0.8 t/ha, LSD (1%) = 1 1 t/ha; in the wet season, LSD (5%) = 1.0 t/ha, LSD (1%) = 1 4 t/ha

Table 11. Yield of IR varieties and promising lines at 5 levels of nitrogen[a] on rainfed farms, IRRI, 1980 wet season.

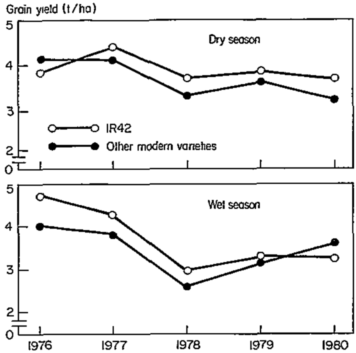
Variety or line	Maturity (days)	Yield[b] (t/ha)				
		0 kg N/ha	30 kg N/ha	60 kg N/ha	90 kg N/ha	120 kg N/ha
IR42	140	2.5	3.0	3 8	3.7	4.1
IR46	124	2 6	4.1	3.7	4.1	4.3
IR48	140	2.1	3 0	4.3	3 9	4.0
IR52	118	1.5	2.4	2.9	2.9	3.8
IR9217-58-2-2	133	2 7	3.9	4.5	4 2	4.5
IR9852-22-3	140	2.6	3.3	3.7	4 2	4.1
IR13146-41-3	133	2.7	3.7	4.2	4 2	3.6
IR13149-3-2-2	140	2.6	3 5	4.2	3 8	4.0
IR13358-85-1-3	140	2.3	3.3	4.0	3.6	3.7
IR13365-25-3-3	140	2 1	3.3	3 7	3.7	3.7
IR13419-113-1	133	2.4	3.3	3.6	4.3	4.1
IR14632-22-3	140	2.7	3.7	4.5	4.0	4 3

[a]Av of 3 replications Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at each N-rate, LSD (5%) = 0.6 t/ha, LSD (1%) = 0.8 t/ha.

Table 12. Yield of IR varieties and promising lines at 4 levels of nitrogen[a] in a rainfed farmer's field, Laguna, Philippines, 1980 wet season.

Variety or line	Maturity (days)	Yield[b] (t/ha)			
		0 kg N/ha	40 kg N/ha	80 kg N/ha	120 kg N/ha
IR42	145	2.9	4 2	4.2	4.0
IR46	133	3.8	4 1	3.1	2.6
IR48	142	3 9	4.6	5.0	3.4
IR52	123	3.0	4.0	2.6	2.1
IR9217-58-2-2	133	3.4	3.7	3.9	3.9
IR13358-85-1-3	145	3 9	4.2	2.5	3.0
IR13365-253-3-2	145	3.0	3.8	3.8	3 8
IR14632-22-3	142	3 3	4.1	4.4	3.4
Mean		3.4	4.1	3.7	3.3

[a]Av of 3 replications. Each treatment, except 0 kg N/ha, includes 20 kg N/ha topdressed at panicle initiation. [b]For comparing variety means at each N-rate, LSD (5%) = 0.9 t/ha, LSD (1%) = 1.2 t/ha.



1. Yields of IR42 and other high yielding varieties without fertilizer nitrogen at IRRI, Maligaya, Bicol, and Visayas, Philippines, during the 1976-80 cropping seasons.

tions (Table 13). The hybrids outyielded IR42, the highest yielding commercial variety, by 7-60%. Two of the hybrids, V20A/IR50 and Zhen Shan 97A/IR54, were derived from crosses made with two cytoplasmic male sterile lines introduced from China. The latter hybrid has also shown promise in the Fukien Province of China. Bulk quantities of seed of these hybrids are being produced on Hainan Island during the current dry season.

The hybrids also showed better lodging resistance despite their being slightly taller than the check varieties (Table 14). Yield, yield components, total dry matter, and harvest index from 1-m^2 plots were monitored in one of the 4 replicated trials including 5 hybrids, their parents, and IR36. The hybrids showed positive heterobeltiosis up to 30% for yield, up to 20% for spikelets per panicle, up to 8% for grain weight, up to 9% for total dry weight, and up to 9% for harvest index (Fig. 2). There was, however, negative heterobeltiosis up to 26% for panicle number. The results indicate that the hybrid breeding approach allows an increase in yield potential of rice varieties.

GROWTH DURATION

Plant Breeding Department

During 1980, a large number of entries with a growth duration of less than 100 days were evaluated in replicated yield trials. Of 368 entries, 97 (26.3%) during the dry season and 78 (21.19%) during the wet season matured in less than 100 days. Many yielded as well as, or slightly better than, IR36 although they matured 8-13 days earlier (Table 15). Their productivity per day, however, was considerably higher than that of IR36.

RATOONING ABILITY AND STEM CARBOHYDRATES

Plant Breeding Department

The changes in carbohydrate concentration in the bases of the stem and their relevance to ratoon management were evaluated in four varieties (IR36,

Table 13. Yields of promising hybrids compared to yields of commercial varieties IR36 and IR42, and better parents. IRRI, 1980 wet season.

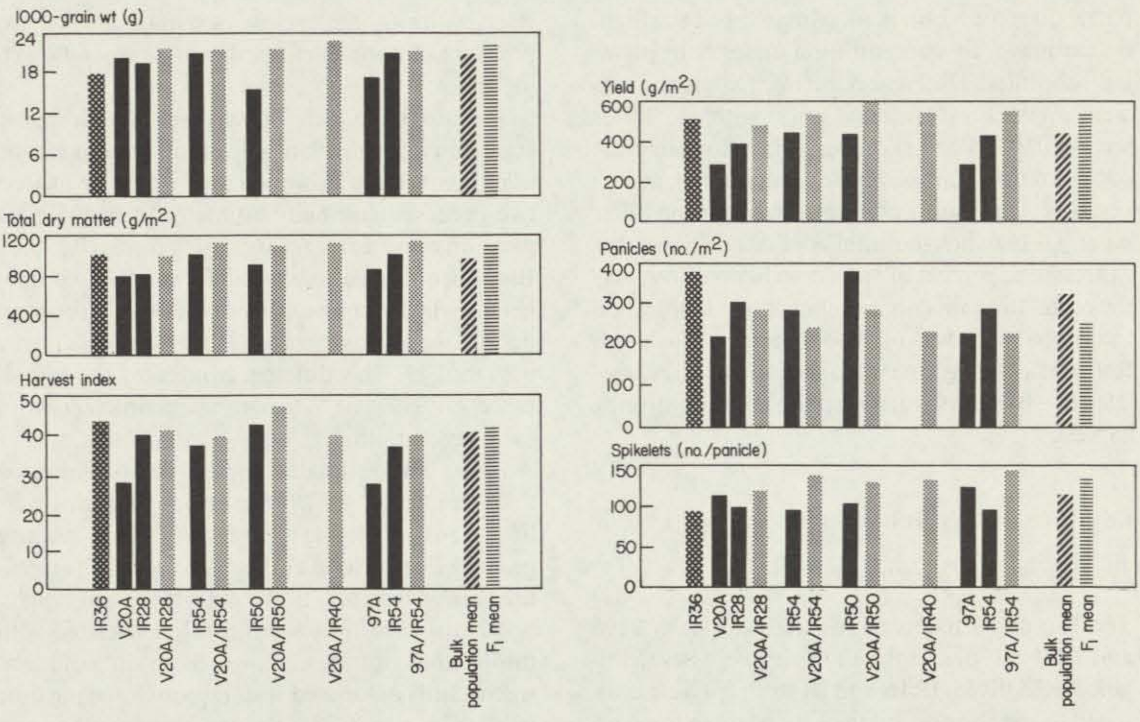
Hybrid	Days to flowering	Yield (t/ha)	% increase over IR36	% increase over IR42	% increase over Better parent[a]
IR11248-242-3-2*/IR15323-4-2-1-3	91	5.9	69	22	35
IR11248/IR15496-219-2-3	83	5.8	65	19	—
IR11248*/IR19672-19-3	93	5.5	57	14	25
IR11248*/IR15324-117-3-2-2	90	5.4	54	12	23
IR10154-23-3-3/IR54*	79	5.6	21	20	50
IR747B2-6-3/IR54*	81	5.5	18	17	46
IR10154-23-3-3/IR2797-105*	81	5.0	8	7	31
IR11248-242-3-2/IR9828-41-2-1*	89	5.4	22	60	28
V20A/IR50*	71	5.2	29	25	28
Zhen Shan 97A/IR54*	91	5.2	28	24	60

[a]The better parent is indicated by an asterisk (*) in the hybrid cross.

Table 14. Yield and agronomic characteristics of some F_1 hybrids compared to those of their parents and commercial varieties. IRRI, 1980 wet season.

Hybrid or variety	Yield (t/ha)	Growth duration (days)	Height (cm)	Lodging (%) at growth stages[a] 4	6	7	9
		Hybrids					
97A/IR54	5.2	121	126	0	0	0	75
V20A/IR50	5.2	101	118	0	0	15	95
V20A/IR54	4.6	120	125	0	0	0	5
V20A/IR40	4.9	119	117	0	0	0	5
V20A/IR28	4.0	102	117	0	0	0	85
Mean	4.8	113	121	0	0	3	53
		Parents					
IR54	3.3	127	121	15	25	40	100
IR50	4.1	105	117	0	0	95	100
IR28	3.5	105	121	0	0	50	100
97B	2.7	97	112	0	0	0	0
V20B	2.5	99	110	0	0	0	0
Mean	3.2	107	116	3	5	37	60
		Commercial varieties					
IR36	4.1	113	102	0	35	100	100
IR42	4.2	135	118	0	0	0	100
Mean	4.1	124	110	0	18	50	100

[a]4 = booting, 6 = 50% flowering, 7 = dough, 9 = maturity.



2. Some agronomic and physiological characteristics of hybrids compared with those of their parents and commercial variety IR36, IRRI. 1980.

Table 15. Yield of early-maturing entries in the replicated yield trials grown at IRRI during the 1980 dry and wet seasons.

Selection	Cross	Growth duration (days)	Dry season		Wet season	
			Yield (t/ha)	Yield per field day[a] (kg)	Yield (t/ha)	Yield per field day (kg)
IR9752-71-3-2	IR28/Kwang Chang Ai//IR36	99	5.70	75.0	4.33	56.8
IR9729-67-3	BG34-8/IR28//IR36	101	5.54	70.8	3.64	46.6
IR15429-268-1-2-1	74-5461/IR36//IR747B2-6	99	5.25	69.0	4.51	59.3
IR19728-6-3-2-2-3	IR8608-298///IR747B2-6/Ai-nan Tsao 1// IR747B2-6	100	5.18	67.2	4.00	51.9
IR19743-25-2-2-3-1	IR9129-192-2///IR747B2-6/29 Lu 1// IR747B2-6	98	4.74	63.2	4.09	54.4
IR19743-46-2-3-3-2	IR9129-192-2///IR747B2-6/29 Lu 1// IR747B2-6	99	4.98	65.3	3.82	50.1
IR19746-28-2-2-3	IR9129-192///IR747B2-6/Kwang Chang Ai// IR747B2-6	99	5.14	67.5	3.95	51.8
IR19774-23-2-2-1-3	IR9698-26-3///IR747B2-6/29 Lu 1// IR747B2-6	95	4.55	63.1	4.23	56.4
IR19819-31-2-3-1-1	IR9715-4///IR747B2-6/29 Lu 1//IR747B2-6	95	4.85	67.2	3.89	54.0
IR36	IR1561-228-1-2/IR1737///CR93-14	108	5.76	63.8	3.83	47.5

[a]23 days in the field.

IR42, IR46, and Mingolo) grown under two planting schedules (simultaneous planting and staggered planting for simultaneous flowering).

All varieties showed a rapid decrease in carbohydrate concentration after anthesis, but the rate of decrease varied among them. The differences were partly due to environment. Mingolo had the highest carbohydrate concentration under both planting schedules. Differences between stem sections were apparent at anthesis only, with the lower section (0.0-7.5 cm) showing higher carbohydrate concentration. Carbohydrate concentration at harvest was significantly correlated with ratoon tillering ($r = 0.26$) when the number of ratoon tillers was expressed as percent of main crop tillers. However, the correlation was nonsignificant ($r = 0.08$) when the actual number of ratoon tillers was used. Ratoon flowering time was also significantly correlated ($r = 0.29$) with carbohydrate concentration at harvest.

GENETICS OF RATOONING ABILITY

Plant Breeding Department

The F_2 and F_3 plants of two crosses (IR36/2196 and IR46/2196) and the F_4 of three crosses (Mingolo/IR36, IR36/IR46, and IR46/2123) were evaluated to test the possibility of breeding to improve ratooning ability. Evaluation in the F_2 was done under a competitive environment (20 × 20-cm spacing and 10-cm main crop cutting height) to study the effectiveness of early generation selection. The ratooning ability of 405 F_4 lines (135/cross) was evaluated using a 15-cm cutting height to determine the nature of the genetic variability and possible phenotypic and genotypic associations of selected traits influencing ratooning ability, expressed as ratoon tiller number and ratoon flowering time.

Evaluation in the F_2 favored late flowering segregants. Single-plant selection for both ratoon tiller number and flowering time would be ineffective because heritability estimates from F_3-F_2 regression were nearly zero (ranging from 0.0 to 0.8). But when calculations used F_3 variance components, which removed genotype × environment interaction effects, heritability values ranged from 0.26 to 0.43. This difference indicates the importance of genotype × environment interaction in early generations.

Heritability estimates in the F_4 plants for ratoon tiller number ($h^2 = 0.28$) and ratoon flowering time ($h^2 = 0.56$) were found to be entirely due to additive genetic effects. None of the main crop traits measured (tiller number, flowering time, plant height, and grain yield) was significantly associated with ratoon tiller number. However, grain yield was significantly associated with ratoon flowering time ($r_p = 0.24$, $r_g = 0.33$). Ratoon tiller number and ratoon flowering time were negatively correlated ($r_p = -0.20$, $r_g = -0.37$).

Selection for slow senescence and late ratoon flowering is recommended for ratoon improvement.

SOURCES OF SEMIDWARFISM

Plant Breeding Department

The search for new sources of semidwarfism continued to broaden the genetic base of the improved semidwarfs, which have primarily the same sd_1 gene derived from Dee-geo-woo-gen. During 1980 seven short/short crosses were evaluated and the F_2 plants were compared with their parents. Reimei of Japan and IRAM 2165 of Malagasy turned out to have nonallelic genes for short stature, while four other parents — Barmda 21, 23, and 828, and KH 863 from India — shared the same recessive gene. Jaganath, a short mutant from the tall T141 variety, had the same compound locus of the sd_1 gene.

To date about 70 semidwarf/semidwarf crosses have been made and studied. More than 40 sources of semidwarfism are nonallelic to the sd_1 gene; others are either identical or belonging to the same compound locus.

RELATION BETWEEN JAVANICA RICES AND TRADITIONAL DRYLAND VARIETIES

Plant Breeding Department

The javanica race of Indonesia (the awned *bulu* and awnless *gundil* types) shares several morpho-agronomic features common with the traditional dryland varieties of Southeast Asia — tall stature, low tillering, thick culms, long and well-exserted panicles, large and bold grains, insensitivity to photoperiod, and nonshattering habit. However, the javanica rices are grown exclusively in irrigated fields, and the dryland varieties are planted on rainfed well-drained soils. The dryland varieties have markedly higher levels of drought resistance than the bulu rices.

A number of crosses between the two types were made to understand their genetic relationship. The dryland varieties were crossed with the aus varieties of Bangladesh; the latter group has been postulated to be closely related to the temperate zone varieties of East Asia. Three F_2 populations along with their F_1 plants and parents were grown in the wet season.

The greater range in heading date of the segregation of F_2 plants was greater in two bulu/dryland crosses than in the aus/dryland cross. For tiller number, the aus/dryland cross showed a wider range. Culm length in the three crosses was similar. For panicle length, one bulu/dryland cross showed a rather narrow range of segregation; the other cross was similar to the aus/dryland cross.

Other traits such as spikelet fertility, grain dimensions, and chromosomal behavior are being investigated. The root systems of the bulu and dryland varieties will be compared for a critical analysis of their genetic relationship.

Genetic evaluation and utilization (GEU) program

Grain quality

Chemistry and Plant Breeding Departments

BREEDING PROGRAM

Plant Breeding and Chemistry Departments

Selection of lines with intermediate amylose content and intermediate gelatinization temperature continued. The proportion of lines with intermediate amylose content in advanced-generation materials increased greatly. In most of the crosses during 1980 at least one parent had intermediate amylose content. The parents were mainly lines with improved plant type and multiple disease and insect resistance. Some, such as IR4215-301-2-2-6 and IR9129-209-2-2-2, inherit intermediate amylose content from C4-63, whereas IR48 and IR4570-124-3-2-2 inherit this trait from BPI-121-407. IR9129-209-2-2-2 was evaluated in advanced yield trials as a possible intermediate-amylose variety.

Numerous breeding lines from crosses involving aromatic-grain parents such as Basmati 370 and Khao Dawk Mali were evaluated. Many lines from Basmati 370 crosses had highly aromatic grains but most had poor plant type. Khao Dawk Mali was a good combiner for aroma and plant type. Several lines from Basmati 370 crosses had as good grain elongation as the Basmati 370 parent.

STORAGE AND MILLING

Chemistry and Plant Breeding Departments

Quality of rough rice *(Chemistry and Plant Breeding).* Preliminary experiments studied the physical properties of 1979 dry and wet season crops of IR8 and 10 more recent varieties — IR36-IR52 — harvested 25-38 days after flowering (DF). The hull ranged from 19.4% for IR36 to 24.0% for IR42 (mean 21.9%). Green grains ranged from 5 to 44% of brown rice (mean 14.9%). The percentage of green grains was lowest for IR42 and highest for IR48. Kett whiteness readings of brown rice ranged from 19 to 25%.

Moisture distribution within a panicle *(Chemistry).* Studies were started on varietal differences in IRRI rices in relation to storage quality of freshly harvested wet grain. Moisture distribution within a panicle was studied in IR8, IR36, IR42, and H4 (dormant) rough rice 21 DF.

For six panicles, grain moisture content ranged from 19 to 57% for IR8, 21 to 71% for IR36, 16 to 53% for IR42, and 16 to 64% for H4. The mean moisture content of grains in the same primary branch of the panicle had these ranges: 28-42% for IR8, 27-47% for IR36, 20-37% for IR42, and 25-33% for H4. The lower branches had higher grain moisture content. The actual weight percentages of immature or green grains at 21 DF were 24.9 (IR8), 28.2 (IR36), 19.7 (IR42), and 9.8 (H4).

The moisture distribution among primary branches in the panicle of 3 photoperiod-insensitive and 1 photoperiod-sensitive BKN6986 lines (6 panicles at 21 DF) was 25-30% moisture for BKN6986-20, 21-32% for BKN6986-27, 20-27% for BKN6986-71, and 23-27% for BKN6986-147-2 (RD19, photoperiod sensitive). Ranges of moisture contents among individual grains were 18-40%, 16-41%, 15-33%, and 15-32%, respectively. Percentages of green grains were 10.4, 10.4, 0, and 0.

Yellow grains *(Chemistry).* Yellowing of the endosperm has been observed in the wet-season crop of IR36 in Central Luzon, Philippines, particularly with delay in drying of the threshed crop. One milled sample obtained through the National Grains Authority had 70% yellow grains. Comparisons indicated that most of the yellow grains were whole, but the white grains had a high percentage of brokens. One-hour alkali spreading tests revealed that the yellow grains were not gelatinized (parboiled). They had higher final gelatinization temperature (GT) — 75.5° vs 72.5° C — than white grains. They also had harder raw grain by the Wig-L-Bug amalgamator (62 vs 52% retained by 80-mesh sieve after 40 seconds grinding) and higher Kiya breaking hardness (6.2 vs 4.8 kg/mm^2). The two grain types had identical amylose contents (28.4%) and cooked rice Instron hardness (8 kg). A rough rice sample with 100% yellow grains had only 6% viability, the embryos were dark, and the milled rice was almost all brokens, suggesting prior contact with water. The yellow color turned to tan on storage.

Methods for degree of milling *(Chemistry).* IRRI chemists participated in the International Association for Cereal Chemistry study group 21 on degree of milling of rice. The samples were two Spanish rices (Bahia and Sequial), two IRRI rices (IR36 and IR29), and one parboiled rice. The methods compared were weight reduction of brown rice, a colorimetric bran pigment test, and the May-Grünwald staining test based on grain surface area still covered by bran.

Bran removal was 9.2-14.0% by weight of brown rice in the well-milled samples based on 100-grain weight, bran pigment removal was 68.5-87.5% by colorimetric method, and residual bran was 2.6-7.6% by the staining method.

No loss of precision results from direct reporting of absorbance at 400 nm, instead of expressing as a percentage of brown rice absorbance; absorbance ranged from 2.16 to 3.11 for brown rice and from 0.27 (87.5%) to 0.98 (68.5%) for well-milled rice. The parboiled brown-rice sample had the highest pigment absorbance, followed closely by IR36. Bran removal of 10% by weight corresponded to absorbance of 0.4 to 1.0, pigment removal of 57-84%, and May-Grünwald values of 0-16% bran surface. A major drawback of the May-Grünwald method using planimetry was the tediousness of measuring the bran area.

VARIETY PREFERENCE TESTS AND SURVEYS

Chemistry Department

Filipino consumer preference tests. A consumer panel survey by the Institute of Human Ecology, University of the Philippines at Los Baños, in Batangas province, Philippines, revealed preference for raw nonwaxy rice based on white, hard, and aromatic grains, and for cooked nonwaxy rice with slightly strong aroma, slightly rich flavor, and moderately tough cooked grain in decreasing order of importance.

Consumer ranking showed low preference for IR2071-137-5 as raw rice in two tests (Table 1). Possible reasons are its short and semiopaque grains. White-belly-grained Early Tongil in one test was also least preferred.

The tests confirmed the preference for low-amylose over intermediate-amylose cooked rice (Table 1). IR24 was well-liked, but the Korean variety Milyang 23 got a slightly better rating. The results suggest that japonica rices may find acceptance in tropical Asia because of their acceptable cooked rice texture. Their grains elongate and approach indica rice in length of cooked grain.

The consumer panel's reasons for choice of the best waxy rice for the preparation of rice cakes were, in order of decreasing importance, aromatic, whole-big grain and rich flavor for raw rice sample; and cohesive, aromatic, and rich flavor for rice cake sample, prepared with coconut milk.

Consumer tests again showed preference for the raw grain of the traditional variety Malagkit Sungsong over the slender IR29 grain (Table 2). For the corresponding rice cakes cooled overnight, Malagkit Sungsong was also preferred, but the short-grain Korean rice Iri 344 was significantly better than IR833-6-1. Malagkit Sungsong gave the hardest rice cakes. Hardness was confirmed by the regular OTMS (Ottawa Texture Measuring System) cell with 9 times the cross sectional area of the modified cell. Although neutral gel consistency did not reflect that hardness, Malagkit Sungsong had a high Amylograph consistency. The UPL-Ri-1 sample had extremely low Amylograph viscosity.

Table 1. Mean preference scores (in order of decreasing preference for boiled rice) by consumer panels in a village at Lemery, Batangas, Philippines, and properties of 2 sets of 5 raw and boiled milled rices. Institute of Human Ecology, University of the Philippines at Los Baños, and IRRI, 1980.

Sample name	Mean preference score[a] Raw	Mean preference score[a] Boiled	Amylose (% dry basis)	Protein (%)	Gel consistency (mm)	Alkali spreading value	Length-width ratio	100-grain wt (g)	Boiled rice hardness (kg)
				Thirty panelists					
IR24	0.31 a	0.74 a	16.0	8.0	75	7.0	3.0	2.0	5.1
IR43	0.61 a	0.26 b	16.6	9.8	58	7.0	3.3	1.8	5 4
IR2071-137-5	−0.34 b	−0.23 c	12 8	9.4	82	3 5	2.7	1 4	5.2
C171-136	−0.24 b	−0.28 c	22.6	8.8	48	4.8	2.8	1.8	6.6
IR9129-209-2	−0.34 b	−0.49 c	22.4	10.5	40	5.0	3.2	1.7	7.2
				Forty panelists					
Milyang 23	0.39 a	0.41 a	17.6	8.9	60	7.0	2.4	1.9	5.0
IR24	0.57 a	0.22 a	17.0	9.2	67	6 8	3.0	1.8	5 7
Early Tongil	−0.71 c	0.13 a	18.8	9 4	56	7.0	2.2	1 7	5 2
IR43	−0.26 b	−0 34 b	17 6	8.0	61	6.9	3 0	2.0	5.1
IR2071-137-5	0.02 b	−0.42 b	16.7	10.0	40	3 5	2.7	1 3	6.7

[a]Based on 1st = 1.16, 2d = 0.50, 3d = 0, 4th = −0.50, and 5th = −1.16. Separation of mean scores within the same set by Duncan's multiple range test at the 5% level.

Table 2 Mean preference scores (in order of decreasing preference for rice cake) by 40 consumers in a village at Lemery, Batangas, Philippines, and properties of 5 raw, waxy[a] milled rices and rice cakes prepared with coconut milk Institute of Human Ecology, University of the Philippines at Los Baños, and IRRI, 1980.

Sample name	Mean preference score[b]		Protein (%)	Neutral gel consistency (mm)	Length-width ratio	100-grain wt (g)	Boiled rice hardness[c] (kg)	Cake hardness[d] (kg)	Amylograph consistency[e] (BU)
	Raw rice	Cake							
Iri 344	0.12 ab	0.29 a	8.7	69	2.2	1 8	3.7	1 6	85[e]
UPL-Ri-1	0 03 ab	0.06 ab	8.2	46	2 5	2 2	3.2	1.4	30
Malagkit Sungsong	0.17 a	−0 05 ab	7.1	77	1.7	1.8	4.4	2.9	165
IR29	−0 27 b	−0.12 ab	8 0	55	3.0	1.5	3.8	2.2	170
IR833-6-1	−0.05 ab	−0.16 b	9.5	48	2.7	2.1	4 2	1.8	60

[a]Amylose content 1.4-1.8% dry basis. Alkali spreading values 6.4-7.0. [b]Based on 1st = 1.16, 2d = 0.50, 3d = 0, 4th = −0.50, and 5th = −1.16. Separation of mean scores within the same set by Duncan's multiple range test at the 5% level. [c]Rice cooker method [d]From cake actually panel-tested [e]12% pastes.

Rice cakes were softer than boiled waxy milled rice prepared by the rice cooker method.

A trial international preference test with 30 GEU trainees and IRRI employees representing various nationalities was conducted for IR nonwaxy rices representing the various amylose-GT types. IR42 was ranked poorer than IR43 in raw form probably because of its shorter grain (Table 3). Ranking for the cooked rices showed a similar trend reflecting the diverse eating qualities of the rice in the respondents' homeland.

Properties of country samples. In 1980, rices from Chile, Egypt, El Salvador, India, Indonesia, Nigeria, Pakistan, and Philippines were analyzed for grain quality properties. The protein content of the samples ranged from 5.0 to 12.4%.

The Bangladesh rices had mainly high amylose and soft gel (Table 4). The samples from Chile had intermediate amylose, low GT, and soft gel. The Egyptian rices represented all three amylose types but had low GT. The El Salvador rices were similar to those from Chile, but two had high amylose content. Samples from All India Coordinated Rice Improvement Project, Hyderabad, India, were mainly high-amylose but differed in GT and gel type. Nigerian samples were the raw rices corresponding to parboiled samples analyzed in 1979. The gel values for raw rice was generally harder than for parboiled rice as previously noted for Sri Lankan rices (Annual report for 1979).

Indonesian rices. Two crops of two bulu and two indica rices from Indonesia were characterized for physicochemical properties, together with 18 other varieties grown in Indonesia and 3 B2791b-MR lines grown at IRRI. Nineteen of them had been organoleptically assessed at Central Research Institute for Agriculture (CRIA), Sukamandi, for taste, texture, and aroma.

Among 11 bulu (javanica) varieties, 8 had the characteristic intermediate amylose, 2 had high amylose (Jedah and Kencana Muara), and 1 had low (Mandolin). Most of them had low GT and

Table 3. Mean preference scores by 30 GEU trainees and IRRI employees[a] and properties of 5 raw and cooked rices. Institute of Human Ecology, University of the Philippines at Los Baños, and IRRI, 1980

Variety or line name	Mean preference score[b]		Amylose (% dry basis)	Protein (%)	Gel consistency (mm)	Alkali spreading value	Whiteness of raw rice	Grain length (mm)	Cooked rice	
	Raw	Cooked							Hardness (kg)	Stickiness (g·cm)
IR43	0.28 a	0.10 a	16.6	9.8	58	7.0	38	6.8	6 2	186
IR48	−0.13 ab	0 21 a	23.3	8 4	38	7.0	41	7 3	8 2	135
IR9129-209-2	0.07 ab	−0 02 a	22.4	10.5	40	5.0	38	6.6	6.3	122
IR32	0.07 ab	−0.23 a	28.2	8.1	100	4.7	40	6 4	10.8	108
IR42	−0 28 b	−0.10 a	28.7	8.4	32	7.0	38	5.7	10.3	94

[a]5 Bangladeshis, 6 Chinese, 1 Dominican, 4 Filipinos, 2 Indonesians, 1 Indian, 1 Korean, 1 Malaysian, 1 Mexican, 1 Nepalese, 1 Pakistani, 1 Sinhalese, 2 Sri Lankans, and 3 Thais. [b]Based on preference score of 1st = 1.16, 2d = 0 50, 3d = 0, 4th = −0.50, and 5th = −1.16. Separation of mean scores within the same column by Duncan's multiple range test at the 5% level.

Table 4. Range of milled-rice properties of country samples. IRRI, 1980

Source	Sample no.	Protein (%)	Amylose type[a]	GT type[b]	Gel type[c]
Bangladesh	9	7.3- 9.8	H > I	I, L > H	S > M, H
Chile	4	8.3-10.3	I	L	S
Egypt[d]	10	5.7- 7.8	L, I, H	L	S > M
El Salvador	7	6.8-10.8	I > H	L > I	S > M, H
India	10	6.7-11.2	H > I	I > L	S, H > M
Indonesia					
Bulu	11	5.0-10.7	I > L, H	L > I > H	M, S > H
Tall indica	7	6.1-10.9	I > H	I	M, S, H
Semidwarf indica	6	8.0- 9.6	I > H	I > L	S > M
Nigeria	28	6.2-10.7	H > I	L > I	H > M, S
Pakistan					
Dokri fine	7	6.5- 8.9	I	I > L	H > M
coarse	12	6.0- 9.6	H > I	L > I	H > S, M
Punjab[d] fine	17	7.3-10.8	I > H	L > I	H > M
coarse	11	7.8-12.4	H > I	L > I	H > M
Philippines					
Waxy	7	6.7- 8.7	waxy	L > H	S
Nonwaxy	7	7.3- 8.9	I > H	I > L, H	M > S

[a]H = high, >25%; I = intermediate, 20-25%; and L = low, <20%. [b]Gelatinization temperature (GT) type based on alkali spreading value L = low, 6-7; I = intermediate, 4-5; H = high, 2-3 [c]Gel consistency S = soft, 61-100 mm; M = medium, 40-60 mm; H = hard, 27-40 mm [d]Mainly selections.

soft or medium gel (Table 4). The tall indica rices had either intermediate or high amylose and were of intermediate GT and variable gel type. The semidwarf indicas had also either intermediate or high amylose, intermediate or low GT, and soft or medium gel type. The survey reflected Indonesian preference for intermediate-amylose rice and for soft-gel type among high-amylose rices.

Stickiness (81-196 g·cm) and hardness (5.6-8.2 kg) of cooked rice overlapped among the javanicas and indicas. Organoleptic tests at CRIA showed that samples with medium to good rating for taste, texture, and aroma of cooked rice had intermediate amylose. Amylograph setback and consistency were higher for high-amylose milled rices than for intermediate and low types.

Among starches prepared from Indonesian milled rices, alkali viscogram peak viscosity of 2% pastes was higher for high-amylose starches (138-180 cps) than for low-amylose starches (94-118 cps). Gel consistency of starch was hard (<40 mm) for all high-amylose samples.

Pakistani rices. A set of Dokri- and Punjab-grown fine and often aromatic varieties, and coarse nonaromatic varieties were characterized for grain properties.

Of the 11 Punjab coarse-grain samples, most were high amylose except for one intermediate-amylose line, and all had hard or medium gel consistency (Table 4). All except one had low GT. Of the 17 fine-grain samples, only 4 were high amylose and the rest were intermediate amylose. GT was mainly low except for a few intermediate GT samples. Gel consistency was hard even for the Basmati 370 check sample.

The Dokri fine rices all had intermediate amylose content and hard gel consistency, but Basmati 370 had medium consistency (Table 4). Most had intermediate GT. The coarse rices had intermediate to high amylose contents. The elongation of cooked fine and coarse rices presoaked for 30 minutes and boiled for 10 minutes were compared. The elongation ratios of the two groups overlapped. Some Basmati rices had extremely soft cooked rices. Grain elongation may have contributed to lower bulk density of cooked rice during the extrusion step of hardness assay. Among the coarse varieties, the IR8 sample was softer than the IRRI 6 sample.

The Pakistani fine varieties showed extremely harder gels for their intermediate-amylose types. GT of the five varieties was higher in the Dokri samples than in the Punjab samples as earlier noted (Annual report for 1971).

Philippine rices. The study of starches in two crops of seven intermediate-amylose and seven waxy rices (Annual report for 1979) was completed. Among the intermediate-amylose starches, those of softer cooked rice had GT ⩾ 70°C, medium to soft gel (110 mg/2 ml) consistency, low alkali viscograph peak viscosity, and greater Amylograph breakdown and lower Amylograph setback and consistency than low-GT starches. A 12% paste of milled rice gave better differentiation in Amylograph viscosity than 10% paste.

Among the waxy starches, gels of low-GT samples were confirmed to have greater freeze-thaw stability than gels of high-GT samples.

INTERNATIONAL COOPERATIVE TESTS ON METHODS

Chemistry Department

Follow-up cooperative tests recommended by the 1978 IRRI workshop on chemical aspects of rice grain quality and performed in 1979 were analyzed and reported in 1980.

The scoring methods for alkali digestibility of milled rice in 1.1, 1.4, and 1.7% KOH by Little and coworkers and by Bhattacharya were compared in a 1979 international cooperative test involving 11 laboratories and 5 samples differing in GT. The data indicated that results by both methods were comparable, and 1.7% KOH gave the best varietal differentiation among the KOH levels used. Major sources of variation were variety, KOH concentration, and scoring method. Use of different KOH concentrations affected the scores of the three samples of intermediate-alkali reaction.

Analysis of the results from 9 cooperating laboratories that used the modified simplified assay for amylose showed that defatted starch (90 mg) and defatted milled rice (100 mg) of 5 nonwaxy rices differing in amylose content gave identical values for samples with >20% amylose. But among samples with <20% amylose, defatted milled rice gave 2 percentage points lower amylose values. Undefatted milled rice generally gave 1.5 to 4.0 percentage points lower mean amylose values than defatted milled rice. Phosphate buffer 0.007 M (pH 8) gave a more stable bluish starch-iodine color than 0.004 M phosphate buffer and is proposed as a substitute for acetate buffer, which gives a greenish starch-iodine color. The use of amylose-amylopectin mixture for the standard curve at IRRI resulted in identical amylose data by the method of Williams et al, the simplified method using acetate buffer, and the simplified method using phosphate buffer for the six defatted milled rice flours.

The data on hardness or stickiness, or both, of 10 cooked milled rices were analyzed using various instrument methods that had been developed specifically for national samples. The rices represented the range of rice texture and were cooked in excess water in 11 laboratories. Instrument indexes for hardness and stickiness of cooked rice generally were more sensitive than the corresponding scores by a laboratory panel of 5 in discriminating among the 10 samples. Variation among samples accounted for 60.5-99.5% (mean 92.1%) of the total variation for instrument hardness as against 48.9% for panel score for hardness. Corresponding values for stickiness were 91.8-98.6% (mean 95.3%) for instrument methods and 64.2% for panel score.

Instrument indexes for hardness correlated positively with each other, as did those for stickiness. Most hardness indexes showed significant negative correlation with stickiness indexes. Among four eating quality indicators tested — protein, amylose, alkali spreading value, and gel consistency — amylose content had the most consistent correlation with hardness and stickiness values of cooked rice (positive with hardness and negative with stickiness). Thus, the continued use of amylose content as an index of eating quality in the rice breeding program is justified, and only promising selections need to be checked for actual texture of cooked rice.

Although the various instrument methods gave significantly correlated values for hardness and stickiness of individual grains, data obtained from bulk samples were more reproducible because of the wide variation of properties among grains.

FACTORS THAT AFFECT COOKED RICE QUALITY

Chemistry Department

Comparison of cooking methods. The laboratory cooking method using excess water and optimum cooking time per sample, and the modified rice cooker method were compared. The modified rice cooker method is similar to the original method in using fixed water-rice ratio for each amylose type (waxy 1.3, low amylose 1.7, intermediate amylose 1.9, and high amylose 2.1), but uses 200 ml water in the outer pot and boiling for 20 minutes. The method gave more reproducible water contents for each amylose class than the original method. The correlation coefficient between hardness and stickiness of cooked rice using a food tester was -0.79** in the excess water method and -0.90** in the rice cooker method.

The water contents of 10 cooked rices used in the international cooperative test on cooked rice texture were compared. Rices cooked in excess water had 70.5-75.8% water content (mean 73.7%), and rices cooked in the electric cooker had 59.5-70.4% (mean 66.0%). Mean cooked rice hardness in the excess-water method was 3.95 kg compared to 5.62 kg in the cooker method. Stickiness values were also lower. When water-rice ratio was adjusted to the calculated constant ratio of 2.46 to achieve 73.7% water content, 4 rices representing the amylose types achieved 73.5-73.6% water content and a mean hardness of 3.85 kg, compared to 73.2-75.8% water content and mean hardness of 3.65 kg for rices cooked in excess water. Hardness values corresponded better to amylose types in the revised cooker method (range 2.2-5.8 kg) than in the excess water method (2.7-4.7 kg).

Gel consistency test in water. Because of the observed tendency for a few milled rice samples to have hard gel consistency (in 0.2 N KOH) during prolonged storage (over 4 months) after harvest (Annual report for 1979), efforts were made to develop a water-solvent system for the gel test that will be identical to actual cooking conditions of rice in water. Studies showed that gel values were affected by the dye and the salt concentration and even the pH of the water. Moreover, the steam evolution that results in mixing, which enables the solution level to reach 3/4 of the test tube in 0.2 N KOH, was absent in the water medium. Addition of one 4-mesh alumina granule improved the mixing of 100 mg flour in 2 ml water at 100° C for 15 minutes.

Further evaluation of the water gel consistency test is in progress because more flour (110-120 mg) was needed to differentiate among high-amylose rices than among low- and intermediate-amylose rices (90-100 mg). The opposite is true with 0.2 N KOH. A high flour weight (150-200 mg) was also used for waxy rice flour. Relative rankings in the two solvents for both milled rice and starch were not similar.

Starch properties and gel consistency. Earlier studies suggest that differences in gel consistency and viscosity were due mainly to amylopectin, particularly to differences in amylopectin molecular size. Chemists at Carlsberg Research Center, Copenhagen, confirmed that the fine structure of two sister line pairs of waxy and nonwaxy rice amylopectins from IRRI was similar. The ratio of A chains to B chains (1.1-1.4) was similar to that of other cereal amylopectins. Hence, waxy rice amylopectin may be used as a model for nonwaxy amylopectin.

Molecular weight (MW) estimation of rice amylopectins by sedimentation coefficient ($S_{20,w}$) using the analytical ultracentrifuge confirmed the higher MW of the two high GT waxy starches (RD4 187 S and C441-1 188 S) compared to that of four other low-GT waxy starches (RD2 16 S, Malagkit Sungsong 105 S, IR29 116 S, and UPL-Ri-1 126 S). The results with nonwaxy rices were not as clear-cut. Amylopectins of two Korean rices had similar $S_{20,w}$ values (20-22 S) although Tongil had a harder starch and milled-rice gel than Jinheung (Annual report for 1979). For four high-amylose IR rices, $S_{20,w}$ values were 42 S (IR5), 54 S (IR8), 67 S (IR32), and 90 S (IR42). IR5 and IR32 are soft-gel rices and IR8 and IR42 are hard-gel rices, so that the relationship was not strictly related to MW.

Amylopectins derived from high-amylose rices by the alcohol-amylose crystallization method are relatively impure and have high iodine blue colorations that sometimes approach that of starch. Blue values tended to be higher in hard-gel amylopectins than in soft-gel. Use of Sepharose CL-2B for MW fractionation of the starch also resulted in amylopectins at the void volume (V_o) still with high iodine blue binding. The results suggest that the blue coloration of amylopectin preparation could not be due to low MW amylose whose complex with alcohol may contaminate the amylopectin fraction during amylose crystallization. Gel filtration should have resulted in a purer amylopectin. Isoamylase treatment of the amylopectins and subsequent gel filtration on Sephadex G-50 confirmed the presence of at least 5-7% linear fraction that stained blue with iodine and with at least 48 glucose units. These amylose-type chains may be part of the amylopectin molecule.

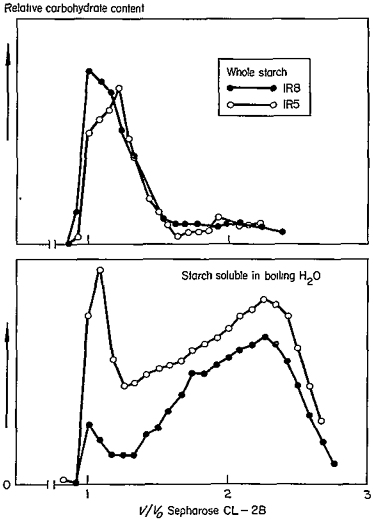
The less efficient extraction of starch and its fractions from starch granules of high-amylose rices with hard gel consistency compared to that from rices with soft gel was confirmed (Table 5). Amylopectin (calculated by difference) was less water soluble than amylose and the ratio of solubility was higher than that for amylose for the two gel types. Gel filtration of whole starch and starch

Table 5. Extractability in boiling water of starch, amylopectin, and amylose from high-amylose rice starch granules differing in gel consistency and gelatinization temperature (GT). IRRI, 1980.

Sample name	Gel consistency (mm)	Final GT (°C)	Extractability (%) in 100°C water of		
			Starch	Amylopectin	Amylose
IR5	90	73	31.0	7	86
IR8	32	65	16.5	2	51
IR32	85	74	37 4	10	≈100
IR42	30	65	18.7	2	61

soluble in boiling water confirmed the lower solubility of amylopectin of IR8 than of IR5 (Fig. 1). The amylopectin peak was also past the void volume ($V/V_0 > 1$) peak for IR5 reflecting a MW lower than that for IR8. Actual amylopectin $S_{20,w}$ values were 42 S (IR5) and 54 S (IR8) for whole starch, and 24 S (IR32) and 18 S (IR42) for soluble starch. Thus, the starch iodine blue test at 100°C also measures the difference in extractable low-MW amylopectin of high-amylose starches, in addition to soluble amylose.

Further study on the phosphorus (P) fraction of eight rice starches differing in amylose content and GT was undertaken with chemists at Kagoshima University, Japan. P was lowest for waxy starch, which was largely accounted for by 6-phosphoglucose residue in the starch. Such glucose ester accounted for 0.2-0.7 μmol P/g. Since P content was higher for nonwaxy rices at 4.5-10.4 μmol/g in starches containing 3.9-9.2 μmol/g choline, 75-89% of the starch P was probably phosphate or choline phospholipids. The choline content was similar in IR5 and IR8 high-amylose starches differing in gel consistency and GT. Because butanol defatting, which removed 80% of the fat, reduced P content of starch to 50%, residual P must be more tightly bound to starch.



1. Molecular weight fractionation on Sepharose CL-2B of whole and hot-water-soluble fractions of IR8 and IR5 rice starch. IRRI, 1980.

Nonstarch polysaccharide preparations. Although a minor fraction of milled rice, the nonstarch polysaccharides (cell wall) hold the cooked rice together and probably influence the direction of grain expansion during cooking. Its water-soluble fraction probably interacts with gelatinized starch.

Cold water (40°C) soluble preparations from eight milled rices differing in grain elongation ratio during cooking (1.4-2.1) and in amylose content (1.5-28.2%) were destarched by salivary α-amylase (Annual report for 1979) and were obtained in 0.1-0.8% recovery. Their major neutral sugars were either arabinose and galactose, glucose, or galactose plus xylose, mannose, fucose, and rhamnose. Hot water (80°C) preparation from IR36 milled rice was mainly glucan.

Water-soluble starch-free extracts from defatted IR32 true bran and embryo had glucose, galactose, and arabinose as principal neutral sugars together with mannose.

Water-insoluble destarched milled-rice preparations from the 8 milled rices were recovered in 0.3-0.7% yield and with less variable sugar composition. Major neutral sugars were xylose, arabinose, mannose and glucose, and lesser amounts of galactose and rhamnose and trace of fucose. The protein content of preparations was variable and the protein was either high (5-8%) or low (1-2%) lysine. Hydroxyproline was not a major amino acid component of the protein, contrary to reports by other workers.

Comparison of various fractionation schemes on IR36 preparation showed that a 10% fraction was soluble in hot 0.25% ammonium oxalate, probably representing pectin. The 0.5 N KOH solvent did not extract all the pentosans (arabinose and xylose); more were extracted with 4.27 N KOH. Mannans required the 6 N NaOH solvent. The residue of 6 N NaOH extraction was mainly glucan, representing cellulose. DEAE-Sephacel was ineffective for DEAE-cellulose borate fractionation of these preparations as it poorly adsorbed the polysaccharides.

Polysaccharides were prepared from defatted IR32 true bran and embryo collected from 5% milling of IR32 brown rice. True bran had higher fiber content than embryo. Protein was removed by 8 extractions with 0.5% SDS -0.6 β-mercaptoethanol, and starch was hydrolyzed with heat-stable α-amylase. Although the 0.5 N KOH extracts were rich in pentoses, additional carbohydrates were extracted with 4.27 N KOH and 6 N NaOH solvents.

Microtest for complexing with starch gel. Amylograph studies on waxy milled rice have shown that water-extractable lipids and carbohydrates alter Amylograph viscosity of the paste. Water extract of potato also suppresses Amylograph viscosity. Because of the large amount of flour (40 g) and complexing agent (0.5 g) needed for the study of starch-complex that alters gel viscosity, a microtest based on gel consistency that will detect such complex formation was sought. IR29 waxy rice starch (defatted with water-saturated butanol at 25° C) gel in water without dye was used to readily obtain stable gels. The defatted starch (100 mg) was dispersed in 1.6 ml water with 0.2 ml 95% ethanol as wetting agent. More wetting agent was required for bulky materials, and a 4-mesh alumina granule facilitated mixing. Palmitic acid increased gel viscosity of the IR29 starch (lower gel consistency value), whereas sucrose softened the IR29 gel. Use of water instead of KOH minimized degradation of organic substances.

Table 6 Effect of ß-amylase treatment on complexing ability of IR29 starch (amylopectin), as indexed by a gel consistency test. IRRI, 1980.

Treatment	Gel consistency[a] (mm)	
	Starch	ß-limit dextrin
None	91	97
Palmitic acid (1 mg)	47	98
Carboxymethyl cellulose (2 mg)	85	98

[a]100 mg IR29 starch or limit dextrin/1.6 ml water and 0.7 ml 95% ethanol

Because complexing with hydrophobic compounds such as palmitic acid has been principally reported with amylose, of which IR29 starch has only 1.5%, an attempt was made to determine the nature of the complexing involved with IR29 amylopectin. Treatment of IR29 starch with β-amylase to reduce its outer chains to 2 or 3 glucose units made the residual β-limit dextrin incapable of complexing with palmitic acid and carboxymethyl cellulose (Table 6). The results suggest that the amylopectin portion involved in complexing are the outer chains, about 12 glucose units or about 2 helices of 6 glucose units each.

Seven waxy rices with gel consistency of 76-92 mm (mean 81.4 mm) were washed with cold water. The washed gels hardened to 62-85 mm (mean 69.1 mm). Interestingly, defatting the same flours with 95% ethanol had a similar hardening effect on their gel values (60 to 76 mm, mean 69.3 mm).

Complexing was suggested by the gel viscosity measurements because the increase in gel viscosity exceeded the sum of the viscosity of IR29 starch and that of the complexing agent alone.

Starch complexing with minor rice constituents. American chemists reported that water-soluble cell-wall polysaccharides of milled rice and bran affect Amylograph peak viscosity and viscosity on cooling to 50° C of milled rices pastes. Total 65°-70° C or 80° C water-soluble extracts were prepared from 2 waxy and nonwaxy rices and fractionated by extraction of lipids with refluxing 95% ethanol. The lipid fractions increased IR29 starch gel viscosity. For the nonlipid fraction, the waxy extracts softened the IR29 starch gel but the nonwaxy extracts hardened it. Since total lipids extracted with water-saturated butanol from IR36 milled rice had a softening effect on IR29 starch gel, the water-extracted lipids probably differ in composition from the total lipids of milled rice.

Starch-free preparations were used for confirmatory tests. Preliminary studies showed that undefatted cold-water-soluble, starch-free extracts from 8 milled rices either hardened or had no effect on the consistency of gel at 1-3 mg levels. UPL-Ri-1 cold-water-soluble preparation (40% lipid) had a similar hardening effect on IR29 starch gel with (0.6 mg) or without (1 mg) defatting with 95% ethanol. Hot-water-soluble nonstarch polysaccharides from UPL-Ri-1 and Malagkit Sungsong waxy milled rices tended to soften IR29 starch consistency, whereas the hot-water-soluble fraction from IR36 and IR32 had a slightly hardening effect.

In contrast, both cold- and hot-water-soluble fractions from IR32 bran hardened IR29 starch gel.

With water-insoluble nonstarch preparations, no general trend was noted for the eight rices. They either had no effect on, hardened, or softened IR29 starch gel at 1-3 mg, and only a small fraction probably dissolved and complexed with the starch. An insoluble cell-wall fraction was noted for all samples. In contrast, water-insoluble IR32 bran cell wall had a softening effect even at 0.2 mg/100 mg IR29 starch gel.

Genetic evaluation and utilization (GEU) program

Disease resistance

Plant Pathology and Plant Breeding Departments

EVALUATING BREEDING MATERIALS FOR DISEASE RESISTANCE

Plant Pathology Department

Multiple disease resistance. Screening of the GEU varieties and elite lines for resistance to fungal, bacterial, and viral diseases of rice continued in 1980. The reactions of the entries to the different diseases studied varied from susceptible to resistant (Table 1). Some varieties were resistant to one disease, the majority to 2-4 diseases, and a few to 5-8 diseases.

Blast resistance. A total of 87,676 rices from different sources were screened for blast resistance

Table 1. Disease reactions of Genetic Evaluation and Utilization elite lines and varieties. IRRI, 1980.

Entry	Reaction[a] to given disease[b]											
	Bl	LSc	SR	ShB	CLS	ShR	BS	BK	BB	RTV	GSV	RSV
IR8	S	S	R	M-MS	M	MS	R	S	MS-S	S	R	S
IR36	S	S	S	M-MS	M	M	MR	R-S	M-S	S	I-R	S
IR42	M-S	M	S	M	MR-S	M-MR	R	S	M-S	S	I-R	S
IR43	S	M	—	M	—	—	M-S	—	M-S	S	R	S
IR44	M-S	S	S	M	M-MS	M-MR	MR	MS-S	M-R	S	R	I-S
IR45	M-S	—	—	—	MS	—	—	MS	S	S	R	S
IR46	S	M	—	M	R	MR	—	R	M-S	S	R	S
IR48	S	M	R	M	MR-R	MR-R	MR	R-S	MS-MR	I-S	R	I-S
IR50	S	S	S	M-MS	MR-MS	M-MR	S	MR-MS	M-S	I	R	I-S
IR52	S	S	S	M	MS	M	S	S	MS-S	I	R	I-S
IR54	S	S	S	M	R	M	S	MR	M-R	I	R	S
IR2071-685-3-5-4	S	S	—	M	MS	MR	—	R	M-S	S	R	S
IR2987-13-1	S	M	S	M	M	MS	R	S	M-S	S	R	S
IR3518-96-2-2-2	S	S	S	M	R	M	VS	S	MS-S	S	R	S
IR3646-8-1-2	S	R	S	M	R	M	MR	S	MS-S	S	R	S
IR3839-1	M-S	S	S	MS	MS	M	R	S	M-S	I-S	R	S
IR3858-6	S	M	S	M	M	MS	MS	S	M-S	I-S	R	S
IR3880-10	S	S	S	M	M	MS	MR	MS-S	M-S	I-S	R	S
IR3880-13-7	S	S	S	MS	MR	M	VS	S	M-R-S	S	R	S
IR3880-29	S	S	S	M	R	M	S	S	M-S	S	R	S
IR4432-28-5	S	S	R	M	R	MR	VS	S	M-S	S	R	S
IR4568-86-1-3-2	S	S	S	M-MR	R	M	VS	S	MR-R	S	R	I
IR5179-2	S	S	—	M	M	MS	R	S	MS-MR	S	R	S
IR5260-1	S	S	S	M	MS	MS	MR	MR-S	M-R	S	R	S
IR5440-1-1-3	M-R	S	S	M-MS	MS-R	M	R	MS-S	M-S	I-S	R	S
IR5716-18-1	S	M	S	M-MS	MS-R	MS	R	S	MS-S	I-S	R	S
IR5853-118-5	M-S	R	—	M-MS	VS	M	—	S	M-S	S	R	I
IR5853-162-1-2-3	M-S	R	—	M	MS	M	—	R	M-R	I	R	S
IR5853-213-6-1	S	R	—	M-MR	M	R	—	S	M-S	R	R	S
IR5929-12-3	M-R	S	S	M-MS	MS-R	M	MS	S	M-S	I-S	R	S
IR5931-110-1	M-R	M	S	MS	MR	M	MR	S	M-S	S	R	S
IR5982-7-6-1	S	S	S	M-MS	MS	M	R	S	MS-R	S	R	S
IR59983-13-1-2	S	S	—	M	MS	—	—	S	S	S	R	S
IR6023-10-1-1	M-R	M	S	M	M	M	VS	R-S	M-S	S	R	S
IR6115-1-1-1	M-S	—	—	M-MS	MS	M	—	MR	M-S	S	R	S
IR7790-18-1-2	M	M	S	M-MS	M-MR	MS	VS	S	M-S	S	R	S
IR8073-65-6-1	S	M	S	M-MS	MR	M	R	MS-S	M-S	S	R	S
IR8192-31-2-1-2	S	—	—	M	MR	M	—	MR	M-S	I	R	S
IR8192-166-2-2-3	S	—	—	M	R	M	—	S	M-S	S	R	S
IR8192-200-3-3-1	S	R	S	M-MS	MS	M-R	VS	MS-S	M-S	I	R	I-S
IR8608-189-2-2-1	S	R	S	M-MS	M	M	S	S	M-S	I	R	I-S
IR8608-298-3-1-1	S	M	S	M-MS	MR-R	M-R	MR	S	M-S	I	R	I
IR9129-209-2-2-2	S	S	S	M	MR	M	—	S	M-S	S	R	S
IR9129-209-2-2-2	S	M	S	M-MS	R	R	S	S	M-R	S	R	I
IR9209-181-3-5	S	R	S	M	R	MR	VS	S	M-R	I	I	S
IR9217-58-2-2	S	M	M	M-MS	MR-R	M-MR	VS	S	M-S	S	R	I-S
IR9224-140-3-2-2	S	—	—	M	MS	M	—	R	M-S	I	R	I
IR9264-321-3	S	S	M	M	R	MR	VS	S	M-S-R	I	R	S
IR9411-5-3-3	S	M	S	M	MS-MR	M-MS	VS	MS	M-S-R	S	R	I-S
IR9669 selection	S	M	S	M	R	M	R	S	M-S	S	R	S
IR9708-51-1-2	S	M	S	M	M	R	R	S	M-S-R	R	R	S
IR9729-67-3	S	S	S	M	MR	MR	VS	MR	M-S-R	I	R	S
IR9752-71-3-2	M-S	S	S	M-MR	MR	M	MR	MS	M-S	I	R	S
IR9761-19-1	S	M	S	M	MS	M	MR	MR	M-S	I	R	I
IR9763-11-2-2	S	M	S	MS	R	M	S	MS	M-R	I	R	I
IR9763-11-2-2-3	S	—	—	M	R	MR	—	R	M-S-R	I	R	I

CONTINUED ON OPPOSITE PAGE

Table 1 continued

Entry	Reaction[a] to given disease[b]											
	Bl	LSc	SR	ShB	CLS	ShR	BS	BK	BB	RTV	GSV	RSV
IR9764-45-2-2	S	M	S	M	R	M-MR	S	R-S	M-S-R	S	R	I
IR9808-9-2	S	M	—	M	MS	M	—	R-S	M-S	I	R	I
IR9809-9-2	S	—	S	M	R	MR	MR	S	M-S	I	R	I
IR9828-91-2-3	S	M	S	M	M	MR	VS	S	M-S-R	S	R	S
IR9846-215-3	S	R	S	M	MS	M	S	MR-S	M-S	S	R	I-S
IR9852-22-3	S	M	S	M	M-MS	M	MR	MR-R	M-S	S	R	I
IR9861-25-1-1	S	—	—	M	MR	M	—	MS	M-S	I	R	I
IR11248-83-3-2-1	S	—	—	M	R	M	—	S	MR-S-R	S	R	I
IR13146-41-3	S	M	R	M-MS	VS	R	MR	MS-S	M-S	S	R	I
IR13149-3-2-2	S	R	R	M	M-VS	MR-R	MR	MS-S	M-S	I	R	I-S
IR13149-19-1	S	R	S	M-MS	M-VS	MR	MR	R-S	M-S	R	R	S
IR13149-43-2	S	R	S	M	R	MR-R	S	S	M-S-R	R	R	S
IR13149-71-3-2	S	S	S	M	M-MS	MR	MR	S	M-S	R	R	S
IR13240-10-1-3-2	M-S-R	—	—	M	M	M	—	R	M-S	S	R	S
IR13240-83-1	S	—	—	M	M	MR	—	R	M-S	S	R	S
IR13299-96-2-2	S	—	—	M	VS	—	—	MS	M-S	S	R	S
IR13358-85-1-3	S	S	S	M	MS	M	VS	S	M-S	S	R	I
IR13365-253-2-2	S	S	S	M	M	M	R	S	M-S	S	R	I
IR13419-113-1	S	M	S	M-MR	M-MS	MR	R	R	M-S-R	S	R	I
IR13423-10-2-3	S	M	S	M-MS	MS	R	MS	S	MS-R	S	R	I
IR13423-17-1-2-1	S	M	S	M-MS	MS-R	MR	R	MR-MS	M-S	I-S	R	I-S
IR13426-19-2	S	S	S	M	M-MR	MR	VS	MS-R	M-S-R	S	R	I-S
IR13427-40-2-3-3	R	M	S	M	M-MR	MR	R	R	M-S-R	I-R	R	I-R
IR13429-109-2-2-1	R	S	S	M	MS-R	MR	MR	MR	M-S	I	R	I-R
IR13429-196-1-2-1	M-S	—	—	M	M-S	—	—	S	M-S	I	R	S
IR13429-196-1-20	S	S	S	M	MS-R	MR	MR	R	M-S-R	I	R	I
IR13429-299-2-1-3	S	S	S	M	R	R	S	R	M-S	R	R	R
IR13525-43-2-3-1	S	S	S	M	MS-R	MR	MR	MS-R	M-S	I-S	S-R	I-R
IR13540-56-3-2-1	S	S	S	M	R	M	R	S	M-R	I	R	R
IR14632-2-3	S	—	—	M	R	—	—	R	M-S	S	R	I
IR14632-22-3	S	R	S	M-MS	R	MR	VS	MR-S	M-S-R	S	R	I-I
IR14753-120-3	S	R	S	M-MS	MR-R	R	MR	MR-S	MS-MR	S	R	S
IR15314-30-3-1-3	M-S	R	S	M	MS-M	M	MR	MS	M-S-R	I-S	R	I-S
IR15314-43-2-3-3	M	S	S	M-MS	R	MR	MR	MS	M-S-R	I	R	R
IR15318-2-2-2-2	M-S	—	—	M	R	—	—	MS	—	I	R	I
IR15318-2-2-2-2	S	M	S	M	MR	MR	S	MR	M-S	S	R	R
IR15496-219-2-3-2	S	S	S	M	R	R	VS	R	M-R	I	R	I
IR15529-256-1	M-S	M	S	M-MS	M-R	M	VS	R-S	M-S	I-S	I	I
IR15538-338-1-2-3	S	M	S	M	MR	MR	VS	S	M-S	S	R	S
IR15675-98-1-2-5	R	S	S	M	MS	MR	VS	S	M-S	S	R	I
IR17491-5-4-3-3	S	—	—	M	R	—	—	S	M-S-R	I	R	S
IR17494-32-1-1-3	S	R	S	M-MS	MR	MR	MR	S	M-R	I	R	I
IR17494-32-3-1-1	S	—	—	M	M	—	—	MR	M-R	I	R	I
IR19657-90-3-3-2	S	S	M	M-MS	R	R	S	S	MS-MR	I	R	I
IR19660-131-3-3-3	S	R	S	M	MR	R	R	R	M-S-R	I	R	I
IR19661-131-1-2	M-S	R	R	M-MS	M-MR	R	R	R-S	MS-MR	I-R	R	R
IR19661-364-1-2-3	S	R	R	M	MR	MR	VS	S	M-S-R	I	R	R
IR19672-140-2-3	S	R	S	M	R	R	VS	R	M-S	I	R	I
IR19728-9-3-2-3	S	R	S	M-MS	MR	M	R	S	M-R	I	R	I
IR19729-5-1-1	R	—	S	MS	MS	—	—	S	M-S-R	I	R	S
IR19729-5-1-1-3	R	R	—	M	MS	MR	VS	MS	M-S-R	I	R	I
IR19735-5-2-3-2	R	M	S	M	VS	M	VS	R	M-S-R	S	R	I
IR19743-25-2-2	S	—	—	M	MS	—	—	MS	M-S	I	R	S
IR19743-25-2-2-3	S	R	S	M	MR	M	R	R	M-S	I	R	I
IR19743-40-3-3-2	S	—	S	M-MS	MR	M	S	MS	M-S	I	R	I
IR19743-46-2-3-3	S	—	—	MS	VS	—	—	MR	M-S	I-S	R	I-S
IR19743-46-2-3-3	S	—	—	M	MS	VS	VS	S	M-S	I	R	I
IR19746-28-2-2	S-R	—	—	MS	VS	—	—	S	M-S	I	R	I
IR19746-28-2-2-3	S	—	—	M	M	MR	R	MR	M-S	S	R	I
IR19759-29-2-1-3	R	—	—	M	R	MR	MS	S	M-S-R	S	R	I
IR19762-2-3-3	R	—	—	M	MS	R	S	R	M-S-R	S	R	I
BR51-282-8	S	—	—	M	R	M	MR	S	MS-MR	S	R	S
IET1444	S	—	—	M	MR	MS	R	S	M-S	S	R	I-S

[a]M = moderately resistant to moderately susceptible, I = intermediate, S = susceptible, VS = very susceptible, and R = resistant. Reactions separated by a dash indicate a range of reactions in two or more tests. [b]Bl = blast, LSc = leaf scald, SR = stem rot, ShB = sheath blight, CLS = Cercospora leaf spot, ShR = sheath rot, BS = brown spot, BK = bakanae, BB = bacterial blight, RTV = rice tungro virus, GSV = grassy stunt virus, and RSV = ragged stunt virus.

Table 2. Summary of screening for blast resistance. IRRI, 1980.

Source of entries	Number with given blast reaction		
	Resistant	Moderate	Susceptible
Elite breeding lines[a]	16	26	191
Germplasm bank[a]	945	558	1,289
Pedigree nursery lines	9,724	10,056	51,236
Hybridization block[a]	132	54	581
Observational yield trial[a]	212	1,036	2,094
Replicated yield trial[a]	69	205	835
Nigerian lines	15	4	0
Korean lines	192	309	5,514
Dryland breeding lines	3	23	609
International nurseries			
International Rice Blast Nursery[a]	149	67	276
International Rice Arid Regions Observational Nursery[a]	22	73	294
International Rice Observational Nursery	16	22	292
International Rainfed Lowland Rice Observational Nursery	8	13	204
International Upland Rice Observational Nursery	5	9	79
International Rice Cold Tolerance Nursery	23	13	183
Total	11,531	12,468	63,677
Percent	13 2	14 2	72.6

[a]Tested 2-3 times.

in IRRI blast nurseries. The entries' reactions varied from resistant to susceptible (Table 2). Some of the varieties and lines with a consistently high level of resistance were Carreon, Tetep, Dissi Hatif, 5709, 5712, 5717, 5720, 5721, OS6, IR1416-128-5-8, IR1905-PP11-29-4-61, IR1905-81-3-1, IR4547-6-2-5, IR4547-6-2-61, IR4547-14-3-1, IR5533-15-1-1, and IR9559-PP870-1.

Leaf scald resistance. Screening for leaf scald resistance continued in the 1980 wet season. Entries in the field were inoculated at maximum tillering with a spore suspension of *Rhynchosporium oryzae*. The disease reactions, which were recorded 21 days after inoculation, varied from highly resistant to highly susceptible (Table 3).

Varieties found highly resistant were Mingolo, Cempo Selak, Carreon, Khao Lo, Kinandang Patong, Kulawai, Moroberekan, and Damodar. Highly susceptible varieties were IR19053-198-1-2-1-2, IR19735-41-3-21, IR21048-53-2, IR21178-26-1, GH33, and IR19728-2-2-2-2-2.

Resistance to sheath blight, Cercospora leaf spot, sheath rot, and brown spot. Field screening for resistance to sheath blight, Cercospora leaf spot, and sheath rot indicated a variation in reactions of some varieties and lines. In greenhouse screening for resistance to brown spot, some varieties and lines were highly resistant and others ranged from moderate to very susceptible (Table 4). Some entries were resistant to one or two diseases, but none was found resistant to all four diseases.

Sheath blight resistance. As in previous years, none of 4,781 cultivars obtained from different sources (elite breeding lines, replicated and observational yield trials, hybridization block, rice/

Table 3. Summary of screening for leaf scald resistance. IRRI, 1980 wet season.

Source	Number with given disease reaction[a]					
	HR	R	MR	MS	S	HS
Replicated yield trial	40	3	57	46	163	10
Elite varieties and breeding lines	15	4	16	11	35	3
Hybridization block	196	18	41	61	52	4
Observational yield trial	0	0	0	4	30	6
Total	251	25	114	122	280	23
Percent	31	3.1	41.1	15.0	34.1	2.8

[a]HR = highly resistant (lesion 0-1 0 cm), R = resistant (lesion 1.01-2.0 cm), MR = moderately resistant (lesion 2.01-3.0 cm), MS = moderately susceptible (lesion 3.01-4.0 cm), S = susceptible (lesion 4.01-6.0 cm), HS = highly susceptible (lesion greater than 6 0 cm).

Table 4. Disease reactions of IRRI breeding lines and varieties screened for resistance to sheath blight (ShB), Cercospora leaf spot (CLS), sheath rot (ShR), and brown spot (BS). IRRI, 1980.

Entry	Disease reaction[a]			
	ShB	CLS	ShR	BS
IR8	M M M M MS	M	MS	R
IR36	M M M MS MS	M M	M M	MR
IR42	M M M M M	MS MR	M MR	R
IR43	M			
IR44	M M M M	MS M	M MR	MR
IR45		MS		
IR46	M M	R	MR	
IR48	M M	R MR	R MR	MR
IR50	M MS	MS MR	M MR	S
IR52	M	MS	M	S
IR54	M	R	M	S
IR2071-685-3-5-4-3	M M M M	MS	MR	
IR2987-13-1	M	M	MS	R
IR3518-96-2-2-2	M	R	M	VS
IR3646-8-1-2	M M M	R	M	MR
IR3839-1	MS	MS MS	M	R
IR3858-6	M	M	MS	MS
IR3880-10	M	M	MS	MR
IR3880-13-7	MS	MR	M	VS
IR3880-29	M	R	M	S
IR4432-28-5	M M M	R	MR	VS
IR4568-86-1-3-2	M M MR M M	R	M	VS
IR5179-2	M	MS	MS	R
IR5260-1	M M	MS MS	MS	MR
IR5440-1-1-3	M MS M M	MS R	M M	R
IR5716-18-1	M MS	MS MR	MS	R
IR5853-118-5	M M MS M M	VS	M	
IR5853-162-1-2-3	M M M	MS	M	
IR5853-213-6-1	M MR M M	M	R	
IR5929-12-3	M MS	MS R	M	MS
IR5931-110-1	MS	MR	M	MR
IR5982-7-6-1	M MS	MS	M	R
IR5983-13-1-2	M M	MS		
IR6023-10-1-1	M M M M	M M	M M	VS
IR6115-1-1-1	MS M M	MS	M	
IR7790-18-1-2	M MS	MR M	MS	VS
IR8073-65-6-1	M MS M M M	MR MR	MS M	R
IR8192-31-2-1-2	M M	MR	M	
IR8192-166-2-2-3	M M	R	M	
IR8192-200-3-3-1-1	M MS M M	MS MS	M R	VS
IR8608-189-2-2-1-3	MS M M M	M M	M	S
IR8608-298-3-1-1-2	M M MS M	MR R	M R	MR
IR9129-209-2-2-2	M M M	MR	M	
IR9129-209-2-2-2-3	MS M M	R	R	S
IR9209-181-3-5	M M	R	MR	VS
IR9217-58-2-2	M M M MS	MR R	M MR	VS
IR9224-140-3-2-2-3	M	MS	M	
IR9264-321-3	M M	R	MR	VS
IR9411-5-9-3	M M	MS MR	MS M	VS
IR9669 Selection	M	R	M	R
IR9708-51-1-2	M M	M	R	R
IR9729-67-3	M M	MR	MR	VS
IR9752-71-3-2	M MR M	MR	M	MR
IR9761-19-1	M M	MS	M	MR
IR9763-11-2-2	MS	R R	M	S
IR9763-11-2-2-3	M	R	MR	
IR9764-45-2-2	M M M M	R	MR M	S
IR9808-9-2	M M M	MS	M	
IR9809-9-2	M	R	MR	MR
IR9828-91-2-3	M M M	M	MR	VS

CONTINUED ON NEXT PAGE

Table 4 continued

Entry	Disease reaction[a]			
	ShB	CLS	ShR	BS
IR9846-215-3	M M M M	MS MS	M M	S
IR9852-22-3	M M M M	MS M	M M	MR
IR9861-25-1-1	M M M	MR	M	
IR11248-83-3-2-1-3	M	R	M	
IR13146-41-3	M M M M MS	VS VS	R R	MR
IR13149-3-2-2	M M M M M	VS M	R MR	MR
IR13149-19-1	M MS M M	VS M	MR MR	MR
IR13149-43-2	M M M M M	R R	R MR	S
IR13149-71-3-2	M M M	MS M	MR MR	MR
IR13240-10-3-2	M	M	M	
IR13240-83-1	M M	M	MR	
IR13299-96-2-2	M	VS		
IR13358-85-1-3	M M M M M	MS	M	VS
IR13365-253-2-2	M M M	M	M	R
IR13419-113-1	M M M MR	MS M	MR	R
IR13423-10-2-3	MS M	MS	R	MS
IR13423-17-1-2-1	M MS M	MS R	MR	R
IR13426-19-2	M M M M M	MR M	MR	VS
IR13427-40-2-3-3	M M	MS R	MR	R
IR13429-109-2-2-1	M M	MS R	MR	MR
IR13429-196-1-20	M	MS R	MR	MR
IR13429-196-1-2-1	M	MS		
IR13429-299-2-1-3	M	R	R	S
IR13525-43-2-3-1	M M	MS R	MR	MR
IR13540-56-3-2-1	M M	R	M	R
IR14632-2-3	M M	R		
IR14632-22-3	M MS M	R R	MR	VS
IR14753-120-3	M MS M M	MR R	R R	MR
IR15314-30-3-1-3	M M M	MS M	M	MR
IR15314-43-2-3-3	MS M M	R	MR	MR
IR15318-2-2-2-2	M M M	R		
IR15318-2-2-2-2-2	M	MR	MR	S
IR15496-219-2-3-2	M M M	R	R	VS
IR15529-256-1	M MS M M	M R	M	VS
IR15538-338-1-2-3	M M M	MR	MR	VS
IR15675-98-1-2-5	M	MS	MR	VS
IR17491-5-4-3-3	M M	R		
IR17494-32-1-1-3-2	M MS M M	MR	MR	MR
IR17494-32-3-1-1-3	M M	M		
IR19657-90-3-3-2	MS M M	R	R	S
IR19660-131-3-3-3	M M	MR	R	R
IR19661-131-1-2	M MS	M MR	R	R
IR19661-363-1-2-3	M M M	MR	MR	VS
IR19672-140-2-3	M M	R	R	VS
IR19728-9-3-2-3	M MS	MR	M	R
IR19729-5-1-1	MS MS	MS		
IR19729-5-1-1-3	M M	M	MR	VS
IR19735-5-2-3-2	M M	VS	M	VS
IR19743-25-2-2	M M	MS		
IR19743-25-2-2-3	M M	MR	M	R
IR19743-40-3-3-2	M MS	MR	M	S
IR19743-46-2-3	MS	VS		
IR19743-46-2-3-3	M M	MS	VS	VS
IR19746-28-2-2	MS	VS		
IR19746-28-2-2-3	M M	M	MR	R
IR19759-29-2-1-3	M M	R	MR	MS
IR19762-2-3-3	M M M	MS	R	S
BR51-282-8	M	R	M	MR
IET1444	M M	MR	MS	R

[a]R = resistant, MR = moderately resistant, M = moderate, MS = moderately susceptible, S = susceptible, VS = very susceptible More than one rating per disease indicates variation in reaction.

Table 5. Summary of sheath blight screening. IRRI, 1980.

Source	Entries (no.)	Entries (no.) with given disease reaction[a]					
		R	MR	M	MS	S	VS
Elite breeding lines	158	0	0	130	28	0	0
Wetland:							
Replicated yield trial	1150	0	33	963	152	2	0
Observational yield trial	923	0	22	813	75	9	4
Dryland:							
Replicated yield trial	140	0	20	117	3	0	0
Hybridization block	696	0	12	650	32	2	0
Rice/sorghum crosses	4	0	0	4	0	0	0
Germplasm bank	1368	0	10	1311	43	4	0
Confirmation test							
Elite breeding lines	7	0	0	5	2	0	0
Wetland:							
Replicated yield trial	39	0	0	35	4	0	0
Observational yield trial	35	0	0	30	5	0	0
Dryland:							
Replicated yield trial	3	0	0	3	0	0	0
Observational yield trial	195	0	0	195	0	0	0
Germplasm bank	49	0	4	45	0	0	0
Crowley Disease nursery	3	0	1	2	0	0	0
Hybridization block	11	0	1	10	0	0	0
Total	4781	0	103	4313	344	17	4
Percent		0	2.1	90.2	7.2	0.4	0.1

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

sorghum crosses, and germplasm bank) and screened for sheath blight resistance showed a resistant reaction to the disease. Only 2.1% were moderately resistant (Table 5).

Reactions of varieties to stem rot. In the 1980 wet season, 84 elite varieties and breeding lines and 182 rices from the germplasm bank were screened at maturity in the field for stem rot reaction.

Eighty-four elite varieties and breeding lines and 60 germplasm bank entries were first evaluated. The entries, each represented by one hill, were taken to the greenhouse for recording of stem rot reaction on a per-tiller basis: 0 indicated the most resistant and 9 the most susceptible. The disease index (DI) was computed:

$$DI = \frac{0\,(n) + 2\,(n) \cdot \ldots + 9\,(n)}{N}$$

where n = number of tillers in indicated class, and N = total number of tillers sampled.

To evaluate more entries, 122 accessions from the germplasm bank were scored in the field using the 0-9 stem rot scale. Most succumbed to natural stem rot infection. The results of computing disease index and direct field scoring did not differ. Direct field scoring may allow faster screening for stem rot.

The resistant entries were IR8, IR48, IR4432-28-5, IR13146-41-3, IR19661-131-1-2, and IR19661-364-1-2-3 — all from elite varieties and breeding lines. Some of those found susceptible were IR50, IR5929-12-3, IR9808-9-2, IR9828-91-2-3, ARC 14719, and ARC13811.

Resistance to rice virus diseases. The reactions of 22,177 entries — 8,100 to tungro, 4,961 to grassy stunt, and 9,116 to ragged stunt — were determined by mass-screening in the greenhouse. The percentages of infected seedlings indicated degree of resistance.

The field reactions — based on the Standard Evaluation System for Rice (SES) — of 30,627 entries to tungro disease in pedigree nurseries were recorded. The incidence of the disease was enhanced by transplanting 599,000 TN1 seedlings inoculated with eggs laid by viruliferous insects produced by the propagation method described in 1979 (Annual report for 1979).

Tungro disease in the nurseries was confirmed by sampling infected plants that served as virus sources for 1,905 virus-free green leafhoppers. The infectivity of the insects was tested by daily serial transmission on TN1 seedlings.

SOURCES OF RESISTANCE

Plant Pathology and Plant Breeding Departments

Identification and evaluation *(Plant Pathology).* A total of 2,102 entries from the germplasm collection previously identified with various degrees of resistance to bacterial blight were further evaluated at IRRI with strain PXO 61 and at the Maligaya Rice Research and Training Center with strain PXO 83 (Table 6). Different disease reactions in the same accession were often observed. Confirmation tests based on single-plant hills suggested that there was segregation of those entries. Selection was made and the reaction to PXO 61 at IRRI and PXO 83 at Maligaya Rice Research Training Center was further confirmed (Table 7).

Entries from IRON and IRLRON were evaluated for their reaction to the bacterial blight syndrome. Twenty-three entries from the 2 nurseries

Table 6. Field evaluation of rice germplasm inoculated with 2 strains of *Xanthomonas oryzae* by the clipping method. Philippines, 1980 wet season.

Disease reaction[a]	Entry[b] (no.)			
	PXO 61		PXO 83	
	MT	FL	MT	FL
1	373	485	315	532
3	433	394	227	266
5	166	134	162	91
7	79	38	324	149
9	0	0	23	13

[a]Scored by 1980 Standard Evaluation System for Rice. [b]The test for PXO 61 was done at IRRI; that for PXO 83 at Maligaya Rice Research and Training Center, Nueva Ecija, Philippines. Inoculation at maximum tillering stage (MT) and at flowering stage (FL).

Table 8. Entries from the International Rice Observational Nursery and International Rainfed Lowland Rice Observational Nursery showing kresek development when transplanted in the field after seedling submergence in a bacterial suspension of about 10^9 cells/ml for 30 minutes. IRRI, 1980 wet season.

Kresek[a] (%)	Entries (no.)
< 10	23
11-25	53
26-50	71
51-75	41
76-100	50
Total	238

[a]Based on total number of tillers showing kresek, divided by number of hills per entry.

Table 7. Result of further evaluation and selection of rices from the IRRI germplasm collection showing diverse bacterial blight reactions[a] in the Philippines, 1980.

Variety	IRRI acc. no.	Country of origin	Reaction at IRRI	Reaction at IRRI (PXO 61)	Reaction at MRRTC (PXO 83)
Lua Ro	24147-a	Vietnam	1	3	7
	-b		7	5	7
Chianung Sen Yu 6	26956-a	China	1	1	7
	-b		7	7	7
Aus 76	28938-a	Bangladesh	1	1	1
	-b		7	5	5
Boway AG 1-54	30664-a	India	1	1	5
	-b		7	7	5
Kada Chopa	34954-a	India	1	1	1
	-b		7	7	7
Khamar	34994-a	India	1	1	3
	-b		7	7	3
Shete Bhado	35152-a	India	1	3	3
	-b		7	7	3
Thalanayar 1	35200-a	India	1	1	7
	-b		7	5	5
BW 249-4	36753-a	India	1	3	7
	-b		7	5	7

[a]Scored by 1980 Standard Evaluation System for Rice.

Table 9. Entries from the International Rice Observational Nursery showing less than 10% kresek development when transplanted in the field after seedling submergence in a bacterial suspension of about 10^9 cells/ml for 30 minutes. IRRI, 1980 wet season.

Entry no.	Designation (cross)	Origin	Leaf blight PXO 61 (%)
8	BR40-39-1-3 (IR140-165-3-3/IR8)	Bangladesh	5
10	BR109-74-2-2-2 (IR20/IR44)	Bangladesh	1
16	BW 242-5-5-2 (BW 173/IR747-B2-6-3)	Sri Lanka	7
38	IR8608-189-2-2-1-3 (IR2061-465-1-5-5/IR2071-625-1)	IRRI	1
124	IR19743-46-2-2-3 (IR9129-192-2-3/IR10176-79)	IRRI	1
129	IR19774-42-1 (IR9698-26-3/IR10176-79)	IRRI	1
231	B2850B-51-2-2 (B541B-KN-91-3-1/IR2071-15-4-1-2)	Indonesia	1
262	IR9224-223-2-2-2-1 (IR2153-14-1-6-2//IR28//IR2070-625-1)	IRRI	1
264	IR9736-16-1-2 (CO 37/IR1058-78-1-3//IR2058-78-1-3)	IRRI	1
267	IR11248-83-3-2-1-3 (IR2071-586-5-6-3/IR2415-49-6-12)	IRRI	1
292	Kau 1734-2 (IET7104) (Triveni/IR1539)	India	1
303	OR 59-6 (T 90/IR8//Hema)	India	1
305	OR 131-3-1 (IET6661) (590/IR8//CR57-49)	India	3
308	Rajendra Dhan 201	India	5
311	RNR 29692	India	5
324	R9-1-6-1-3-1-1 (IR22/Sigadis)	India	3

Table 10. Entries from International Rainfed Lowland Rice Observational Nursery showing less than 10% kresek development when transplanted in the field after seedling submergence in a bacterial suspension of about 10^9 cells/ml for 30 minutes. IRRI, 1980 wet season.

Entry no.	Designation (cross)	Origin	Leaf blight PXO 61 (%)
26	IR13168-143-1 (Cauvery/IR36//IR2071-625-1-252)	IRRI	1
56	C1117-2	Philippines	1
53	C168 (Intan/BPI-76-1)	Philippines	5
67	CR 1023 (Pankaj/Jaganath)	India	5
134	IR13146-179 (BG90-2/IR34//IR2058-78-1-3-2-3)	IRRI	1
178	Kau 1925 (Jyothy/IR2153)	India	3
183	Kau 2011 (Jaya/IR2058//Mahsuri)	India	1
190	Kau 2039 (Jaya/IR2071//Mahsuri)	India	5

showed less than 10% kresek in the field (Tables 8, 9, and 10); however, their leaf blight reaction to strain PXO 61 was varied.

Utilization of resistance sources *(Plant Pathology and Plant Breeding).* Seven genes for resistance to bacterial blight from 60 different varieties are used in the breeding program. In addition, 84 varieties with different resistance to the disease serve as sources of resistance (Table 11). Thirty-six of the resistance donors carried *Xa 4*, which is in about 55% of 33,898 crosses (Table 12). Two allelic genes are at the *Xa 4* locus: $Xa\ 4^a$ and $Xa\ 4^b$. The resistance expression conditioned by $Xa\ 4^a$ is functional to bacterial strain PXO 61 or to strains in pathotype I in the Philippines at both vegetative and reproductive stages, while resistance by $Xa\ 4^b$ is functional to that strain only at the reproductive stage. The second largest group (about 9%) of 19 resistance donors involved in the crossing program have the recessive gene *xa 5*. Other genetic sources of bacterial blight resistance are *Xa 6, Xa 7, xa 8,* and *xa 9*, but few crosses have been made with them either in single or in compound crosses.

Once the sources of resistance have been recommended for hybridization, the progenies of many different gene donors may be potentially recombined (Table 13). Among the 33,898 crosses made at IRRI until 1980, 24,307 or 67% involved genes known for bacterial blight resistance. Many crosses were known to have more than one of such genes. Some combinations could have involved three or four genes (Table 14).

Specific and adult plant resistance *(Plant Pathology).* The responses of rices with specific and adult plant resistance to different sources of inoculum varied (Table 15). When the disease pressure was high, disease severity increased from early tillering to flowering on rice with adult plant resist-

Table 11. Parental donors having specific genes for resistance to bacterial blight of rice used in the IRRI crossing program.

Gene and variety	Acc. no	Origin	Gene and variety	Acc. no.	Origin
Xa 3			Rante	18609	Indonesia
Wase Aikoku	525	Japan	Rathu Heenati	15609	Sri Lanka
Xa 4[a]			Rengesi	18628	Indonesia
CO 10	3691	India	Remadja	679	Indonesia
CO 22	6400	India	Sintawati	18863	Indonesia
Nam Sagui 19	11462	Thailand			
Pelita I/1	14560	Indonesia	*xa 5*		
Pelita I/2	14561	Indonesia	ARC 5756	20200	India
Sigadis	6525	Indonesia	Aus 32	28895	Bangladesh
Taothabi	13746	India	Aus 251	29043	Bangladesh
TKM6	237	India	Aus 449	29206	Bangladesh
Gui Do	19745	Korea	Bageri	16193	Bangladesh
Pakheng	30154	Laos	BJ1	3711	Nepal
			Chinsurah Boro II	11484	India
Xa 4[b]			DD 48	8620	Bangladesh
Bajang	17183	Indonesia	Dharial	3396	Surinam
Beak Ganggap	17253	Indonesia	DL 5	8593	Pakistan
Bulu Putih	17350	Indonesia	Dular	636	India
Bulu Sampang	17352	Indonesia	DV29	8816	Bangladesh
Camor	17366	Indonesia	DV139	8870	Bangladesh
Gropak Gede	17687	Indonesia	DZ192	8518	Bangladesh
Kentajana	9224	Indonesia	Hashikalmi	3397	Surinam
Ketan Bajong	17830	Indonesia	Kaliboro 600	29367	Bangladesh
Ketan Bas	17834	Indonesia	Kele	25881	Bangladesh
Ketan Gondel	17857	Indonesia			
Ketan Gondopuro	17859	Indonesia	*xa 5, Xa 7*		
Ketan Pandan	17932	Indonesia	DV85	8839	Bangladesh
Ketan Temon	17967	Indonesia	DV86	8840	Bangladesh
Lenggang Genuk Bulu	18119	Indonesia	*Xa 6*		
Padi Tomat	18408	Indonesia	Zenith	131	USA
Palotan Melati	18426	Indonesia	M. Sungsong	38794	Philippines
Pare Djerah	18458	Indonesia			
Pulo Banrakaja	20073	Indonesia	*xa 8*		
Pulut Banda Kaya	27391	Indonesia	PI 231129	11113	USA
Pulut Bongo	27397	Indonesia	*xa 9*		
Pulut Kemandi	24621	Indonésia	Sateng	30193	Laos

ance, but remained stable on rice with specific resistance.

Dose-response of Cas 209 to strains of *Xanthomonas oryzae* differing in virulence *(Plant Pathology).* In 1979, Cas 209 was identified as a good differential variety. It separates the group II bacterial strains into pathotypes II and III. It is resistant to pathotype II but susceptible to I, III, and IV. Further investigation of the response of Cas 209 to the representative strains in the four pathotypes was made during 1980. Infectivity of strain PXO 86 (of pathotype II) to Cas 209 was remarkably different from that of PXO 61 (I),

Table 12. Sources of genes for resistance to bacterial blight of rice used in the IRRI crossing program. 1980.

Gene for resistance	Donor varieties (no.)	Crosses (no.)	Frequency[a] (%)
Xa 3	1	49	0.14
Xa 4	36	18,576	54.80
xa 5	19	3,099	9.16
Xa 6	1	883	2.60
Xa 7	1	95	0.28
xa 8	1	3	0.09
xa 9	1	1	0.03
Unknown	84	1,688	4.97
Total	114	24,394	72.07

[a]Based on a total of 33,898 crosses

Table 13. Some selected crosses made at IRRI involving 2 or more gene combinations.

IRRI cross no.	Cross	Genes involved
IR4475B	TKM 6/BJ1	*Xa 4/xa 5*
IR4985B	IR22//M S./BJ1	*Xa 4//Xa 6/xa 5*
IR9623	DZ192/TKM 6	*xa 5/Xa 4*
IR10950	IR30/Zenith	*Xa 4/Xa 6*
IR14093	DV85/IR28	*xa 5, Xa 7/Xa 4*
IR25875	DV85/IR36//IR36	*xa 5, Xa 7/Xa 4//Xa 4*

Table 14. Different known genes for bacterial blight resistance used in various combinations in IRRI's crossing program. 1980.

Combination of genes	Crosses	
	Number	Frequency[a] (%)
Xa 3, Xa 4	2	0.008
Xa 3, Xa 6	3	0.012
Xa 4, xa 5	698	2.873
Xa 4, Xa 6	261	1.073
Xa 4, Cas 209	43	0.177
xa 5, Xa 6	20	0.082
xa 5, Xa 7	2	0.008
Xa 4, xa 5, Cas 209	1	0.004
Xa 4, xa 5, Xa 7	35	0.144
Xa 4, xa 5, Xa 6	12	0.049
Xa 4, xa 5, Xa 6, Xa 7	1	0.004
Total	1078	4.435

[a]Of 24,307 crosses having genes for bacterial blight resistance.

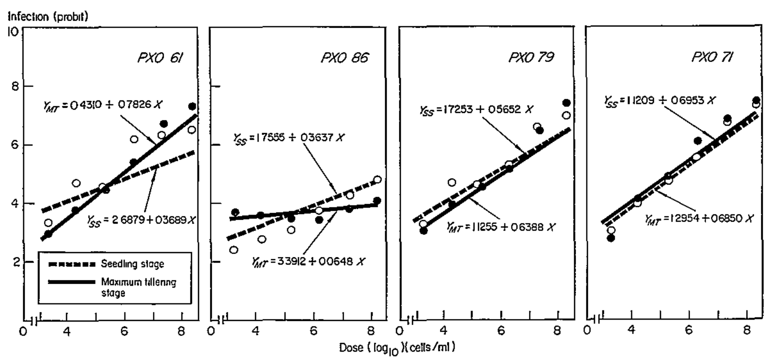
PXO 79 (III), and PXO 71 (IV) at either seedling or maximum tillering stage (Fig. 1).

Comparison of the strain's ED_{50} (the effective dose to cause 50% positive infection) at 2 growth stages — early tillering and maximum tillering — indicated that PXO 86, which was avirulent to Cas 209, caused no visible infection at those stages 7 days after inoculation. At 14 days after inoculation, the cell number required to cause 50% positive infection differed from that of the three other strains by 10^3-fold at early seedling stage to 10^9-fold at maximum tillering (Table 16). The disease score initiated on Cas 209 by PXO 86 at 1.5×10^6 cells was 1.3. PXO 61 at 1.92×10^6 cells gave a disease score of 8.7, PXO 71 at 1.82×10^6 cells gave 8.6,

Table 15. Response of rices with specific and adult plant resistance to bacterial blight to inoculum sources of *Xanthomonas oryzae* strain PXO 61 generated within the plant population and from a foreign source. IRRI, 1980 wet season.

Variety	Type of resistance	Disease severity[a] (11-99)					
		Inoculum within			Foreign inoculum		
		ET	MT	FL	ET	MT	FL
IR20	Specific[b]	22 ± 22	26 ± 16	11 ± 0	29 ± 16	39 ± 3	36 ± 5
IR50	Specific	22 ± 13	32 ± 3	16 ± 3	36 ± 18	25 ± 3	17 ± 3
IR944	Adult plant[c]	55 ± 0	39 ± 9	28 ± 5	56 ± 2	63 ± 5	72 ± 4
IR1695	Adult plant	28 ± 21	41 ± 10	24 ± 3	58 ± 10	64 ± 12	67 ± 9
Cempo Selak	Unknown	39 ± 6	48 ± 4	32 ± 14	58 ± 20	61 ± 3	72 ± 1

[a]When inoculum source was generated within plots, 4 hills of the variety were inoculated at tillering stage, disease at early tillering (ET) was scored 14 days after, then at maximum tillering (MT) and flowering (FL) stages. Border rows of IR8 were inoculated to provide inoculum from foreign source. [b]Incomplete resistance to PXO 61. [c]Susceptible to PXO 61 at vegetative stage.



1. Response of Cas 209 to infectivity of 4 strains of *Xanthomonas oryzae* (PXO 61, PXO 86, PXO 79, and PXO 71 for pathotypes I, II, III, and IV) at different dosages. The infection was scored at 14 days after inoculation. IRRI, 1980.

Table 16. ED_{50} [a] of the different strains on variety Cas 209 at 2 growth stages, 14 days after inoculation. IRRI, 1980.

Strain	ED_{50} (cells/ml)	
	Seedling stage	Maximum tillering stage
PXO 61	2.7 × 10^5	5.12 × 10^5
PXO 71	2.9 × 10^5	1.6 × 10^5
PXO 79	2.9 × 10^5	6.08 × 10^5
PXO 86	6.46 × 10^8	6.74 × 10^{24}

[a]Effective dose to produce 50% infection.

Table 17. Rating of Cas 209, a differential rice variety, for the virulence of *Xanthomonas oryzae* based on infection initiated at different inoculum densities. IRRI, 1980.

Strain	Rating[a] (1 to 9) at inoculum density[b] (cells/ml) of					
	× 10^1	× 10^2	× 10^3	× 10^4	× 10^5	× 10^6
PXO 61	0.1	1.9	2.7	8.3	8.2	8.7
PXO 71	0.1	1.2	3.3	6.7	8.5	8.6
PXO 79	0.2	2.6	1.9	4.4	8.0	7.9
PXO 86	0	0	0	0.5	0.7	1.3

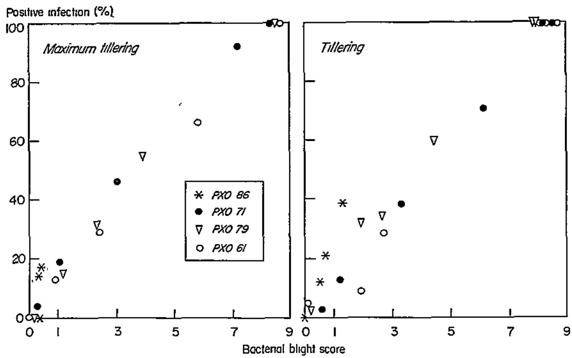
[a]Mean of 3 replications. Scored by 1980 Standard Evaluation System for Rice. [b]By a factor of 1.92 for PXO 61, 1.82 for PXO 71, 1.93 for PXO 79, and 1.51 for PXO 86.

and PXO 79 at 1.93 by 10^6 cells gave 7.9 (Table 17). Positive infection appears well correlated with the disease reaction to specific strains at different dosage levels (Fig. 2).

Infectivity of pathotypes I, II, and III *(Plant Pathology).* As previously reported (Annual reports for 1978, 1979), resistance of the differential varieties was the major factor that differentiates the pathotypes. When strains of a pathotype group of *Xanthomonas oryzae* were virulent to a variety, different lesion sizes were also noted. Previous results indicated that the variation in lesion size caused by a pathotype on a variety was inconsistent in any given strain. Dose-responses of IR8 to pathotype I and of IR36 to pathotypes II and III were used to titrate the infectivity of the strains and thus compare their virulence.

The ED_{50} based on cell numbers in the inoculum suggests that the range of bacterial cell numbers among the strains varied according to plant age (Tables 18, 19, and 20). On IR8, the ED_{50} values of pathotype I strains were different among strains at maximum tillering but similar at the flowering stage. In contrast the ED_{50} values for pathotype III differed at the flowering stage but were similar at maximum tillering. Variation in ED_{50} was noted among pathotype II strains at both maximum tillering and flowering stages. The results further confirmed the variation in virulence of strains in each pathotype according to rice susceptible to them. Strain virulence appeared to be independent of plant age if a variety's resistance was matched.

Sources of resistance to rice viruses *(Plant Pathology).* Several sources of resistance to rice virus diseases were identified. ARC11554 (IRRI acc. no. 21473) consistently showed a low percentage of tungro infection in 46 tests involving inoculations of 1,138 seedlings. In addition to Ptb 21,



2. Correlation of positive infection induced by strains PXO 61, PXO 86, PXO 79, and PXO 71 at different dosages at 2 growth stages of Cas 209. IRRI, 1980.

Table 18. Relationship of induction of positive infection[a] and challenge doses of strains in virulence group I of *Xanthomonas oryzae* on IR8 at 2 growth stages. IRRI, 1980.

Strain	Intersection (a)	Slope (b)	ED_{50}[b]	
			Cells[c] (no./ml)	95% fiducial limit
		Maximum tillering		
PXO 52	−1.768093	1.180829	5.4 × 10⁵ a	4.0 × 10⁵ − 7.2 × 10⁵
PXO 61	−1.485948	1.123830	5.9 × 10⁵ a	2.6 × 10⁵ − 1 3 × 10⁶
PXO 80	−1.034755	1.143749	1.9 × 10⁵ b	4.5 × 10⁴ − 7.5 × 10⁵
PXO 84	−1.448995	1.175264	3.1 × 10⁵ ab	1.0 × 10⁵ − 9.4 × 10⁵
PXO 85	−0.863743	1.002507	7.1 × 10⁵ a	5.2 × 10⁵ − 9.6 × 10⁵
		Flowering stage		
PXO 52	−0.694496	1.030680	3.3 × 10⁵ a	5.3 × 10⁴ − 2 3 × 10⁶
PXO 61	−0.589263	1.011782	3.3 × 10⁵ a	1.0 × 10⁵ − 1.2 × 10⁶
PXO 80	0.490349	0.855707	1.9 × 10⁵ a	3.6 × 10⁴ − 9.1 × 10⁵
PXO 84	−0.195718	1.013959	1.3 × 10⁵ a	3.3 × 10⁴ − 4.7 × 10⁵
PXO 85	−0.853099	1.029445	4.8 × 10⁵ a	1.7 × 10⁵ − 1.5 × 10⁶

[a]Scored at 14 days after inoculation. [b]Based on bacterial cell number in the inoculum suspension. [c]Separation of ED_{50}s at the same stage by Duncan's multiple range test at 5% level.

Table 19. Relationship of induction of positive infection[a] and challenge doses of strains in virulence group II of *Xanthomonas oryzae* on IR36 at 2 growth stages. IRRI, 1980.

Strain	Intersection (a)	Slope (b)	ED_{50}[b]	
			Cells[c] (no./ml)	95% fiducial limit
		Maximum tillering		
PXO 63	−1.283629	1.193854	1.8 × 10⁵ c	1.4 × 10⁵ − 2.4 × 10⁵
PXO 78	0.778038	0.864323	7.7 × 10⁴ d	5.4 × 10⁴ − 1.1 × 10⁵
PXO 82	0.124390	0.913277	2.2 × 10⁵ bc	9.1 × 10⁴ − 4.9 × 10⁵
PXO 83	−0.844036	1.026089	4.9 × 10⁵ a	2.4 × 10⁵ − 1.0 × 10⁶
PXO 86	−0.290847	0.948272	3.8 × 10⁵ ab	2.7 × 10⁵ − 5.2 × 10⁵
		Flowering stage		
PXO 63	−1.216944	1.091421	4.9 × 10⁵ ab	3.6 × 10⁵ − 6.8 × 10⁵
PXO 78	−1.018771	1 029397	7.0 × 10⁵ ab	5.2 × 10⁵ − 9 6 × 10⁵
PXO 82	−1.534185	1.169987	3.8 × 10⁵ b	1.3 × 10⁵ − 1.1 × 10⁶
PXO 83	−0.154857	0 922782	3.9 × 10⁵ b	7.1 × 10⁴ − 1 8 × 10⁶
PXO 86	0.216349	0.780476	1.3 × 10⁶ a	2.5 × 10⁵ − 5.7 × 10⁶

[a]Scored at 14 days after inoculation. [b]Based on bacterial cell number in the inoculum suspension. [c]Separation of ED_{50}s at the same stage by Duncan's multiple range test at 5% l evel.

Table 20. Relationship of induction of positive infection[a] and challenge doses of strains in virulence group III of *Xanthomonas oryzae* on IR36 at 2 growth stages. IRRI, 1980.

Strain	Intersection (a)	Slope (b)	ED_{50}[b]	
			Cells[c] (no./ml)	95% fiducial limit
		Maximum tillering		
PXO 22	−0.172836	0.852449	1.2 × 10⁶ a	2.5 × 10⁵ − 4 7 × 10⁶
PXO 79	1.113828	0.711859	2.9 × 10⁵ a	6.5 × 10⁴ − 1.0 × 10⁶
PXO 81	−0.288778	0.975468	2.6 × 10⁵ a	5 5 × 10⁴ − 1.1 × 10⁶
PXO 87	0.923749	0.690078	8.1 × 10⁵ a	1.6 × 10⁵ − 3.3 × 10⁶
PXO 88	1.491207	0.648439	2.6 × 10⁵ a	1.4 × 10⁴ − 1.4 × 10⁶
		Flowering stage		
PXO 22	−0.841707	0.981978	8.9 × 10⁵ b	7 8 × 10⁴ − 6.2 × 10⁶
PXO 79	−1 379009	1.063169	9.9 × 10⁵ b	4.6 × 10⁵ − 2.0 × 10⁶
PXO 81	0.043882	0.867777	5.1 × 10⁵ b	— —
PXO 87	−2.754767	1.110812	9.5 × 10⁶ a	7.2 × 10⁶ − 1.3 × 10⁷
PXO 88	−1 363441	1.092269	6.7 × 10⁵ b	3 2 × 10⁵ − 1.4 × 10⁶

[a]Scored at 14 days after inoculation [b]Based on bacterial cell number in the inoculum suspension. [c]Separation of ED_{50}s at the same stage by Duncan's multiple range test at 5% level.

Table 21. Rice varieties with low percentage of ragged stunt infection, and their reaction to brown planthopper (BPH) biotypes in mass screening in the greenhouse. IRRI, 1980.

Variety	IRRI acc. no.	Tests (no.)	Seedlings		Reaction[a] to BPH biotypes		
			Inoculated (no.)	Infected (%)	1	2	3
Balaratawee	15524	14	287	20	R	R	S
Hathili	15195	16	349	16	R	R	S
Hathili	15200	14	307	13	R	R	S
Hondarawala 502	12705	10	228	19	R	R	R
Molagu Samba	15222	10	184	15	R	R	S
Murungakagan 101	12072	10	248	19	R	R	S
Ptb 18	11052	14	352	22	R	R	S
Ptb 21	6113	76	1476	16	R	R	R
Sudurvi	3476	10	219	26	R	S	R

[a]Reactions are from the Master List of Germplasm Collection, IRRI.

seven varieties consistently showed low percentages of ragged stunt infection. These varieties were also resistant to at least two biotypes of the brown planthopper (Table 21).

Varietal resistance to ragged stunt may not always be a result of resistance to the ragged stunt vector, the brown planthopper. Andaragahewewa, ARC5757, ARC5785, Bakia, Co 10, Lekam Samba, Malalwariyan, Sulai, Su Yai 20, and WC1259 showed more than 60% ragged stunt infection after inoculation, but were listed as resistant to at least two biotypes of the brown planthopper.

Sitopas is tolerant of ragged stunt, but showed more than 90% ragged stunt infection after inoculation. At the later stages of growth, however, the infected plants produced normally long flag leaves and about 60% of panicles emerged completely although vein-swellings were present on leaf blades and leaf sheaths.

INTERNATIONAL COLLABORATION

Plant Pathology Department

IRRI-TARC collaborative research project on bacterial blight. Pathotypes of *X. oryzae* in Japan were distinctly different from those in the Philippines. Some rice varieties were more resistant to the Philippine strains than to the Japanese ones, and vice versa. DV85 was resistant to strains in both countries (Table 22).

Table 22. Reaction of Japanese and Philippine pathotypes of *Xanthomonas oryzae* to differential rice varieties of Japan and IRRI.[a]

Differential variety	Gene for resistance	Reaction[b]								
		Japanese pathotype[c]					Philippine pathotype[d]			
		T7174 (I)	T7147 (II)	T7133 (III)	H75373 (IV)	H75304 (V)	PXO 61 (I)	PXO 86 (II)	PXO 79 (III)	PXO 71 (IV)
Japanese										
Kinmaze	None	7.0	7.0	6.8	7.0	6.6	6.7	6.4	6.7	6.9
Kogyoku	*Xa 1*	0 3	6.7	7.0	6.6	0.1	6.9	6 6	6 4	6.9
Tetep	*Xa 1, Xa 2*	0.0	0.2	6.6	6 6	0.0	4.8	6.3	6.0	4.9
Wase Aikoku 3	*Xa 3*	1.0	0.7	0.2	6.7	5.1	0.9	0.5	0.8	0 3
Java 14	*Xa 1, Xa 3, Xa kg*	0.0	2.0	1.3	6.1	0.1	0.7	0.4	2.0	1.2
IRRI										
IR8	?	6.3	1.2	1.9	6.5	1.1	6.6	6.4	6.2	5.9
IR20	*Xa 4*	0.0	2.3	3.9	4.5	0.0	1.9	6 3	7.0	3.0
IR1545-339	*xa 5*	1.5	2.0	2.0	1.4	1.8	1.9	2.0	1.7	5.6
DV85	*xa 5, Xa 7*	0.0	2.0	1.8	1.9	0.0	1.5	1.5	1.8	1.8
Cas 209	?	6.5	6.8	7.0	7.0	3.1	6 0	0.0	6.8	6.8
Cempo Selak	?	1.7	1 2	0.1	6.0	6.1	1.6	1.2	2.6	3.1

[a]Inoculation of flag leaf [b]Based on a scale of 0 to 7. The pathotype group is indicated in parentheses after each isolate. [c]Data recorded in Japan. [d]Data recorded in the Philippines.

Plant Pathology and Plant Breeding Departments

Determination of pathogenic races of ***Fusarium moniliforme*** ***(Plant Pathology).*** To determine if races of *Fusarium moniliforme* exist, 56 isolates were separately inoculated onto 20 varieties and elite breeding lines. Seeds were soaked in spore suspension for 4 days. The germinating seeds were planted in trays and placed on benches outside the greenhouse. Disease reactions were recorded at weekly intervals beginning 1 week after planting. The percentage of infected seedlings of each cul-

Table 23. Reaction of rice differentials to 56 isolates of ***Fusarium moniliforme*** **Sheldon that causes bakanae disease. IRRI, 1980.**

Fusarium isolate	Reaction[a]																			
	IR32	IR36	IR42	IR44	IR45	IR38	IR7760-4-8-2	IR7790-18-1-2	IR8192-166-2-2-3	IR9129-457-2-2-1-2	IR9761-47-3	IR9763-11-2-2	IR9784-42-3-1	IR9788-19-2-3-3	IR9808-31-2	IR9814-6-3-3-2	IR9852-22-3	IR13149-19-1	IR9846-215-3	IR9703-41-3-3-1
I-1, I-8, I-10(B)Bb-1, C-1, P-16, P-16(A), M-9(A), M-14(B1), SFV-7, SFV-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-2	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0
SFV-3	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
M-12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
M-14(B2)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
I-11	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0
SFV-12	0	0	0	0	0	0	2	3	1	0	0	1	3	3	3	0	1	1	2	0
I-1, I-3	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
M-9(A2)	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0
MV-7	0	0	0	0	0	2	0	2	0	0	1	0	1	2	1	1	1	1	1	0
P-3	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
I-9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TM-3	0	0	0	0	1	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0
I-9(A)	0	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TM-7(A)	0	0	4	0	0	3	0	4	4	0	3	0	2	1	0	3	2	6	6	3
M-12(C)	0	0	3	1	0	0	0	3	2	0	3	2	4	0	0	0	3	3	0	0
P-7	0	0	1	0	0	0	0	1	2	0	0	0	0	0	0	2	2	3	1	1
I-2	0	0	1	0	0	1	0	3	1	0	2	0	1	0	1	2	1	3	6	1
M-12(A)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SFV-9	0	9	9	4	0	3	5	5	4	4	4	0	3	4	3	5	4	9	6	6
TM-6	0	9	9	0	9	6	9	9	3	4	3	2	5	3	3	2	3	2	2	3
MV-12	0	5	6	2	1	4	3	7	4	6	2	0	4	1	1	3	1	4	3	2
MV-1	0	3	1	0	1	3	3	5	3	2	3	1	3	2	2	0	0	4	7	2
MV-3	0	2	5	1	4	3	6	7	3	2	3	2	6	3	6	3	3	5	7	3
TM-4	0	2	2	0	0	4	3	3	5	3	0	1	1	4	2	2	3	6	4	4
P-1	0	1	3	1	2	4	4	3	4	2	2	2	7	3	3	4	1	7	5	3
TM-3(A)	0	1	3	0	0	2	2	4	4	4	1	1	5	3	1	2	2	5	5	0
P-15	0	1	0	0	0	0	2	1	0	1	0	0	0	0	1	0	0	0	1	2
P-3(A)	0	1	0	0	0	0	1	2	0	0	0	0	1	2	0	0	1	2	0	0
TM-7	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
I-4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-16(B)	1	6	9	9	9	9	9	9	9	9	9	2	9	9	9	9	9	9	9	9
TM-3(B)	1	6	9	1	9	9	9	9	9	9	3	2	7	4	3	9	7	9	9	8
SFV-8	1	5	6	1	3	6	5	6	7	4	3	2	5	4	4	4	4	7	5	4
MV-2	1	4	8	0	1	5	3	5	5	3	3	2	9	7	3	8	0	5	7	8
P-3(B)	1	4	3	1	2	4	3	4	6	3	4	1	5	4	3	4	2	6	6	4
I-5	1	4	2	0	2	6	7	5	7	7	4	0	3	5	3	4	2	6	4	5
P-9	1	1	6	0	0	3	6	6	7	6	0	2	4	1	0	1	2	6	6	4
M-14(B)	1	1	1	0	1	0	2	2	2	1	2	7	4	2	1	3	4	5	3	0
SFV-1	1	0	0	0	0	1	4	1	0	3	0	0	2	1	2	2	0	1	2	3
MV-11	2	3	8	0	2	3	4	6	3	4	6	1	6	6	0	2	4	8	7	9
P-13(A)	2	2	7	0	7	8	9	9	9	9	3	1	6	6	5	9	4	9	9	9
TM-5	9	8	9	4	1	9	9	9	9	9	8	3	9	9	9	9	8	9	9	9

[a]Scored by 1980 Standard Evaluation System for Rice.

tivar was computed and used as criterion for evaluating varietal reactions to each of the 56 isolates. Disease reaction was scored on a scale of 0 to 9.

The reactions of 20 varieties and lines to the different isolates varied from resistant, moderately resistant, to susceptible (Table 23).

From the 20 cultivars and lines tested, 8 differential varieties were selected. The various isolates were classified into pathogenic races, with the reactions of the different cultivars as criterion. Reactions R and MR were considered as resistant and all other reactions were considered susceptible. The race number was standardized by predesignating the pathogenicity patterns of all the theoretical race numbers, following the international Standard Evaluation System for Rice scale for *Pyricularia oryzae*. On the basis of the reactions of 8 differentials, the 56 isolates were classified into 9 race groups (Table 24). The most virulent race FA-1 has 3 isolates and the least virulent race FI-1 includes 31 isolates. The races of *F. moniliforme* identified in the Philippines can be compared with races occurring in other countries by using the same set of differential varieties. The isolates had a mean virulence index (VI) of 6.9 based on the reaction of 20 varieties and lines. Most of the isolates were nonpathogenic, with a VI of 1.

Races of *Pyricularia oryzae* (*Plant Pathology*). One hundred and fifty-nine isolates of *Pyricularia oryzae* collected mostly from the IRRI blast nursery and field in 1978 and 1979 were inoculated into nine new Japanese differential varieties. Fifty-four races were identified and five were identical to Japanese races (Table 25). Based on pathogenicity, the prevailing races were R-102 (13 isolates), R-100 (12), R-002 (11), R-103 (9), and R-003 (6).

Nineteen isolates of race number R-000 did not induce disease reaction on any of the nine Japanese differentials, and were unable to cause infection in other supplementary varieties. This suggests that the nine Japanese differentials cannot identify some races of *P. oryzae* in the Philippines. The results also showed that the races varied in their virulence and pathogenicity on the differential varieties used. Most of the races identified can overcome two to three genes for resistance. Seven races were able to break one resistance gene, seven overcame five resistance genes, and five overcame six resistance genes. One race, R-747, overcame seven resistance genes, indicating that it is the most virulent race in the test.

International Rice Blast Nursery test of breeding lines and varieties *(Plant Pathology)*. The reactions of some of the breeding lines and varieties in different scales of 0 to 9 in the International Rice Blast Nursery (IRBN) from the period 1975 to 1980 were compiled: 0 indicated most resistant and 9 most susceptible. The average disease reaction of each line and variety were computed to indicate susceptibility indices (SI).

$$\frac{N_R + 3\,N_M + 5\,N_S}{\text{Total number of tests } (N)}$$

where $R = 0\text{-}2$, $M = 3\text{-}4$, and $S = 5\text{-}9$.

Low average disease reaction values indicate resistance and high average disease reaction values

Table 24. Races of *Fusarium moniliforme* in the Philippines. 1980.

Differential variety	Race*																				
	FA-1	FA-65	FA-81	FB-1	FB-9	FB-33	FB-57	FC-1	FC-3	FC-7	FC-13	FC-21	FC-22	FD-8	FD-12	FE-1	FE-8	FF-4	FG-1	FH-1	FI-1
	*Reaction**																				
IR44	S	S	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
IR45	S	R	R	S	S	S	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R
IR36	S	S	S	S	S	R	R	S	S	S	S	S	S	R	R	R	R	R	R	R	R
IR38	S	S	R	S	S	S	R	S	S	S	S	R	R	S	S	R	R	R	R	R	R
IR9703-41-3-3-1	S	S	S	S	R	S	R	S	S	S	R	S	S	S	R	S	S	R	R	R	R
IR7760-4-8-2	S	S	S	S	S	S	S	S	S	R	R	R	R	R	S	S	R	S	R	R	R
IR42	S	S	S	S	S	S	S	S	R	R	S	S	S	R	R	S	R	R	S	R	R
IR7790-18-1-2	S	S	S	S	S	S	S	S	S	S	S	S	R	R	R	S	R	R	S	S	R
	Isolates (no.)																				
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2	31
	Virulence index																				
	69	63	43	57	38	55	39	45	35	3.3	2.9	58	37	2.4	28	36	15	1.2	23	16	10

*R = resistant S = susceptible

Table 25. Races of *Pyricularia oryzae* identified by new Japanese differentials. IRRI, 1980.

Isolates (no.)	Reaction[a] of isolates to each differential variety									Race no.
	Shin 2 (*Pi-K*^{s}, 1)	Aichi Asahi (*Pi-a*, 2)	Ishikare shiroke (*Pi-i*, 4)	Kanto 51 (*Pi-K*, 10)	Tsuyu-ake (*P-m*, 20)	Fukuni-shiki (*Pi-Z*, 40)	Yashiro mochi (*Pi-ta*, 100)	Pi No. 4 (*Pi-ta*^{2}, 200)	Toride 1 (*Pi-Z*^{t}, 400)	
19	R	R	R	R	R	R	R	R	R	000
1	S	R	R	R	R	R	R	R	R	001
11	R	S	R	R	R	R	R	R	R	002
6	S	S	R	R	R	R	R	R	R	003
1	R	R	S	R	R	R	R	R	R	004
2	R	R	R	S	R	R	R	R	R	010
1	R	R	S	S	R	R	R	R	R	014
1	R	S	S	S	R	R	R	R	R	016
2	S	R	R	R	S	R	R	R	R	021
1	R	S	R	R	S	R	R	R	R	022
1	S	S	R	R	S	R	R	R	R	023
1	R	S	R	S	S	R	R	R	R	032
12	R	R	R	R	R	R	S	R	R	100
13	R	S	R	R	R	R	S	R	R	102
9	S	S	R	R	R	R	S	R	R	103
4	R	R	S	R	R	R	S	R	R	104
5	R	S	S	R	R	R	S	R	R	106
2	S	S	S	R	R	R	S	R	R	107
2	R	R	R	S	R	R	S	R	R	110
1	R	S	R	S	R	R	S	R	R	112
2	R	S	R	R	S	R	S	R	R	122
1	S	S	S	R	S	R	S	R	R	127
2	R	S	R	S	S	R	S	R	R	132
2	R	S	S	S	S	R	S	R	R	136
2	S	S	S	S	S	R	S	R	R	137
1	R	R	R	R	R	R	R	S	R	200
1	R	S	R	R	R	R	R	S	R	202
1	R	S	R	S	R	R	R	S	R	212
1	R	S	R	S	S	R	R	S	R	232
1	R	S	S	S	S	R	R	S	R	236
1	S	R	R	R	R	R	S	S	R	301
1	R	S	R	R	R	R	S	S	R	302
5	S	S	R	R	R	R	S	S	R	303
3	R	R	R	R	R	R	R	R	S	400
1	S	R	R	R	R	R	R	R	S	401
5	S	S	R	R	R	R	R	R	S	403
1	S	S	S	R	R	R	R	R	S	407
1	S	S	R	R	S	R	R	R	S	423
2	S	S	R	S	S	R	R	R	S	433
1	R	R	R	R	R	R	S	R	S	500
3	R	S	R	R	R	R	S	R	S	502
5	S	S	R	R	R	R	S	R	S	503
1	S	S	S	R	R	R	S	R	S	507
1	S	S	S	R	R	S	S	S	S	547
3	S	S	R	R	R	R	R	S	S	603
1	S	S	R	S	S	R	R	S	S	633
1	S	R	R	R	R	R	S	S	S	701
2	R	S	R	R	R	R	S	S	S	702
4	S	S	R	R	R	R	S	S	S	703
2	S	S	S	R	R	R	S	S	S	707
1	R	S	R	R	R	S	S	S	S	742
4	S	S	S	R	R	R	S	S	S	743
1	S	S	S	R	R	S	S	S	S	747
Total 159										

[a]R = resistant, S = susceptible. The specific resistance gene and code number are given in parentheses after the variety's name.

connote susceptibility. The number of tests for the varieties in the IRBN ranged from 43 to 133. Many of the lines consistently exhibited higher percentages of resistant reactions to blast in many countries (Table 26). However, none of the selected lines were resistant to blast in all the countries where they were tested.

The 1980 results showed low average disease

Table 26. Blast resistance of selected breeding lines, resistant donors, and other varieties in IRBN tests, 1980.

No.	Designation or variety	Total no tested	Number of tests in different disease scales										Average disease reaction
			0	1	2	3	4	5	6	7	8	9	
1	IR5533-PP854-1, IR8^{3}/Carreon//Tetep	106	9	58	21	9	5	0	2	2	0	0	1.632
2	IR3259-PP5-160-1, IR8^{3}/Tetep	39	1	22	8	3	1	3	0	0	1	0	1.897
3	IR5533-P855-1, IR8^{3}/Carreon//Tetep	79	4	44	18	7	2	1	2	1	0	0	1.684
4	IR1905-PP11-29-4-61, IR8/Tetep	123	5	67	26	12	8	1	1	3	0	0	1.781
5	IR9660-50-3-1-1, IR8^{6}/IR3260	78	5	46	14	6	4	1	0	1	1	0	1.641
6	Tetep	136	11	70	30	13	4	4	1	3	0	0	1.706
7	IR1905-81-3-1, IR8/Tetep	103	7	59	22	9	4	1	1	0	0	0	1.524
8	IR9660-00951-1, IR8^{6}/IR3260	40	4	23	6	2	2	2	0	0	1	0	1.675
9	IR5533-PP856-1, IR8^{3}/Carreon//Tetep	78	6	40	16	11	2	0	1	1	1	0	1.718
10	IR4547-14-3-1, IR8^{6}/PK203//IR4477///IR3266	78	2	42	19	7	6	0	1	1	0	0	1.769
11	IR9669-PP830-1, IR8^{3}/Carreon	40	4	19	8	5	2	2	0	0	0	0	1.700
12	IR5533-15-1-1, IR8^{3}/Carreon//Tetep	77	2	37	21	10	4	1	0	2	0	0	1.870
13	IR3259-PP18-821-2, IR8^{3}/Tetep	76	4	43	13	10	5	0	0	0	1	0	1.671
14	IR9559-4-1-1, IR8^{3}//IR1904/IR1905	79	2	43	16	9	5	2	1	0	0	1	1.861
15	IR4547-16-3-4, IR8^{6}/PK203//IR4477///IR3265	59	0	37	12	5	4	1	0	0	0	0	1.644
16	IR9669-PP846-1, IR8^{6}/Carreon	112	7	50	23	19	8	3	1	1	0	0	1 902
17	IR5533-56-1-12, IR8^{3}/Carreon//Tetep	136	9	68	30	10	10	5	2	2	0	0	1 831
18	IR3273-342-1-6, IR8^{6}/PK203	80	5	41	15	8	9	1	0	0	1	0	1.800
19	IR3271-760-1482, IR8^{4}/PK203//Dawn	76	4	33	16	13	7	0	2	0	0	1	2.013
20	IR9559-PP870-1, IR8^{3}//IR1904/IR1905	112	2	57	23	17	6	3	1	2	1	0	1.973
21	IR1905-PP19-73-2, IR8/Tetep	78	5	43	15	8	4	2	0	1	0	0	1.667
22	IR4547-16-3-7, IR8^{6}/PK203//IR4477///IR3265	63	0	33	15	7	6	2	0	0	0	0	1.873
23	Carreon	137	5	60	44	12	8	4	2	2	0	0	1 912
24	IR3259-PP11-182-4, IR8^{3}/Tetep	39	5	22	5	5	0	1	0	0	0	1	1.564
25	IR5533-13-1-1, IR8^{3}/Carreon//Tetep	77	3	41	17	9	3	4	0	0	0	0	1.740
26	IR4547-6-1-3	76	4	35	12	7	14	3	0	0	1	0	2.092
27	IR4547-6-2-4	76	4	41	13	7	8	1	0	1	0	1	1 855
28	IR4547-6-3-2	111	5	54	26	16	5	3	1	0	0	1	1 838
29	IR4547-16-3-2	79	4	41	15	5	9	3	0	2	0	0	1.911
30	IR4547-6-2-6	73	3	44	10	7	8	0	0	0	0	1	1.726
31	IR5533-15-1-11, IR8^{3}/Carreon//Tetep	79	5	43	14	11	3	3	0	0	0	0	1.658
32	IR4547-6-2-5	132	9	63	26	15	5	6	6	0	1	1	1.992
33	IR4472-53-10-8-1-2, IR8^{8}/Dawn	24	0	15	4	3	1	1	0	0	0	0	1 708
34	IR3273-289-2-1473, IR8^{6}/PK203	112	4	41	25	13	21	5	2	0	1	0	2.313
35	IR9669-PP836-1, IR8^{3}/Carreon	77	4	43	15	8	3	2	1	0	0	1	1.740
36	IR1909-1-3-3, IR8^{4}/Dawn	62	0	32	16	7	3	3	1	0	0	0	1.903
37	IR4547-10180-20-7, IR8^{6}/PK203//IR4477///IR3265	109	4	46	20	16	10	9	3	0	0	1	2.257

CONTINUED ON OPPOSITE PAGE

Table 26 continued

No.	Designation or variety	Total no. tested	Number of tests in different disease scales 0	1	2	3	4	5	6	7	8	9	Average disease reaction
38	IR9559-3-1-1, IR8³//IR1904/IR1905	79	1	32	15	13	10	5	2	1	0	0	2.342
39	Dawn	106	5	34	22	18	8	6	6	4	0	3	2 689
40	Kataktara DA-2	124	5	28	20	24	21	10	7	5	1	3	3.113
41	KTH 17	130	3	11	12	15	8	22	6	14	12	27	5.348
42	Kung-Shan-Wu-Shen-Ken	32	1	1	0	2	0	2	0	6	3	17	7.375
43	Fanny	80	0	2	0	3	2	4	3	5	9	52	7.000
44	B-40	127	1	0	4	2	12	17	31	29	14	17	6 000
45	Taichung T.C W.C	84	0	1	1	10	5	8	16	9	19	15	6.000

reaction for IR5533-PP854-1, IR3259-PP5-160-1, IR5533-PP855-1, IR1905-PP11-29-4-61, and IR9960-50-3-1-1, indicating that they have a broad spectrum of resistance. Those lines have outranked Tetep, Carreon, Dawn, and Kataktara (donor parents) in resistance to blast.

Inheritance of resistance to blast *(Plant Breeding and Plant Pathology).* Fifteen cross-combinations and their parents were used to determine the mode of inheritance of resistance to blast. Seedlings of the F_1, F_2, and parents were grown to early tillering before the tillers were inoculated separately with three isolates of *Pyricularia oryzae.* The isolates were I-41 (IB-45), I-43 (IH-1), and PO6-6 (ID-16).

Table 27. Reaction[a] of F_1 and F_2 plants to race IB-45 (I-41). IRRI, 1980.

Cross	Observed ratio F_1 R	F_1 S	F_1 Total	F_2 R	F_2 S	F_2 Total	Expected ratio for F_2	X^2	P
IR1905-81-3-1 (R)/ IR3259-PP5-160-1 (R)	50	0	50	223	0	223	1:0		
IR1905-81-3-1 (R)/ IR3259-PP8-172-7 (R)	5	0	5	240	0	240	1:0		
IR1905-81-3-1 (R)/ Pai-kan-tao (S)	42	0	42	274	120	394	45·19	0.111	0.70-0.50
IR1905-81-3-1 (R)/ IR442-2-58 (S)	37	0	37	679	482	1161	9:7	2.35	0.25-0.10
IR1905-81-3-1 (R)/ IR8 (S)	37	0	37	399	275	674	9:7	2 38	0.25-0.10
IR3259-PP8-172-7 (R)/ IR3259-PP5-160-1 (R)	6	0	6	219	0	219	1:0		
IR3259-PP8-172-7 (R) /Pai-kan-tao (S)	44	0	44	194	70	264	45:19	1 272	0.50-0.25
IR3259-PP8-172-7 (R) /IR442-2-58 (S)	46	0	46	655	505	1160	9:7	0.164	0.75-0.50
IR3259-PP8-172- 7 (R)/IR8 (S)	5	0	5	100	73	173	9:7	0.169	0.75-0 50
IR3259-PP8-172- 7 (R)/Peta (S)	5	0	5	35	27	62	9:7	0.001	0.95-0.90
IR3259-PP5-160-1 (R) /Pai-kan-tao (S)	21	0	21	216	83	299	45:19	0.532	0.50-0.25
Pai-kan-tao (S)/ IR442-2-58 (S)	0	13	13	0	774	774	0:1		
Pai-kan-tao (S)/Peta (S)	0	11	11	0	337	337	0:1		
IR442-2-58 (S)/Peta (S)	0	26	26	0	228	228	0:1		
Peta (S)/Nongbaek (S)	0	6	6	0	190	190	0:1		

[a]R = resistant, S = susceptible.

Table 28. Reaction[a] of F_1 and F_2 plants to race IH-1 (I-43). IRRI, 1980.

Cross	Observed ratio F_1 R	S	Total	F_2 R	S	Total	Expected ratio for F_2	X^2	P
IR1905-81-3-1 (R)/IR3259-PP5-160-1 (R)	50	0	50	166	0	166	1.0		
IR1905-81-3-1 (R)/IR3259-PP8-172-7 (R)	5	0	5	230	0	230	1:0		
IR1905-81-3-1 (R)/Pai-kan-tao (R)	51	0	51	207	24	231	57:7	0.071	0 90-0.75
IR1905-81-3-1 (R)/IR442-2-58 (S)	46	0	46	566	179	745	3:1	0 376	0.75-0 50
IR1905-81-3-1 (R)/IR8 (S)	44	0	44	330	111	441	3:1	0.006	0.95-0.90
IR3259-PP8-172-7 (R)/IR3259-PP5-160-1 (R)	5	0	5	245	0	245	1:0		
IR3259-PP8-172-7 (R)/Pai-kan-tao (R)	53	0	53	130	13	143	57:7	0.500	0.50-0 25
IR3259-PP8-172-7 (R)/IR442-2-58 (S)	66	0	66	628	198	826	3:1	0.466	0.50-0 25
IR3259-PP8-172-7 (R)/IR8 (S)	5	0	5	140	35	175	3·1	2 33	0 25-0.10
IR3259-PP8-172-7 (R)/Peta (S)	6	0	6	50	15	65	3·1	0.128	0.50-0 25
IR3259-PP5-160-1 (R)/Pai-kan-tao (R)	38	0	38	194	27	221	57:7	0.371	0.75-0.50
Pai-kan-tao (R)/IR442-2-58 (S)	13	0	13	458	333	791	9:7	0.876	0 50-0.25
Pai-kan-tao (R)/Peta (S)	9	0	9	230	156	386	9:7	1.745	0.25-0.10
IR442-2-58 (S)/Peta (S)	0	27	27	0	185	185	0:1		
Peta (S)/Nongbaek (S)	0	5	5	0	200	200	0.1		

[a]R = resistant, S = susceptible.

Table 29. Reaction[a] of F_1 and F_2 plants to race ID-16 (I-PO6-6). IRRI, 1980.

Cross	Observed ratio F_1 R	S	Total	F_2 R	S	Total	Expected ratio for F_2	X^2	P
IR1905-81-3-1 (R)/IR3259-PP5-160-1 (R)	50	0	50	94	0	94	1:0		
IR1905-81-3-1 (R)/IR3259-PP8-172-7 (R)	5	0	5	176	19	195	57·7	0.285	0 75-0.50
IR1905-81-31 (R)/Pai-kan-tao (S)	27	0	27	64	23	87	3.1	0.095	0.90-0.75
IR1905-81-3-1 (R)/IR442-2-58 (S)	25	0	25	143	49	192	3:1	0.027	0.90-0.75
IR1905-81-3-1 (R)/IR8 (S)	28	0	28	103	37	140	3:1	0 152	0 75-0 50
IR3259-PP8-172-7 (R)/IR3259-PP5-160-1 (R)	5	0	5	275	33	308	57.7	0.015	0.95-0.90
IR3259-PP8-172-7 (R)/Pai-kan-tao (S)	31	0	31	43	31	74	9:7	0 103	0.75-0.50
IR3259-PP8-172-7 (R)/IR442-2-58 (S)	36	0	36	128	96	224	9.7	0.072	0.90-0.75
IR3259-PP8-172-7 (R)/IR8 (S)	6	0	6	115	85	200	9:7	0.126	0 75-0.50
IR3259-PP8-172-7 (R)/Peta (S)	5	0	5	30	27	57	9:7	0 303	0 75-0 50
IR3259-PP5-160-1 (R)/Pai-kan-tao (S)	30	0	30	43	17	60	3:1	0 355	0 75-0 50
Pai-kan-tao (S)/IR442-2-58 (S)	0	15	15	0	85	85	0:1		
Pai-kan-tao (S)/Peta (S)	0	15	15	0	87	87	0:1		
IR442-2-58 (S)/Peta (S)	0	22	22	0	69	69	0.1		
Peta (S)/Nongbaek (S)	0	5	5	0	174	174	0:1		

[a]R = resistant, S = susceptible.

Pai-kan-tao, IR442-2-58, IR8, Peta, and Nongbaek were susceptible to isolate I-41, which is designated as race IB-45. IR1905-81-3-1, IR3259-PP5-160-1, and IR3259-PP8-172-7 were resistant. The F_1 plants from the eight cross-combinations between resistant and susceptible parents gave resistant reactions, while cross-combinations between susceptible parents yielded susceptible reactions (Table 27). The segregation for disease resistance in crosses between resistant parents and susceptible parents were in close agreement with the simple monohybrid ratio of 3 resistant to 1 susceptible. However, in F_2 of the cross-combination of IR3259-PP8-172-7/IR442-2-58 the segregation ratio was 9:7. The reactions of the F_1 and segregation ratio of the F_2 showed that resistance was dominant over susceptibility.

The reactions of the parents, F_1, and F_2 of the different cross-combinations to isolate I-43 (Race IH-1) are summarized in Table 28. The F_1 plants of the resistant and susceptible crosses were resistant. The F_2 populations of five cross combinations inoculated with race IH-1 gave simple Mendelian segregation ratios of 3 resistant to 1 susceptible. In cross-combinations of Pai-kan-tao/IR442-2-58 and Pai-kan-tao/Peta, ratios of 9:7 were obtained. In cross-combinations involving resistant parents, all the F_2 were resistant. The results suggested that resistance is dominant over susceptibility.

The segregation of the F_2 in four cross-combinations in response to isolate PO6-6 (race ID-16) conformed closely with the Mendelian ratio of 3 resistant to 1 susceptible (Table 29). However, in combinations IR1905-81-3-1/IR3259-PP8-172-7 and IR3259-PP8-172-7/IR442-2-58, ratios of 57 resistant to 7 susceptible and 9 resistant to 7 susceptible were obtained, respectively. The F_2 populations from cross-combinations of susceptible parents were susceptible to the race, and F_2 of resistant parents were all resistant. The results again indicate that resistance to blast is dominant over susceptibility.

Genetic evaluation and utilization (GEU) program

Insect resistance

Entomology, Plant Breeding, and Chemistry Departments

SOURCES OF RESISTANCE

Entomology and Plant Breeding Departments

Since the beginning of the varietal resistance program, thousands of varieties have been screened and hundreds of sources of resistance identified (Table 1). Most of the world collection have been screened against the green leafhopper and more than 1,100 sources of resistance have been identified. In 1980 almost 400 additional varieties were identified in nonreplicated trials. For yellow stem borer resistance, the relatively few sources that have been identified have only a low level of resistance. In 1980 more than 200 accessions from the wild rice collection were screened and several with resistance to the stem borer and biotypes 1, 2, and 3 of the brown planthopper, whitebacked planthopper, and green leafhopper were found.

In the regular stem borer screening program 30 to 45-day-old plants are infested with larvae and deadhearts are counted 20 days later. To accelerate the stem borer resistance program, 2- and 4-week-old seedlings were tested at 3 row spacings and deadhearts were counted 1 week after infestation. Resistance was detected in the 2-week-old seedlings but was higher in 4-week-old seedlings (Table 2).

Table 1 Number of germplasm collection varieties screened and selected for resistance at IRRI through 1980.

Insect	Accessions (no.)		
	Tested	Selected	For retesting
Brown planthopper			
Biotype 1	32,298	280	329
2	9,652	200	175
3	9,399	215	117
Whitebacked planthopper	26,833	267	414
Green leafhopper	35,290	1,155	386
Zigzag leafhopper	1,959	401	186
Yellow stem borer	18,000	39	23
Striped stem borer	15,000	21	—
Whorl maggot	40,000	5	—
Leaf folder	2,683	11	21

Table 2. Reaction of a susceptible (S) and a resistant (R) variety to yellow stem borer, by the seedling bulk test. IRRI greenhouse, 1980.

Row spacing (cm)	Deadhearts[a] (%)		
	Rexoro (S)	IR1820 (R)	S/R
	Two-week-old		
4.5	97.3	52.2	1.9
5.0	87.9	39.2	2.2
6.0	76.7	46.0	1.7
	Four-week-old		
4.5	58.0	11.8	4.9
5.0	56.8	15.7	3.6
6.0	48.0	11.8	4.1

[a]Observed 7 days after infestation.

NATURE AND CAUSES OF RESISTANCE

Entomology and Chemistry Departments

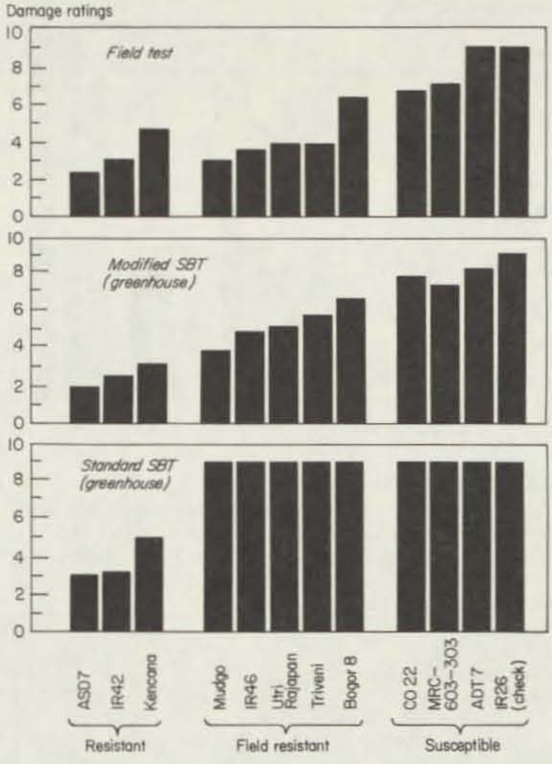
Moderate resistance to brown planthopper *(Entomology).* In 1979 the search began for moderately resistant (MR) varieties with minor genes that would exert less pressure for brown planthopper (BPH) biotype selection than highly resistant major-gene varieties. Some of the varieties that were susceptible in the greenhouse were resistant in the field where BPH attack occurred on older plants.

The modified standard greenhouse test in 1980 allowed identification of the MR or field-resistant varieties in the greenhouse (Table 3). Varieties such

Table 3. Damage ratings on selected varieties resistant to brown planthopper biotype 2 in greenhouse and field tests. IRRI, 1980.[a]

Variety	IRRI acc no.	Greenhouse test[b]		Field test[c] damage rating
		Standard	Modified	
Manchel Paragahakaleyan	36322	MR	R	R
Kencana	36756	MR	R	MR
Sudurvi 305	3475	S	R	R
Utri Rajapan	16684	S	R	R
Alewee	36218	S	R	R
Maharathkundawee	36480	S	R	MR
Sudhubalawee	8900	S	R	MR
Tibiriwewa	11969	S	R	R
Heenukkuluma	11978	S	R	MR
Bata Suduwee	31368	S	R	R
IR46	32695	S	R	R
Heenmurunga	31409	S	R	R
Kalubalawee	36264	S	MR	R
Kokkali	36463	S	R	R
Japan wee	15605	S	R	MR
Kirikunda	15558	S	MR	MR
Triveni	14785	S	MR	R
Bogor 8	4657	S	S	S
Kachepota	31419	S	MR	S
Andaragahawewa	11974	S	MR	S
Sinna Sivappu (R check)	1544	R	R	R
ASD7 (R check)	6303	R	R	—
IR26 (S check)	30413	S	S	S
TN1 (S check)	105	S	S	S

[a]Damage was rated when 90% of the susceptible check (IR26) plants were killed or attained an average damage rating of 8.0. R = resistant, MR = moderately resistant, S = susceptible. [b]Standard seedling bulk test was conducted by putting 12 insects on each seedling of 6-day-old plants and scoring damage at 14 days after infestation (DI). The modified seedling bulk test was done by putting 3-5 insects on each seedling of 10-day-old plants and scoring the damage at 34 DI. Av of 6 replications. [c]Insect counts and damage ratings were at about 70 DI. Av of 3 replications.



1. Field resistance to brown planthopper detected in the greenhouse by the modified seedling bulk test (SBT). IRRI, 1980.

as Mudgo, IR46, Utri Rajapan, and Triveni, which are susceptible to biotype 2 in the standard greenhouse screening but have field resistance, were identified as MR by the modified technique (Fig. 1).

Nature of moderate resistance to the brown planthopper. Compared with resistant and susceptible varieties, MR varieties allow an intermediate amount of BPH feeding and population growth (Fig. 2). It was evident that resistance levels were similar on 30-, 45-, and 60-day-old plants. Therefore, field resistance to the BPH cannot be considered mature plant resistance.

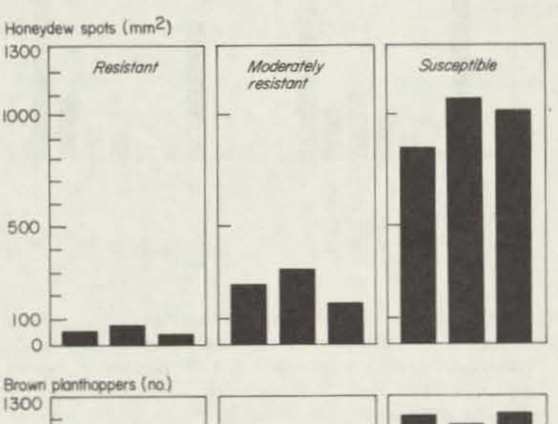
Moderate resistance in IR46, Triveni, and Utri Rajapan as measured by population growth and feeding activity was active against all biotypes at IRRI (Fig. 3).

IR26 and IR46 were equally susceptible to biotype 2 in the standard greenhouse screening, but IR46 was resistant in the field. In greenhouse feeding studies the minor gene effect of IR46 was indicated by the lower feeding activity on it than on IR26 (Fig. 4). Although Utri Rajapan is susceptible in seedling screening, it showed lower insect feeding activity. The population growth technique was a useful tool for detecting moderate levels of resistance in IR46 and Utri Rajapan (Fig. 5).

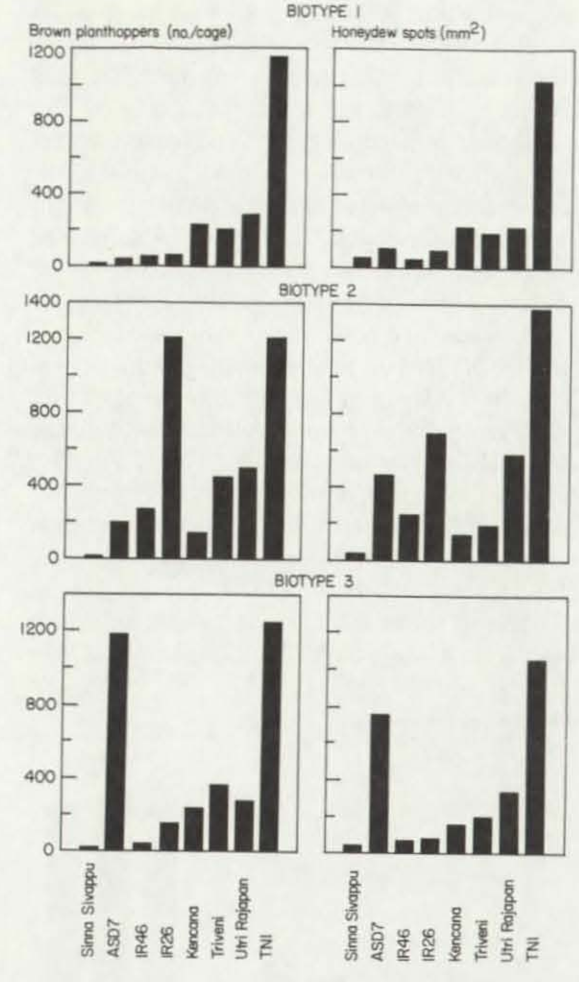
Because population growth and feeding studies are difficult to conduct, a modification of the commonly used seedling bulk screening technique was tested. Decreasing the number of insects and infesting older plants allowed detection of the moderate level of resistance in Triveni (Fig. 6, 7).

Tolerance as a component in the moderate resistance of Triveni. In screenhouse studies Triveni had less damage and was able to survive and produce grain despite a brown planthopper population equal to that on susceptible TN1 (Table 4).

In a field study yield reduction in Triveni was significantly less than in TN1 when the variety was infested with an initial population of 200 or 400 brown planthoppers/hill (Table 5). The ability of Triveni to tolerate high insect density at 3 plant ages from 35 to 75 days after transplanting is indi-



2. Brown planthopper feeding activity as indicated by area of honeydew excretion spots on filter paper, and population growth of the brown planthopper on resistant, moderately resistant, and susceptible varieties at 3 plant ages. IRRI greenhouse, 1980.

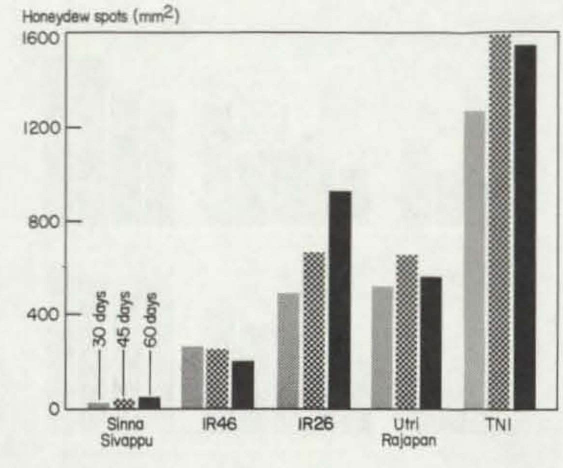


3. Feeding activity indicated by area of honeydew spots from the excretion of 5 3-day-old brown planthopper females in 24 hours, and population growth based on number of brown planthoppers per cage at 26 days after infestation with 5 pairs of 3-day-old adults. Results are means for 30-, 45-, and 60-day-old plants. IRRI greenhouse, 1980.

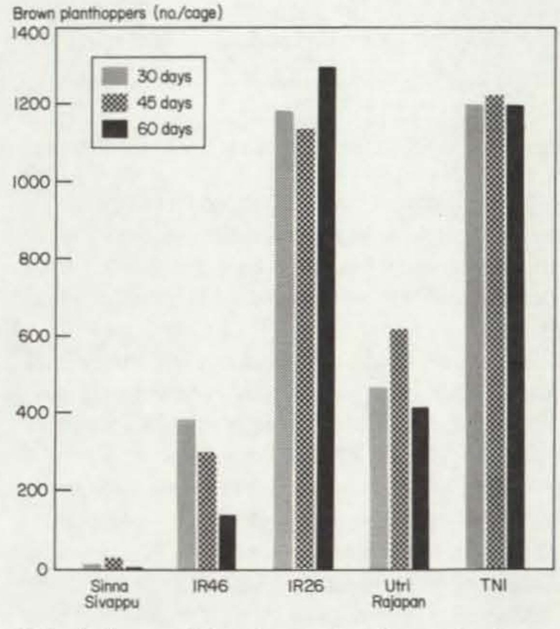
cated in Table 6. Where TN1 yield reduction was almost 100%, yield reduction in Triveni was only 40-50%. Triveni was able to produce a high percentage of productive tillers despite insect infestation, but productive tillers in TN1 were reduced to about 80% (Table 7).

Greenhouse studies using ^{14}C indicated a 74% reduction in carbon dioxide uptake in insect-damaged TN1 seedlings and 56% in Triveni (Table 8). This indicates that Triveni can maintain a higher photosynthetic rate when damaged by brown planthoppers.

Biochemical factors for resistance to brown

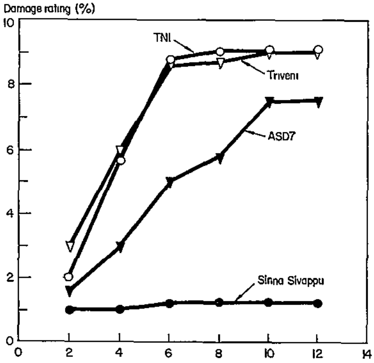


4. Feeding activity as indicated by area of honeydew spots from the excretion of 5 3-day-old biotype 2 brown planthopper adult females feeding on 30-, 45-, and 60-day-old plants for 24 hours. Sinna Sivappu is highly resistant, IR26 and TN1 are susceptible, and IR46 and Utri Rajapan moderately resistant to biotype 2. IRRI greenhouse, 1980.



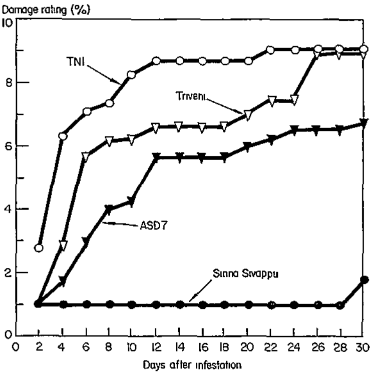
5. Population growth, based on number of brown planthopper *Nilaparvata lugens* per cage, at 26 days after 5 pairs of 3-day-old adults were caged on 30-, 45-, and 60-day-old plants. Sinna Sivappu is highly resistant, IR26 and TN1 are susceptible, and IR46 and Utri Rajapan moderately resistant to biotype 2. IRRI greenhouse, 1980.

planthopper *(Entomology and Chemistry).* Honeydew collected from biotype 2 brown planthoppers feeding on susceptible IR24 and resistant IR26 plants had comparable levels of soluble protein



6. Damage ratings of 8-day-old seedlings of rice varieties when infested with 15 brown planthopper nymphs/seedling. IRRI greenhouse, 1980. 1 = slight damage, 9 all plants dead

(0.33 mg/ml and 0.30 mg/ml) and free amino acids (1.0 mg/ml and 1.2 mg/ml). Glutamic and aspartic acids were the major amino acids in both samples. The honeydew from insects feeding on IR24 had more aspartic acid and less serine, carnosine, and sarcosine. However, total sugar (principally sucrose) was twice as much in IR24 (1.3 mg glucose



7. Damage ratings of 11-day-old seedlings of rice varieties when infested with 5 brown planthopper nymphs/seedling. IRRI greenhouse, 1980. 1 = slight damage, 9 = all plants dead

Table 4. Rating of plant damage due to *Nilaparvata lugens* on rice varieties TN1 and Triveni in the screenhouse. IRRI, 1980.

Plant age (DT[a])	*N. lugens*[b] (no./hill)	Damage rating[c]	Plant condition
		TN1	
15	5	1.0	Healthy
30	12	7.5	Yellowish and stunted
45	92	9.0	Hopperburned[d]
60	—	9.0	—
		Triveni	
15	3	1.0	Healthy
30	35	2.4	Lower leaves yellowish
45	81	4.1	Yellowish
60	11	7.5	Yellowish and stunted[e]

[a]Days after transplanting. [b]Av of 15 hills. [c]On a 1-9 scale: 1 = no damage, 9 = all plants dead. Av of 60 hills. [d]Hopperburned = no recovery. [e]Insect population decreased on the damaged plants. The plants recovered and grain was produced.

/ml) than in IR26 (0.7 mg/ml) despite the similarity in sugar content of their leaf sheath diffusates.

Crude steam distillates from IR24 and IR26 plants were recovered in 0.008% yield from IR24

Table 5. Damage rating and yield reduction in varieties TN1 and Triveni at different levels of brown planthopper *Nilaparvata lugens* infestation in the field.[a] IRRI, 1979.

N. lugens (no./hill)	Damage rating[b]		Yield reduction[c] (%)		
	TN1	Triveni	TN1	Triveni	Difference
400	8.8 a	7.0 a	99 a	44 a	54**
200	7.2 a	5.4 b	55 b	26 ab	29**
100	7.0 a	6.2 b	30 c	20 b	10 ns

[a]Means of 10 hills. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]1 = no damage, 9 = all plants dead.

[c]Yield reduction =

$$\frac{\text{yield of noninfested hills} - \text{yield of infested hills}}{\text{yield of noninfested hills}}$$

Table 6. Insect population, damage ratings, and yield reduction of rice varieties TN1 and Triveni as affected by feeding of the brown planthopper *Nilaparvata lugens* at 3 plant growth stages.[a] IRRI, 1979.

Plant age (days after transplanting)	Variety[b]	Damage rating[c]	*N. lugens* population (no./hill)[d]	Yield reduction[e] (%)
35	TN1	8.4 a	529 a	97 a
	Triveni	8.6 a	516 a	41 a
55	TN1	8.6 a	548 a	99 a
	Triveni	7.2 ab	496 a	40 b
75	TN1	8.4 a	396 a	94 a
	Triveni	5.7 b	209 a	52 b
Check (no insects)	TN1	1.0 c	0	—
	Triveni	1.0 c	0	—

[a]Means of 10 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. Each replication initially infested with 400 first- and second-stage nymphs at given plant ages. *N. lugens* were counted 6 weeks after infestation. [b]TN1 is susceptible check, Triveni is a moderately resistant variety. [c]Damage rating taken 1 week before harvest: 1 = no damage, 9 = all plants dead. [d]Recorded at 6 weeks after plant infestation. [e]Yield reduction when compared to the check.

Table 7. Dry matter production, tiller number, and percentage of productive tillers of rice varieties TN1 and Triveni as affected by feeding of the brown planthopper *Nilaparvata lugens* at 3 plant growth stages.[a] IRRI, 1979.

Plant age (DT)	Dry matter (g/hill)		Tillers (no.)		Productive tillers (%)	
	TN1	Triveni	TN1	Triveni	TN1	Triveni
35	9 5 b	12 9 a	14 b	9 b	14 b	51 a
55	6 0 b	13 3 a	12 b	12 ab	7 b	48 a
75	9 4 b	13 2 a	15 b	10 b	15 b	76 a
Check (no insects)	32 0 a	18 7 a	22 a	16 a	73 a	58 a

[a]Means of 10 hills in a cage under field conditions, infested with 400 third- and fourth-stage nymphs The insects were removed after 6 weeks Separation of means in a column by Duncan's multiple range test at the 5% level.

and 0.006% from IR26. Both resulted in more than 50% mortality of brown planthoppers within 24 hours.

Whitebacked planthopper resistance gene sources *(Entomology).* The strength of varieties having genes for whitebacked planthopper resistance was evaluated. Based on rate of population growth and feeding of the whitebacked planthopper, IR2035-117-3, with genes *Wbph 1* + *Wbph 2,* had the highest level of resistance; N22, with the *Wbph 1* gene, had the lowest (Fig. 8).

Although IR varieties have not been bred for whitebacked planthopper resistance, evaluation of IR5-IR54 using the seedling screening method indicated distinct differences among the varieties.

Green leafhopper resistance gene sources *(Entomology).* The nature of resistance to green leafhopper (GLH) of seven gene sources is indicated in Figure 9. On the highly resistant varieties, fewer eggs were laid and nymphal survival and population growth were low. Egg hatchability was the same for all gene sources. ASD7, IR8, and ASD8,

Table 8. Amount of ^{14}C in rice seedlings and in honeydew excreted by *Nilaparvata lugens* feeding on rice seedlings IRRI, 1979.

Treatment	Amount of ^{14}C[a] (CPM)		Reduction in net CO_2 uptake[c] (%)
	Honeydew	Plant[b]	
		TN1	
Healthy	3.45 a	14.26 c	—
Damaged	0 74 b	3.77 d	74
		Triveni	
Healthy	2 73 a	60 33 a	—
Damaged	0.12 b	26.85 b	56

[a]CPM = counts per minute. Separation of means in a column by Duncan's multiple range test at the 5% level [b]Amount of ^{14}C taken up by rice seedlings as total amount in plant, insect body, and honeydew
[c]Reduction in net CO_2 uptake =

$$\frac{\text{CPM in healthy seedling} - \text{CPM in damaged seedling}}{\text{CPM in healthy seedling}} \times 100$$

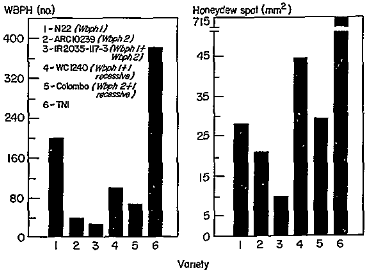
with *Glh 2, Glh 3,* and *Glh 5* were the most resistant as indicated by the population growth study.

Virulence of Philippine green leafhopper cultures. GLH collected at 15 sites throughout the Philippines were tested to determine the presence of biotypes in field populations. Although the cultures differed in virulence there was no distinct evidence of Philippine GLH biotypes that are significantly more virulent than the IRRI greenhouse culture, which is maintained on susceptible TN1 (Fig. 10).

INHERITANCE OF RESISTANCE TO THE WHITEBACKED PLANTHOPPER

Plant Breeding and Entomology Departments

Fourteen WBPH resistant varieties were analyzed to find new genes for resistance (Table 9). They

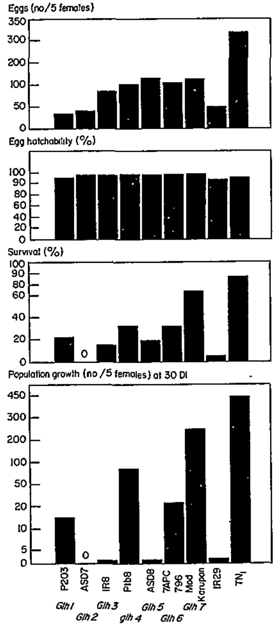


8. Population growth and feeding activity of whitebacked planthopper (WBPH) *Sogatella furcifera* on varieties having genes for resistance. In the population growth study, 5 3-day-old adults were placed on plants and population was counted 30 days after infestation. In the feeding rate study, 5 3-day-old adults were caged overnight on 30-day-old plants over bromocresol green-treated filter papers IRRI, 1980.

Table 9. Whitebacked planthopper-resistant rice varieties analyzed for new genes for resistance. IRRI, 1980.

Variety	IRRI acc. no	Country of origin
ADR52	40638	India
T1471	53427	India
Cheriya Chittari	53424	India
Chempan	53421	India
Chemparampandi	53422	India
Chenninayakan	53423	India
T1426	53426	India
Ptb 12	53430	India
T1421	53425	India
Podiwi-A8	15201	Sri Lanka
ARC6650	53429	India
Ptb 19	53431	India
ARC6564	53428	India
ARC14342A	42898	India

were crossed with susceptible variety TN1 and the F_1, F_2, F_3 progenies were analyzed to determine the mode of inheritance. Twelve F_1 progenies were resistant, indicating resistance governed by dominant genes (Table 10). However, F_1 progenies of TN1/Podiwi-A8 and TN1/ARC6650 were susceptible, indicating that recessive genes convey resistance in those two varieties. The F_2 populations from the crosses of TN1 with 12 varieties segregated in a ratio of 3 resistant to 1 susceptible, showing that a single dominant gene governs resistance in each variety. The F_2 populations from the TN1 crosses with Podiwi-A8 and ARC6650 segregated in a ratio of 1 resistant to 3 susceptible, showing resistance conveyed by a single recessive gene. The F_3 populations from all crosses confirmed the conclusions drawn from the F_2 data. The F_3 data agreed with the ratio 1:2:1 (resistant: segregating:susceptible) expected for monogenic control of resistance.

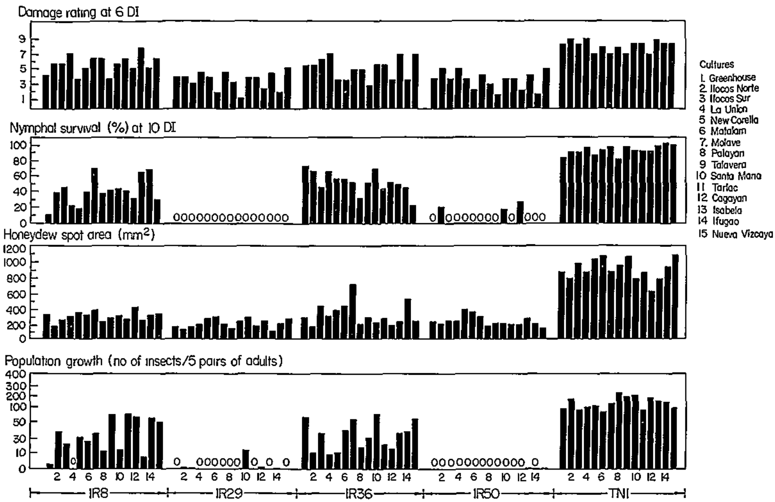


9. Relative levels of resistance of rice varieties having genes for resistance to the green leafhopper Survival percentage is of first-instar nymphs at 15 days after plant infestation Population growth at 30 days after infestation (DI) resulted from 5 pairs of 3-day-old adults placed on 30-day-old plants IRRI, 1980

Table 10 Reaction[a] to whitebacked planthopper of F_1, F_2, and F_3 populations from crosses of resistant cultivars with TN1. IRRI, 1980.

Cross	F_1	F_2 seedlings				F_3 families			
		R (no)	S (no)	X^2 3:1	X^2 1:3	R (no.)	Seg (no)	S (no)	X^2 1 2 1
TN1/ADR52	R	710	218	1.13		32	87	34	2 92
TN1/T1471	R	734	269	1.77		42	82	30	2 52
TN1/Cheriya Chittari	R	663	243	2 03		35	69	31	0.30
TN1/Chempan	R	717	268	2 58		22	62	26	2 07
TN1/Chemparampandi	R	660	247	2 41		32	86	35	2 48
TN1/Chenninayakan	R	771	281	1 64		32	85	37	1.99
TN1/T1426	R	647	235	1.69		31	88	35	3 35
TN1/Ptb 12	R	643	242	2 60		32	82	40	1.48
TN1/T1421	R	844	245	3 66		35	88	31	3 35
TN1/Podiwi-A8	S	174	596	—	2 48	39	83	32	1.56
TN1/ARC6650	S	208	533	—	3 75	33	80	41	1 06
TN1/Ptb 19	R	675	221	2 32		31	83	40	1 99
TN1/ARC6564	R	787	242	2 68		40	83	31	1.99
TN1/ARC14342A	R	707	259	2 32		34	80	40	0 70

[a]R = resistant, S = susceptible, Seg = segregating.



10. Comparative virulence of 15 green leafhopper colonies on 5 rice varieties, based on seedling bulk test, nymphal survival, honeydew excretion, and population growth DI = days after infestation. IRRI, 1980

The 14 varieties were crossed with IR13475-7-3-2, which is homozygous for *Wbph 1*. As expected all the F_1 progenies were resistant (Table 11). The F_2 populations of IR13475-7-3-2/Podiwi-A8 and IR13475-7-3-2/ARC6650 segregated in a ratio of 13 resistant to 3 susceptible, showing that the recessive genes for resistance in Podiwi-A8 and ARC6650 segregate independently of *Wbph 1*. The F_2 populations from the remaining 12 crosses segregated in a ratio of 15 resistant to 1 susceptible, indicating that the dominant genes for resistance in the test varieties segregate independently of *Wbph 1*. The F_3 families of all crosses segregated in a ratio of 7 resistant to 8 segregating to 1 susceptible confirming the conclusions drawn from the F_2 data.

Table 11. Reaction[a] to whitebacked planthopper of F_1, F_2, and F_3 populations from the crosses of resistant cultivars with IR13475-7-3-2. IRRI, 1980.

Cross	F_1	F_2 seedlings				F_3 families			
		R (no.)	S (no.)	X^2 15:1	X^2 13:3	R (no.)	Seg (no.)	S (no.)	X^2 7:8:1
IR13475-7-3-2/ADR52	R	823	68	3.09		69	80	5	2.38
IR13475-7-3-2/T1471	R	873	84	10.43		64	79	11	0.42
IR13475-7-3-2/Cheriya Chittari	R	864	72	3.32		69	73	12	0.83
IR13475-7-3-2/Chempan	R	899	71	1.89		66	75	13	1.26
IR13475-7-3-2/Chemparampandi	R	955	75	1.87		72	74	8	0.71
IR13475-7-3-2/Chenninayakan	R	931	49	2.61		74	71	9	1.16
IR13475-7-3-2/T1426	R	890	72	3.20		68	76	10	0.03
IR13475-7-3-2/Ptb 12	R	851	70	2.87		63	81	10	0.51
IR13475-7-3-2/T1421	R	962	80	3.62		68	74	12	0.71
IR13475-7-3-2/Podiwi-A8	R	907	216	—	0.17	60	84	10	1.46
IR13475-7-3-2/ARC6650	R	568	114	—	1.85	60	86	8	2.13
IR13475-7-3-2/Ptb 19	R	886	69	1.55		70	73	7	1.03
IR13475-7-3-2/ARC6564	R	979	79	2.70		59	82	13	2.55
IR13475-7-3-2/ARC14342A	R	839	66	1.68		63	79	12	0.92

[a]R = resistant, S = susceptible, Seg = segregating

Table 12. Reaction[a] to whitebacked planthopper of F_1, F_2, and F_3 populations from the crosses of resistant cultivars with IR30659-1. IRRI, 1980.

Cross	F_1	F_2 seedlings				F_3 families			
		R (no)	S (no)	X^2 15 1	X^2 13 3	R (no)	Seg (no)	S (no)	X^2 7 8 1
IR30659-1/ADR52	R	859	69	2 48		74	67	13	3.13
IR30659-1/T1471	R	988	63	1.07		67	75	12	0.64
IR30659-1/Cheriya Chittari	R	827	5	—		154	0	0	—
IR30659-1/Chempan	R	894	7	—		148	0	0	0
IR30659-1/Chemparampandi	R	915	78	4 37		73	70	10	1 12
IR30659-1/Chenninayakan	R	822	66	2 13		72	75	7	1 08
IR30659-1/T1426	R	852	63	2 74		60	83	11	1 47
IR30659-1/Ptb 12	R	688	36	2 02		59	82	13	2 55
IR30659-1/T1421	R	725	61	3 06		64	77	12	0 75
IR30659-1/Podiwi-A8	R	816	179	—	3 29	54	74	10	1 25
IR30659-1/ARC6650	R	817	211	—	2 21	71	68	13	2.44
IR30659-1/Ptb 19	R	775	47	2.46		74	70	10	1 30
IR30659-1/ARC6564	R	953	60	2 50		62	80	10	0 54
IR30659-1/ARC14342A	R	893	77	4 72		60	82	12	1.72

[a]R = resistant, S = susceptible, Seg = segregating.

The varieties were also crossed with IR30659-1, which is homozygous for *Wbph 2.* The F_1 progenies were resistant. The F_2 populations from the crosses of IR30659-1 with ADR52, T1471, Chemparampandi, Chenninayakan, T1426, Ptb 12, T1421, Ptb 19, ARC6564, and ARC14342A segregated in a ratio of 15 resistant to 1 susceptible (Table 12). The data indicate an independent segregation of two dominant genes. The F_3 families of these crosses showed a good fit to the segregation ratio of 7 resistant to 8 segregating to 1 susceptible. The data confirm the conclusions from F_2 data that the test varieties have single dominant genes that are nonallelic to *Wbph 2.*

In the F_2 populations from the crosses of IR30659-1 with Cheriya Chittari and Chempan, only a few susceptible seedlings were observed and all the F_3 families of these two crosses were resistant (Table 12). No segregation for susceptibility was observed. It appears that the two varieties have *Wbph 2* for resistance. The F_2 progenies from the crosses of IR30659-1 with Podiwi-A8 and ARC6650 showed a segregation ratio of 13 resistant to 3 susceptible and F_3 families segregated in a ratio of 7 resistant to 8 segregating to 1 susceptible. The data indicate that the recessive genes of Podiwi-A8 and ARC6650 segregate independently of *Wbph 2.*

Table 13. Summary of information on genes for resistance to whitebacked planthopper in test rice varieties. IRRI, 1980.

Variety	Nature of resistance	Resistance gene
ADR52	Monogenic, dominant	*Wbph 3*
T1471	Monogenic, dominant	?
Cheriya Chittari	Monogenic, dominant	*Wbph 2*
Chempan	Monogenic, dominant	*Wbph 2*
Chemparampandi	Monogenic, dominant	?
Chenninayakan	Monogenic, dominant	?
T1426	Monogenic, dominant	?
Ptb 12	Monogenic, dominant	?
T1421	Monogenic, dominant	?
Podiwi-A8	Monogenic, recessive	*wbph 4*
ARC6650	Monogenic, recessive	?
Ptb 19	Monogenic, dominant	?
ARC6564	Monogenic, dominant	?
ARC14342A	Monogenci, dominant	?

The results show that single dominant genes in each of 12 varieties are nonallelic to *Wbph 1.* However, Cheriya Chittari and Chempan have *Wbph 2* (Table 13). Dominant genes in the remaining 10 are different from *Wbph 1* and *Wbph 2.* By the international rules for gene nomenclature, the dominant gene of ADR52 is designated as *Wbph 3.* Allele tests between *Wbph 3* and dominant genes of nine other varieties should be made to determine whether they possess *Wbph 3* or different genes. The recessive genes of Podiwi-A8 and ARC6650 segregate independently of *Wbph 1* and *Wbph 2.* The recessive gene of Podiwi-A8 is designated *wbph 4.* Allele tests between *wbph 4* and the recessive gene of ARC6650 should also be made.

BIOCHEMICAL EVIDENCE FOR FEEDING SITES OF GREEN LEAFHOPPER

Entomology Department

Semiquantitative biochemical analyses by paper chromatography-densitometry and pH determinations of honeydew excreted by *Nephotettix virescens* (Distant) feeding on rice plants revealed a much higher free amino compound and sugar concentrations in excreted honeydew from the sus-

Table 14. Estimated concentrations (μg/10 μgl) of free amino compounds in sap exudates and in basic or acidic honeydew of *Nephotettix virescens*, from susceptible (TN1) and resistant (ASD7 and Pankhari 203) rice varieties, and honeydew-sap ratios.[a] IRRI, 1980[b]

Free amino compound	TN1: Concn (μg/10 μgl) in Sap	TN1: Concn in Honey dew, Acidic	TN1: Concn in Honey dew, Basic	TN1: Basic honey-dew: sap	ASD7: Concn (μg/10 μgl) in Sap	ASD7: Concn in Honeydew (Acidic)	ASD7: Honeydew sap	Pankhari 203: Concn (μg/10 μgl) in Sap	Pankhari 203: Concn in Honeydew (Acidic)
Alanine	0.2	tr	0.4	2.0	0.3	0.1	0.3	0.3	—
Arginine	0.5	—	1.0	2.0	0.5	tr	0.4	1.0	tr
Asparagine	2.7	tr	3.7	1.4	2.6	1.4	0.4	1.9	—
Aspartic acid	0.3	0.5	4.6	15.3	0.7	0.2	0.6	0.5	0.1
Glutamine	2.3	0.5	2.3	1.0	2.2	0.4	0.3	2.2	0.6
Glutamicacid	0.3	1.4	12.0	40.0	1.4	0.9	0.6	1.0	0.8
Glycine	0.2	tr	0.5	2.5	0.2	0.1	0.5	0.2	tr
ILE + PHE[c]	1.3	tr	1.6	1.2	2.1	0.2	0.2	2.2	—
Serine	0.8	0.2	1.6	2.0	2.0	0.3	0.2	1.2	0.1
Threonine	0.3	tr	0.4	1.3	0.5	0.1	0.2	0.4	tr
Tyrosine	0.2	tr	0.5	2.5	0.4	tr	0.5	0.5	—
Valine	0.7	0.2	1.1	1.6	1.1	0.3	0.3	1.1	0.3
Total	9.8	2.8	29.7		14.0	4.0		12.5	1.9
Honeydew sap		0.3		3.0			0.3		0.2

[a]Mean of 4-10 readings per value for sap and honeydew on TN1 and ASD7; mean of 1-9 readings for sap, and 1-6 readings for honeydew on Pankhari 203 The standard deviation of sap readings for the 3 varieties is 0.56-0.70, that for basic honeydew is 1.7. [b]tr = detected in trace amount, — = not detected [c]A mixture of isoleucine and phenylalanine was used as a standard in the control chromatograms The samples probably contained these and leucine

ceptible variety TN1 than from resistant ASD7 or Pankhari 203 (Table 14). Furthermore, sap exudates from the three varieties, presumed to be mainly from the xylem, as well as honeydew excreted on the resistant varieties were acidic, but honeydew from TN1 was predominantly basic (Table 15). Phloem sap in herbaceous plants usually gives an alkaline reaction, but xylem sap is acidic. Because phloem sap contains much higher concentrations of sugars and free amino acids than xylem sap, the biochemical evidence strongly suggests that *N. virescens* is primarily a xylem feeder on the resistant plants tested, but is a phloem feeder on susceptible TN1.

Table 15. Estimate of pH of honeydew droplets excreted by *Nephotettix virescens* feeding on leaves of susceptible (TN1) and resistant (ASD7 or Pankhari 203) rice varieties as indicated by pH indicator sticks IRRI, 1980

Period (h) of insect confinement in sachets	Honeydew samples: TN1 Acidic (no.)	TN1 Basic (no.)	TN1 Basic (%)	ASD7 Acidic (no.)	Pankhari 203 Acidic (no.)
0.5-1	13	0	0	5	5
1-2	29	0	0	18	11
2-3	46	2	4	20	12
3-4	12	16	57	6	13
4-5	31	46	60	33	14
5-7	18	33	65	6	11
22-24	19	68	78	39[a]	18[a]
Total samples	168	165		127	84

[a]One sample was basic

MORPHOLOGICAL VARIATIONS AMONG BROWN PLANTHOPPER BIOTYPES

Entomology Department

Identification of brown planthopper biotypes is based principally on the differential reactions of the host rice varieties to the pest or on host-mediated, differential behavioral and physiological responses of the pest. An in-depth evaluation of morphological and morphometric differences among BPH biotypes 1, 2, and 3, emphasizing body parts possessing receptors, was made in 1980.

One hundred adults each of biotypes 1, 2, and 3 (maintained at IRRI for 6-10 years as stock cultures on TN1, Mudgo, and ASD7) were examined. About 109 morphological characters of the rostrum (including mandibular stylets), legs, and antennae were measured and examined separately in both sexes and both morphs — macropterous male, macropterous female, brachypterous male, and brachypterous female (Table 16).

Multiple discriminant analysis was used to differentiate the three biotypes based on the available morphological and morphometric data. Wilks' Stepwise method was followed in the selection of certain independent variables on each discrimination. Discriminant analyses to classify the three biotypes were run on the combined characters of rostrum, legs (forelegs, midlegs, and hind legs),

Table 16 Codes used in morphometric evaluation of rostral, leg, and antennal characters of biotypes 1, 2, and 3 of adult *Nilaparvata lugens*. IRRI, 1980

Code	Structures and their morphometric parameters
	Rostrum
	Setae of ultimate rostral segment (no.)
RL1	1st anterocentral setae
RL2	1st anterolateral setae
RL3	1st posterolateral setae
RL4	1st posterocentral setae
RL5	2d posterocentral setae
RL6	2d posterolateral setae
RL7	2d anterolateral setae
RL8	2d anterocentral setae
RL9 & RR9	Teeth of left and right sides of second rostral groove (no.)
RL10	Ultimate rostral segment (UR) (length in μ)
RL11	Penultimate rostral segment (PR) (length in μ)
RL12 & RR12	Anterocentral setae of left and right sides of PR (no.)
RL13	PR (length in μ)/UR (length in μ)
RL14	UR (length in μ)/3d hind tarsus (length in μ)
RL15 & RR15	Teeth of left and right mandibular stylets (no.)
	Leg — foretarsus
	Setae of 3d subsegment of tarsus (no.)
LL16 & LR16	1st dorsocentral setae of left and right tarsi
LL17 & LR17	2d dorsocentral setae of left and right tarsi
LL18 & LR18	anterodorsal setae of left and right tarsi
LL19 & LR19	posterodorsal setae of left and right tarsi
LL20 & LR20	anteroventral setae of left and right tarsi
LL21 & LR21	posteroventral setae of left and right tarsi
LL22	Dorsal plate (length in μ)
LL23	Tarsal membrane (length in μ)
LL24	Unguitractor plate (length in μ)
LL25 & LL26	Claw (max length and max width in μ)
LL27	Claw (length in μ)/claw (width in μ)
LL28	3d subsegment of foretarsus (length in μ)
	Leg — midtarsus
	Setae of 3d subsegment of tarsus
LL29 & LR29	1st dorsocentral setae of left and right tarsi
LL30 & LR30	2d dorsocentral setae of left and right tarsi
LL31 & LR31	anterodorsal setae of left and right tarsi
LL32 & LR32	posterodorsal setae of left and right tarsi
LL33 & LR33	anteroventral setae of left and right tarsi
LL34 & LR34	posteroventral setae of left and right tarsi
LL35	Dorsal plate (length in μ)
LL36	Tarsal membrane (length in μ)
LL37	Unguitractor plate (length in μ)
LL38 & LL39	Claw (max length and max width in μ)
LL40	Claw (length in μ)/claw (width in μ)
LL41	3d subsegment of midtarsus (length in μ)
	Leg — hind tarsus
	Setae of 3d subsegment of tarsus (no.)
LL42 & LR42	1st dorsocentral setae of left and right tarsi
LL43 & LR43	2d dorsocentral setae of left and right tarsi
LL44 & LR44	anterodorsal setae of left and right tarsi
LL45 & LR45	posterodorsal setae of left and right tarsi
LL46 & LR46	anteroventral setae of left and right tarsi
LL47 & LR47	posteroventral setae of left and right tarsi
LL48	Dorsal plate (length in μ)
LL49	Tarsal membrane (length in μ)
LL50	Unguitractor plate (length in μ)
LL51 & LL52	Claw (max length and max width in μ)
LL53	Claw (length in μ)/claw (width in μ)
LL54	3d subsegment of hind tarsus (length in μ)
	Antenna
AL55	1st antennal segment (length in μ)
AL56	2d antennal segment (length in μ)
	Pegs of sensoria of 2d antennal segment (no.)
AL57 & AR57	1st anterodorsal sensorium of left and right antennae
AL58 & AR58	2d anterodorsal sensorium of left and right antennae
AL59 & AR59	3d anterodorsal sensorium of left and right antennae
AL60 & AR60	1st dorsocentral sensorium of left and right antennae
AL61 & AR61	2d dorsocentral sensorium of left and right antennae
AL62 & AR62	3d dorsocentral sensorium of left and right antennae
AL63 & AR63	4th dorsocentral sensorium of left and right antennae
AL64 & AR64	5th dorsocentral sensorium of left and right antennae
AL65 & AR65	1st posterodorsal sensorium of left and right antennae
AL66 & AR66	2d posterodorsal sensorium of left and right antennae
AL67 & AR67	3d posterodorsal sensorium of left and right antennae
AL68 & AR68	4th posterodorsal sensorium of left and right antennae
AL69 & AR69	1st posteroventral sensorium of left and right antennae
AL70 & AR70	2d posteroventral sensorium of left and right antennae
AL71 & AR71	anteroventral sensorium of left and right antennae
AL72 & AR72	ventrocentral sensorium of left and right antennae
AL73 & AR73	Sensoria of 2d antennal segment of left and right antennae (total no.)

and antennae representing a total of 109 variables for each of the four groups.

The insect antennae, rostrum, and legs possess many sensory structures, which aid in host location and discrimination. The 1980 study was primarily on the chaetotaxy or arrangement of the setae on the rostrum and legs, and sensoria of antennae. The chaetotaxy of the rostrum provided important discriminating characters. The third subsegment of the tarsus showed remarkably few modifications, but its chaetotaxy provided useful characters.

The antenna, which is composed of three main segments (scape, pedicel, flagellum), also offers valuable characters. The pedicel has a number of sensoria distributed throughout. Each sensorium is composed of a number of pegs and alternating or interspersed setae.

Discriminant analyses were performed using

Table 17 Discriminating power of adult rostral, leg, and antennal characters in classifying biotypes 1, 2, and 3 of *Nilaparvata lugens* IRRI, 1980.[a]

Variables[b] selected	Macropterous male			Wilks'[c] Lambda	Macropterous female			Wilks'[c] Lambda	Brachypterous male			Wilks'[c] Lambda	Brachypterous female			Wilks'[c] Lambda
	Mean value				Mean value				Mean value				Mean value			
	B1	B2	B3		B1	B2	B3		B1	B2	B3		B1	B2	B3	
LR32					4 0	3 1	3 5	0 456								
LL20					4 7	4.8	4 1	0.276								
LL17					3 9	3 7	3 9	0 167								
AR57					8 5	9 2	10 3	0 083								
AR71					9 9	10 0	10 7	0 059	9 7	10 2	10 2	0 000				
RL1					8 7	8 7	9 3	0 035								
LL32					3 7	3.2	3 5	0 026					3 5	3 4	3 5	0 000
LR20	4.6	4 5	4 4	0 000	4 8	4 3	4 6	0 017	4 4	4 4	4 1	0 000				
LR47					4 8	4 8	5 1	0 012								
RL13					1 06	1 07	1 06	0 009	1 20	1 07	1 06	0.000	1 08	1 05	1 04	0 015
LR44					4 1	4 1	4 1	0 007					4 8	4 2	4 1	0 400
LL44					4 1	4 5	4 2	0 005								
AL67					8 3	8 9	8 0	0 003								
RL4					7 0	7.7	6 3	0 002								
LR31					3 5	3 3	3 6	0 001								
LL21					4 4	4 4	4 4	0 001								
LR34					4 4	4 3	4 3	0 000								
LL45	4.2	3 8	4 0	0 000	4 2	4 2	4 2	0 000					4 5	4 3	4 3	0 000
LL16					4.7	5 1	4.8	0 000	4 9	4 9	4 2	0.350				
LL52					27 0	29.0	27 0	0 000	24 0	28 0	24 0	0 000				
AL62	8 5	8.5	8.4	0 000	8 5	9 2	8 8	0 000								
AL71					10 3	10 1	11 0	0.000								
RL6					5 6	7 9	6 7	0.000					7 2	7 5	7 5	0 000
LL50	592 0	278 0	278 0	0 015												
LL54	4.6	4 0	4 2	0 000												
LR18	3 4	3.1	3.4	0 000												
RL2	9 0	9 9	9.1	0 000												
LR30	3.8	3 8	4 1	0.000												
AR62	8 0	8.4	8 0	0 000												
RL5	5 6	6 8	6.2	0 000					6 2	7 6	6 2	0.043				
AR61	8 5	8 9	8 7	0 000												
LL18	3 1	3 4	3 3	0 000					3.4	3 3	3 2	0 001				
AR65	9 1	8 8	8.8	0 000												
AL58	8 1	8 6	8.2	0 000												
LL42	6 0	6 1	5.9	0 000												
RL7	9 9	10 4	9.9	0 000												
AL73	16.5	16 7	17.7	0 000												
LL28	191.2	191 8	201 3	0.000												
RL8	8 3	9.3	7 7	0 000					8 7	8 5	9 0	0 000				
AR73	16 2	16 3	16.7	0 000					16 2	16 3	16 7	0 000				
AR58	8 5	8 6	8.5	0 000					8 5	8 6	8 4	0 000				
LL46	4 1	3.9	4 1	0 000												
LL48													192 0	182 0	158 0	0 576
AL60													8 5	9 8	8 6	0 285
LL30													3 6	3 5	3 9	0 166
AL61													8 3	8 9	9 7	0 124
AR72													9 6	10 4	10 5	0 084

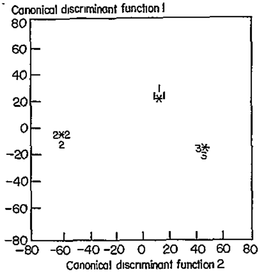
CONTINUED ON OPPOSITE PAGE

Table 17 continued

AR64					6 5	6 2	6 1	0.056
LL22	8.6	8 5	7.7	0 068	7 8	8 8	8.9	0 039
LL25					73.6	70 2	73.3	0 022
AL63	6 7	7 5	6.9	0 000	7.2	8 1	7 5	0 009
RL14					0 94	0 92	0 89	0.005
LL33					4 6	4 5	4 8	0 002
AL55					25 8	18 4	14 5	0 000
LR19					3 4	3 5	3.2	0 000
LR46					4.6	4 3	4 5	0.000
LL35					18 0	18 9	20 6	0 000
LL53					1.98	2 23	2 26	0 000
RL10	219 0	241.0	226 0	0 585				
LL34	4.2	4 0	4 3	0 199				
AL59	7 7	6 6	6 7	0 120				
AL51	50.0	56 0	53 0	0 023				
AL72	7 8	9 1	9 0	0 013				
LL41	102 0	110 0	104 0	0.006				
AR72	9 8	10 2	9.6	0 004				
AL56	289 0	303.0	306.0	0 002				
AR63	7 2	7.0	6.4	0.001				
AR73	16 2	16 3	16.7	0.000				
AL68	6 5	6.6	7.0	0.000				
RL12	20 2	21.3	20.8	0.000				
LL25	61 0	65 0	64 0	0 000				

	Macropterous male[d]		Macropterous female[d]		Brachypterous male[d]		Brachypterous female[d]	
	F1	F2	F1	F2	F1	F2	F1	F2
Eigenvalue	64123 97	16076.35	1258.04	575 07	3426 62	581.19	2171 57	340 39
Variance (%)	80 0	20 0	69 0	31.0	86 0	14.0	86 0	14 0
Cumulative %	80 0	100 0	69 0	100 0	86 0	100.0	86 0	100 0
Canonical correlation	0 999	0 999	0 999	0 999	0 999	0.999	0.999	0 998
Final Wilks'Lambda	0 000	0 000	0 000	0 002	0 000	0.002	0 000	0 000
Chi-square	322 06	154.96	215 91	101 70	232 10	101 87	216 27	93 33
Significance	0 000	0 000	0 000	0 000	0 000	0 000	0.000	0 000
Degrees of freedom	46	22	46	22	46	22	46	22

[a]B1 = biotype 1, B2 = biotype 2, B3 = biotype 3 [b]Mean values for variables RL10, RL14, LL22, LL25, LL28, LL35, LL41, LL48, LL50, AL51, LL52, LL55, and LL56 are in μ, variables RL13, RL14, and LL53 are ratios, mean values of other variables represent number of setae, sensoria, etc [c]All Wilks' Lambda values are significant at below 0 5% level [d]F1 = discriminant function 1, F2 = discriminant function 2



11. Discriminant scores of three biotypes of *Nilaparvata lugens* based on rostral, leg, and antennal characters of brachypterous females. The numbers indicate biotype designation; the asterisk (*) indicates a group centroid. IRRI, 1980.

Wilks' stepwise selection method. When all the morphological characters of the rostrum, legs, and antennae of each of the forms of both sexes were combined and run together, a significant degree of discrimination among BPH biotypes was achieved (Table 17). The scatter diagrams based on the computed discriminant scores of the three biotypes strongly revealed a high degree of segregation, indicating distinct populations. For example, Figure 11 illustrates the discriminant scores of BPH biotypes 1, 2, and 3 based on rostral, leg, and antennal characters of brachyterous females. The group centroids of the three biotypes are evidently separated.

The computed high degree of classification and the distinct segregation of the three biotypes suggest that morphological characters used in the study discriminated or segregated the expected biotype populations (Table 18).

Table 18. Predicted group membership of biotypes 1, 2, and 3 of *Nilaparvata lugens* based on rostral, leg, and antennal characters of macropterous and brachypterous males and females. IRRI, 1980.

Data set	Group[a]	Adult character description[b]	Variables entered (no.)	Variables in the function (no.)	Variance (%) accounted for by		Group (%) cases correctly identified
					Function 1	Function 2	
I	1	Rostral, MAC male	16	9	94	6	97
	2	Rostral, MAC female	16	9	71	29	90
	3	Rostral, BRAC male	16	3	79	21	73
	4	Rostral, BRAC female	16	9	78	22	87
II	1	Leg, MAC male	57	25	93	7	100
	2	Leg, MAC female	57	25	85	15	100
	3	Leg, BRAC male	52	25	94	6	100
	4	Leg, BRAC female	57	24	99	1	100
III	1	Antennal, MAC male	36	19	67	33	100
	2	Antennal, MAC female	36	17	98	2	100
	3	Antennal, BRAC male	36	24	87	13	100
	4	Antennal, BRAC female	36	22	79	21	100
IV	1	Rostral + leg + antennal, MAC male	109	23	80	20	100
	2	Rostral + leg + antennal, MAC female	109	23	69	31	100
	3	Rostral + leg + antennal, BRAC male	109	23	86	14	100
	4	Rostral + leg + antennal, BRAC female	109	23	86	14	100

[a]Each group comprised 10 individuals for each of biotypes 1, 2, and 3 [b]MAC = macropterous, BRAC = brachypterous

Genetic evaluation and utilization (GEU) program

Nutrient content

Chemistry, Plant Breeding, Plant Physiology, Statistics, and Agronomy Departments

Plant Breeding, Statistics, and Chemistry Departments

Yield trials *(Plant Breeding, Statistics, and Chemistry).* Brown-rice protein continued to be highly correlated with rough rice yield in rainfed and irrigated replicated yield trials. Similar trends were observed in previous irrigated trials, except in 1977 (Table 1).

In the 1980 rainfed trial, the correlation coefficient was -0.27** (n = 185) in the dry season and -0.32** (n = 186) in the wet season. IR36 continued to have higher protein but lower yield than IR42 in all trials. Some lines had 2 percentage points higher protein than IR42 but similar yields particularly in the irrigated trials.

In the dry-season irrigated replicated yield trials, only IR13429-287-3 had higher protein content but similar yields compared to IR36 and IR42, but seven lines had higher protein content than IR36 in the wet season (Table 2). Only IR13429-287-3 had yields comparable to those of the check varieties and higher protein content in both seasons. Five lines had either comparable protein or lower yield than the check varieties in the dry-season crop; no yield data were available for one line. All lines matured in 99-108 days after seeding.

In 1979, IR13429-287-3 had protein (11.0%) and yield (4.30 t/ha) comparable to those of IR36 in the wet season (10.8% protein and 4.16 t/ha), and had as low protein (8.2 vs 8.5% for IR36) but lower yield (5.84 t/ha vs 6.89 t/ha for IR36) in the dry season. The performance of this line will be checked in 1981.

High-protein parents *(Plant Breeding and Chemistry).* From 938 viable high-protein entries selected from the germplasm bank with these characteristics — maturity >100 days, indica type, low spikelet sterility, dry-season brown rice protein ⩾11% and wet season protein ⩾12%, and 1000-grain weight ⩾20 g — 41 were selected based on 1979 wet season protein data. They were planted in a replicated yield trial in the 1980 wet season. Tungro infestation caused low yields of all entries including the four checks. Rough rice yield ranged from 0.04 to 1.42 t/ha (mean 0.41 t/ha) and brown rice protein from 9.5 to 13.7% (mean 11.8%). The correlation coefficient between the two grain properties was -0.12 (n = 41). The protein values for the 1980 crop were significantly correlated with those for the 1979 crop (r = 0.52**, n = 41).

Table 1. Brown-rice protein content and its correlation coefficients with rough rice yield in irrigated yield trials. IRRI, 1973-80.

Year	Dry season				Wet season			
	Entries (no.)	Brown-rice protein (%) Range	Brown-rice protein (%) Mean	r	Entries (no.)	Brown-rice protein (%) Range	Brown-rice protein (%) Mean	r
1973	232	6.7- 9.6	7.9	-0.36**	184	8 6-13.9	10 6	-0 24**
1974	416	6 8-11 0	8 2	-0.13**	370	7.3-11.3	8.8	-0 47**
1975	301	6.9-10 8	8 6	-0.50**	278	6.4-11.2	8.8	-0 36**
1976	370	5.7- 9.7	7.3	-0.24**	416	5.7-10 0	7.6	-0.15**
1977	324	5.8- 9.1	7.4	0 02	278	6.1-11 4	9.3	-0.03
1978	361	6 4-10.4	8 2	-0 22**	–	–	–	–
1979	370	6.7-11.1	8 3	-0.50**	369	8 2-12.5	10 2	-0.33**
1980	369	7 2-12 3	9.6	-0.59**	369	6 9-15 2	10 1	-0.44**

Table 2. Brown-rice protein (BRP) and rough rice yield of 7 selected lines with higher protein but similar yields compared to check varieties IR36 and IR42 in either dry or wet season. IRRI, 1980.

Selection	Parents	Dry season[a] BRP (%)	Dry season[a] Yield (t/ha)	Wet season BRP (%)	Wet season Yield (t/ha)
IR9752-1-2	IR28/Kwang-chang-ai//IR36	[10 6	5.46]	11 5	4.26
IR9752-71-3	IR28/Kwang-chang-ai//IR36	[10.2	5.70]	12.1	4.33
IR13429-287-3	IR4432-53-33/Ptb 33//IR36	11 2	5.93	11.8	3 78
IR15429-268-1	74-5461/IR2071-625-1//IR747B2-6-3	[10.3	5.25]	11 7	4.51
IR19198-9-2	IR747B2-6-3/IET 5446//IR36	—[b]	—[b]	11.8	4.28
IR19722-9-1	IR8608-167//IR747B2/Kwang-chang-ai//IR747B2	[11.9	4 88]	12.3	4.35
IR19735-5-2	IR9129-77-1///IR747B2-6-3/29 Lu 1//IR747B2	[10.8	5 61]	11.6	4.39
IR36[c]	IR1561-228-1//IR24[4]/*O. nivara*//CR94-13	10.8	5.71	11.4	3 77
IR42[c]	IR1561-228-1/IR1737//CR94-13	9.0	6.32	10.3	4.30

[a]The brackets [ ] indicate either no advantage over check varieties in yield and protein content, or lower yield. [b]Protein and yield data not available [c]Mean of 4 sets in dry season and 3 in wet season, in which the 7 lines were included.

Table 3. Brown-rice protein content and rough rice yield of 5 high-protein varieties from the germplasm bank, of 4 check samples, and of all 41 entries.[a] IRRI, 1980 wet season.

Variety or line	Brown-rice protein (%) 1979 wet season	Brown-rice protein (%) 1980 wet season	Rough rice yield, 1980 wet season (t/ha)
ASD8 (Acc. No. 4894)	15.2	12 6	1 12
ASD8 (Acc. No. 6393)	15.8	11.5	1 18
Colio	13.0	11.3	1 01
Jappine tung kungo	13.3	12 0	1 32
PI 193175-1	14.4	12.5	1 42
IR36	11 9	10 6	2 31
IR42	10 7	10 8	1 78
IR480-5-9	—	11.2	0 46
IR2135-38-3	—	10 4	0.35
LSD (0 05)		1 3	0.39
Coefficient of variation (%)		5 8	42.2

[a]Mean of 2 replications for 1980 wet season and unreplicated data for 1979 wet season.

Susceptibility of the high-protein varieties to diseases and insects continues to complicate the estimation of their yield potential at IRRI. Yield reductions due to pests have been shown to result in higher percentage of grain protein. The five varieties that yielded more than 1 t/ha and with protein content as high as that of IR480-5-9 are listed in Table 3. Two samples with more than 13% protein — Gidej 113 and Fai-yao-zai — had yields of only 0.17 and 0.23 t/ha.

Plant nitrogen metabolism *(Chemistry).* Preliminary pot experiments were done to determine if the efficient mobilization of nitrogen from senescing leaf blades observed in IR480-5-9 also characterized the plants of high-protein rices at the vegetative stage. No trend in residual N (0.45-0.64%) in senesced leaves and subsequent grain protein content was noted in 7 rices at 58 days after transplanting. But at 79 days after transplanting the 2 samples with less than 9% brown-rice protein had 0.66% and 0.64% residual leaf N, and the 5 samples with more than 9% protein had 0.57-0.60% leaf N, regardless of previous classification of grain protein type. The high- and low-protein plants had similar zymogram patterns for peroxidase and esterase and had overlapping specific activities for peroxidase and esterase.

Greenhouse experiments by botanists at the University of Durham, England, reflected the large environmental effect on rough-rice protein — the eight IR rices used differed in sensitivity of protein-content response to added nitrogen fertilizer. Detailed compositional analysis of rough rice of IR26 (8.9% crude protein) and IR480-5-9 (10.6% protein) was used to calculate the theoretical glucose substrate requirements of the grain; similar values of 1.3 g glucose/g rice were obtained.

PROTEIN DIGESTIBILITY AND RETENTION
Chemistry Department

Degree of milling and nutrient availability. Nutrient levels in IR32 brown, undermilled, and milled rices suggest that brown rice is more nutritious than milled rice (Table 4). Brown rice had slightly higher protein content, higher lysine content of protein, and higher fat and higher total phosphorus levels. It also had higher levels of crude and dietary fiber and phytin. Because brown rice has higher levels of thiamine and riboflavin and fiber, its consumption in place of milled rice has been advocated. Limited studies in rats and preschool children suggested, however, that nitrogen retention was lower for brown rice than for milled rice. Phytin and fiber may be involved in lowering protein absorption.

Table 4. Properties and nitrogen balance of IR32 brown, undermilled, and milled rice in growing rats and preschool children. National Institute of Animal Science, Copenhagen, Denmark; Nutritional Evaluation Laboratory, Food and Nutrition Research Institute, Manila; and IRRI, 1980.

	Brown rice	Undermilled rice	Milled rice
Nutrient content			
Protein (% N × 6 25)	8.7	8.5	8 3
Lysine (g/16 g N)	3 8	3.6	3 6
Crude fat (%)	2 3	1 5	0 7
Crude ash (%)	0.8	0 6	0.4
Crude fiber (%)	0.7	0 5	0 2
Dietary fiber (%)	2.6	1 8	0 8
Total phosphorus (%)	0.14	0.14	0 08
Phytin phosphorus (%)	0 06	0.05	0.02
N-balance in 5 growing rats[a]			
True digestibility (%)	96 9 ± 0 5	97.2 ± 0.7	98 4 ± 0 5
Biological value (%)	68.9 ± 1.1	69.7 ± 1.3	67 5 ± 0 6
Net protein utilization (%)	66.8 ± 1 0	67.7 ± 1.0	66.4 ± 0 4
N-balance in 6 preschool children[a,b]			
Apparent absorption (% of intake)	67.4 ± 3.9	70 0 ± 3 2	70 4 ± 4 9
Apparent retention (% of intake)	36.1 ± 3.7	37.3 ± 6 2	36 9 ± 5 1

[a]Mean ± standard deviation. [b]250 mg N/kg body weight daily, 2/3 from rice and 1/3 from casein. For casein 1, dietary nitrogen was 80 9% absorbed and 33.4% retained; for casein 2, nitrogen was 79 9% absorbed and 34.1% retained. Rice diets were given in randomized order to each child

In view of the importance of rice in the diets of tropical Asia (it contributes 58% calories and over 43% protein in the Filipino diet according to the 1978 nationwide survey), a cooperative study was undertaken to check the protein and energy availability in IR32 brown, undermilled, and milled rice for growing rats and preschool children. Bran-polish removal from brown rice was 5% and 9% by weight for the two milled samples.

The nitrogen-balance data in growing rats showed that digestibility was slightly higher for milled rice protein than for brown and undermilled rice protein (Table 4). The biological value (BV) of milled rice protein, however, was correspondingly lower. The net protein utilization (NPU) of brown and milled rice were similar; that of undermilled rice was slightly higher than NPU of milled rice.

Nitrogen-balance data on 6 preschool Filipino children on a rice-casein diet containing 250 mg N/kg body weight (2/3 from rice and 1/3 from casein) did not show that brown rice had significantly lower apparent nitrogen absorption than the two milled rices (Table 4). As with the NPU of the rat study, apparent nitrogen retention by the children was similar on the three diets. Because earlier studies at Food and Nutrition Research Institute using rice-milk diets containing 200 mg N/kg body wt (1/2 each from rice and powdered milk) showed lower apparent absorption and retention of nitrogen from brown rice than that from milled rices, additional studies with a reduced nitrogen intake of 200 mg/kg body weight are under way.

Pigments and protein quality. Seed coat pigments in cereals such as sorghum and barley are known to reduce the digestibility and solubility of protein because the pigments complex with protein. Because little study has been done on pigmented rices, and because red rices are common in countries such as Sri Lanka and among *Oryza glaberrima,* the phenolic content and nitrogen balance in growing rats for brown and milled samples of the purple rice Perurutong, the red rice H4, and nonpigmented rices IR8 and IR32 were determined.

The two pigmented brown rices had more phenolics than the two nonpigmented samples (Table 5), but protein and lysine contents were similar. True digestibility was lowest for Perurutong and highest for IR8 and IR32, but the pigmented rices had higher BV for absorbed proteins. The resultant NPU was highest for IR8 followed by IR32 and H4, and lowest for Perurutong. Thus only dark-colored rices such as the purple Perurutong had lower NPU than nonpigmented and red rices.

Milling reduced the phenolic content of the grains and improved the nitrogen digestibility of the two pigmented rices (Table 5). In addition, the pigmented rices attained a NPU similar to that of IR32; however, IR8 had highest protein quality among the four samples.

The higher BV and NPU of IR8 milled-rice

Table 5. Properties and nitrogen balance of brown and milled pigmented and nonpigmented rices in growing rats. National Institute of Animal Science, Copenhagen, Denmark, and IRRI, 1980.

	Perurutong	H4	IR32	IR8
		Brown rice		
Grain property				
Color	Purple	Red	Light tan	Light tan
Methanol-soluble phenolics (% as catechin)	0.62	0 25	0 01	0 02
Protein (% N × 6 25)	8 3	8 0	8.7	8 0
Lysine (g/16 g N)	3.8	3.7	3 8	3.9
Nitrogen balance in 5 rats[a]				
True digestibility (%)	72 4 ± 1.8	83 0 ± 0 8	96.9 ± 0 5	97.1 ± 0 5
Biological value (%)	81.6 ± 1 2	80 3 ± 1.5	68.9 ± 1.1	72.7 ± 0 8
Net protein utilization (%)	59.1 ± 0 3	66.6 ± 0 9	66 7 ± 1.0	70 6 ± 0.9
		Milled rice		
Grain property				
Methanol-soluble phenolics (% as catechin)	0 07	0 05	0 01	0.02
Nitrogen balance in 5 rats[a]				
True digestibility (%)	97 5 ± 1 0	99.2 ± 0.7[b]	98 4 ± 1.0	96 2 ± 0 4[b,c]
Biological value (%)	68 4 ± 1.2	65 7 ± 0 8[b]	67.5 ± 1 4	73 1 ± 0.8[b,c]
Net protein utilization (%)	66.7 ± 1.3	65 2 ± 0.8[b]	66.4 ± 1 2	70.3 ± 0 7[b,c]

[a]Mean ± standard deviation [b]Another sample of the same variety. [c]1972 data

protein were probably not due to the lower final gelatinization temperature (GT) of its starch (67° C vs 76° C for H4 and IR32, and 78° C for Perurutong). Other low-GT milled rices in earlier studies did not necessarily have higher BV and NPU.

Poorly digested cooked-rice protein. The major poorly digested protein of cooked milled rice with molecular weight (MW) 16000 subunit was further characterized (Annual report for 1979). Pepsin-treated cooked IR480-5-9 milled-rice protein bodies and fecal protein had properties closer to the 70% isopropanol-0.6% β mercaptoethanol soluble (prolamin-like) fraction of rice glutelin than to the whole MW 16000 subunit of glutelin. This prolamin-like fraction also has MW 16000 and constitutes at least 5% of glutelin. Its amino acid pattern is similar to that of poorly digested proteins such as 1% lysine and 4% cysteine and methionine. Isoelectric focusing in disc gels showed that the undigested protein soluble in 8 M urea has 6 bands with isoelectric points (pI) at pH 4.9, 5.1, 6.1, 7.0, 7.3, and 7.4. The prolamin-like fraction of glutelin had polypeptides with pI at pH 4.9, 6.1, 7.0, 7.3, and 7.4. In contrast, the unfractionated MW 16000 subunit of glutelin had higher lysine content (2.6%) and two major polypeptides soluble in 8 M urea with pI of 7.1 and 7.5, plus 11 minor bands (2 with pI $>$7.5, 3 with pI at 7.1-7.5, and 6 with pI at 5.1-7.1) indicating its greater complexity.

The minor MW $<$ 5000 fraction of rice glutelin with V/V_o of 3.1 on SDS-Sephadex G-100 gel filtration had high UV absorption but low N content. It is probably a polypeptide — its ninhydrin color recovery increased threefold after HCl hydrolysis. Equilibrium dialysis showed the peptide to be freely dialyzable through a membrane with cutoff MW 2000. The fraction was poor in phenolics, nucleotides, or unsaturated fatty acids. The corresponding MW $<$ 5000 fraction of fecal protein particles was about 7% of total N and increased 14-fold in ninhydrin reaction after HCl hydrolysis. All these low MW preparations did not bind protein-staining dyes.

OTHER NUTRIENTS

Chemisty, Agronomy, and Plant Physiology Departments

Distribution of elements in rough rice *(Chemistry and Agronomy).* Distribution of selected elements in rough rice in milling fractions was determined in IR8 and IR36 rices grown in the 1979 dry and wet seasons at IRRI. Rice is a major source of these elements in Asian diets. Brown rice (77.4% by wt of IR8 rough rice and 79.8% for IR36) accounted for 90% of rough rice nitrogen in IR8 and 94% in IR36, 100% of rough rice phosphorus, 76-77% of rough rice potassium, 95-100% of magnesium, and 70% of calcium in the two rices. Among the five microelements of rough rice, 100% of zinc, 46-64% of copper, sodium, and manganese, and 21-23% of iron were retained in brown rice.

Corresponding retention of rough rice nutrients in milled rice was 74-80% of nitrogen, 33-42% of phosphorus, 20-26% of potassium, 26-28% of magnesium, 40-55% of calcium, 60-74% of zinc, 47-65% of sodium, 22% of copper, 17-22% of manganese, and 6-15% of iron.

Brown rice oils *(Plant Physiology and Chemistry).* Earlier work suggested the brown rice oil extracted with petroleum ether from indica rice had less polyunsaturated fatty acids (linoleic plus linolenic) than oil from japonica rice from grains produced at IRRI. Confirmatory analysis, however, showed overlapping values of 36-41% polyunsaturated acids in total fatty acids (mean 38%) for 4 indica oil samples, 37% for 1 javanica oil sample, and 40% for 1 japonica oil sample. Ranges of fatty acid composition for the 6 rices were 16-21% palmitic, 1-2% stearic, 38-44% oleic, 34-39% linoleic, and 1-2% linolenic acid of the total fatty acids.

Genetic evaluation and utilization (GEU) program

Drought resistance

Agronomy, Plant Breeding, Plant Physiology, and Irrigation Water Management Departments

HYBRIDIZATION AND SELECTION

Plant Breeding Department

During 1980, 104 single crosses and 86 multiple crosses were made, primarily to incorporate insect pest and disease resistance into breeding lines that have higher levels of drought resistance and good yield potentials.

In the wet season, 230 single crosses were grown in a farmer's field in Batangas and in the upland area of IRRI, and 5,451 F_2 plants were selected. In addition, 425 lines were selected from more advanced generations grown at IRRI. Selection emphasized plants with early growth duration, heavy panicles, and long grains.

Twenty-seven F_2 bulk populations were grown in rainfed-wetland plots in both seasons and 279 F_2 plants were selected.

Breeding efforts were directed to incorporate resistance to tungro, grassy stunt, sheath blight, and to several insect pests into a drought-resistant background.

VARIETAL SCREENING

Agronomy and Plant Breeding Departments

Field screening rices for drought resistance *(Agronomy).* Tests for drought resistance at IRRI during the dry season consisted of selections from previous years' tests (233 entries); 1979 wet and 1980 dry season elite lines, irrigated and rainfed wetland replicated and observational yield trials, pedigree nurseries and hybridization blocks (3,481); 1979 wet season dryland replicated and observational yield trials (99); 1979 and 1980 International Rice Testing Program materials (657); germplasm bank (45); and miscellaneous selections (25).

The rices were seeded on dry granular soil on 17 January 1980 and sprinkler-irrigated every 3-6 days until 3 March (30 days from full seedling emergence), at which time irrigation was stopped. An 18-mm rain on 9 March and a typhoon at the end of March brought 100 mm of rainfall over a period of 4 days. That relieved soil moisture stress, which was in the range of 0.8 to 1.5 bars soil moisture tension (SMT). Another drying period followed. At SMT of 1-2 bars (14 April), the entries were individually scored for drought resistance using the Standard Evaluation System for Rice (SES) where 1 = no to slight effects of soil moisture stress and 9 = all plants apparently dead. Two rices, Salumpikit and IR442-2-58, were used as drought-resistant checks, and IR20 and IRAT 9 were used as drought-susceptible checks. Scorings were also done at 4-5 bars SMT (18 April) and 8-10 bars SMT (22 April). After scoring at 8-10 bars SMT, the soil moisture stress was relieved by 2 sprinkler irrigations and drought recovery was scored 20 May by SES (1 = 90% of plants fully recovered and 9 = no plants fully recovered).

Because rains relieved the early soil moisture stress, many entries were in the reproductive stage when scored. Some accessions, especially those from China (composed of 8 rice-sorghum hybrids), were already maturing at 1-2 bars SMT. Only 28 entries had SES scores of 3 or better at 8-10 bars SMT (Table 1). Of those, 6 were in the reproductive stage. Salumpikit and IR442-2-58 had drought scores of 5 and 6 at 8-10 bars SMT and IR20 and IRAT 9 both scored 8.

Among the entries 141 scored 4 and 28 scored 3 to make a total of 169 better than Salumpikit, the drought-tolerant check. Table 2 gives the percentages of outstanding rices among those tested for drought resistance from 1975 to 1980.

Table 3 shows 7 IR lines with drought scores comparable to or better than those of the resistant checks IR442-2-58 and Salumpikit for 3-4 years of field screening.

Screening for drought resistance in rainfed dryland fields *(Plant Breeding).* During the dry season, 3,157 varieties and lines were screened for drought resistance in rainfed dryland fields (Table 4). Plot size was increased from one row to three rows per test entry. That eliminated shading of semidwarfs by taller plants and avoided biased scores.

Of entries from the germplasm collection, the majority of which are the ARC (Assam Rice Collection) accessions from India, 9% had a score of 4 or less during vegetative growth. ARC14101, ARC14108 and ARC14123 were found to have moderate resistance to drought at the reproductive stage.

Most of the dryland breeding lines had a combination of high levels of drought resistance and good recovery ability at vegetative stage. Only 10 percent of the test materials from the wetland breeding nurseries scored less than 4 at the vegetative stage of growth. Most of the entries were mod-

Table 1. Promising drought-resistant rices in field screening. IRRI, 1980 dry season.[a]

Designation	Origin	1st scoring (14 Apr) 1-2 bars		2d scoring (18 Apr) 4-5 bars		3d scoring (22 Apr) 8-10 bars		Recovery score[b]
		GS	DT	GS	DT	GS	DT	
IR45 (IR2035-242-1)		2	1	2	1	2	3	3
IR3259-P5-160-1		2	1	2	1	2	3	1
IR5624-110-2-A_1		2	1	2	3	2	3	1
IR5793-55-1-1-1		2	1	2	3	2	3	3
IR7790-18-1-2		4	1	4	3	5	3	3
IR8098-194-2		2	1	2	2	2	3	3
IR8103-120-3-A_1		2	2	2	3	2	3	3
IR8235-194		2	1	2	3	2	3	3
IR9266-124		2	1	4	3	4	3	3
IR9669 selection		2	1	2	3	2	3	1
IR9782-111-2-1-2		4	1	4	3	5	3	3
IR9852-19-2		2	1	2	2	2	3	3
IR9852-22-3		2	1	2	2	2	3	3
IR9852-53-2		2	1	2	2	2	3	3
IR10206-29-2		2	1	2	2	3	3	3
IR11288-B-B-288-1		2	1	2	3	2	3	3
IR11297-170-3-2		2	1	2	3	2	3	3
IR13149-23-2		2	1	2	3	2	3	3
IR13149-71-3-2-3		2	1	2	3	2	3	3
IR13576-18-2-3-1		2	1	2	3	2	3	3
IR15718-28-2-2		2	1	2	2	2	3	3
IR15821-73-2		2	1	2	2	2	3	1
IR15849-132-3-3		2	1	4	2	4	3	1
IR17076-61-1		2	1	2	3	2	3	3
BKN6986-147-2 (RD19)	Thailand	2	1	2	2	2	3	3
BL169	Nigeria	4	1	5	1	5	3	5
LAC 23	Liberia	2	1	2	2	2	3	5
Mal Siraz	Bangladesh	2	2	2	2	2	2	3

[a]Growth stage (GS) numbers and drought tolerance (DT) scores are from the 1975 Standard Evaluation System for Rice (SES) [b]Based on 1975 SES

Table 2. Entries and outstanding selections in field screening of rices for drought resistance at vegetative stage from 1975 to 1980 dry season, IRRI

Year	Entries (no.)	Outstanding selections[a] No	Percentage
1975	1003	32	3.19
1976	1016	6	0.59
1977	4119	51	1.24
1978	4757	43	0.90
1979	3897	145	3.72
1980	4540	169	3.72

[a]Drought tolerance score comparable to or better than that of IR442-2-58 and Salumpikit at 10 bars soil moisture tension (SMT), except in 1979 test which was at 5 bars

erately susceptible to drought at the reproductive stage.

The four progenies of the rice-sorghum cross headed during the stress period and were completely sterile. Their drought resistance at the vegetative stage was not outstanding.

Screening for field resistance to drought in rainfed wetland fields *(Plant Breeding).* During the dry season 914 varieties and lines from the wetland breeding nurseries were tested for field resistance to drought in a simulated rainfed-wetland culture. The test varieties were transplanted in a puddled soil and allowed to grow for 20-30 days, after which the field was drained and allowed to dry. They were scored 20 days later when the susceptible check (Intan) showed distinct symptoms of stress. Table 5 shows the distribution of drought resistance scores. Those that scored 4 or less at the reproductive stage probably escaped drought because they headed near the end of March when there were rains. Most of the entries that headed during the rainless days of April showed panicle sterility.

Lines found to be moderately resistant to drought at the reproductive stage of growth were IR8235-196-3-2, IR9129-320-3-3-3, IR9224-223-2-2-2-1, IR9698-16-3-3-2, IR9830-27-2-3, and IR21335-29. They were also entered in the 1980 wet season hybridization block and are being used in crosses. Those lines are resistant to several insect pests and have good yield potentials.

Drought screening in the greenhouse *(Agronomy).* A special greenhouse screening facility for drought resistance was used from 1976 until the

Table 3. Outstanding selections for drought resistance at vegetative stage in field screening, and their possible source of resistance. IRRI, 1977-1980 dry seasons.

Designation	Possible source of resistance	Origin	Drought score[a]						
			1977		1978		1979	1980	
			4 bars	10 bars	5 bars	10 bars	5 bars	5 bars	10 bars
IR5953-118-5 (IR52)	Nam Sagui 19		3	3	1	3	3	5	6
IR8098-194-2	Aus 12		2	3	3	7	3	2	3
IR8103-120-3	Aus 197		3	3	1	1	3	3	3
IR9669 selection	Carreon		4	4	1	3	1	3	3
IR5624-110-2	Khao Dawk Mali 105		—	—	1	3	3	3	3
IR8234-174-3	Nam Sagui 19		—	—	2	3	3	4	5
IR9995-96-2	Nam Sagui 19		—	—	1	3	3	4	5
Nam Sagui 19		Thailand	7	7	3	7	3	5	7
Carreon		Philippines	3	3	3	5	3	—	—
Leb Mue Nahng 111		Thailand	3	3	2	4	3	4	6
Khao Dawk Mali 105		Thailand	3	6	3	6	3	5	7
IR442-2-58	Leb Mue Nahng 111		4	5	1	5	3	4	6
Salumpikit		Philippines	4	5	1	4	3	4	5
IRAT 9		Ivory Coast	7	8	6	9	7	7	8
IR20			7	8	5	8	5	6	8

[a]Based on 1975 Standard Evaluation System for Rice A dash indicates no test Soil moisture tension ranged from 4 to 10 bars.

Table 4. Summary of drought resistance scores of 3,157 varieties and lines grown in rainfed-dryland fields, IRRI, 1980 dry season.

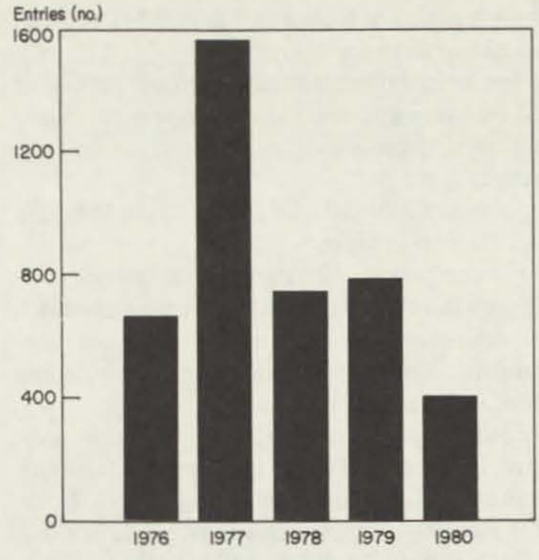
Type of entry	Stage scored	Entries (no.)	Entries (no) with decimal[a] scores of								
			1	2	3	4	5	6	7	8	9
Germplasm collections	Vegetative	1,783			7	156	683	830	101	6	
	Reproductive	1,017				3	16	19	196	68	715
Dryland breeding nurseries	Vegetative	571		7	10	84	326	132	10	2	
	Reproductive	118				1	1	1	17	6	92
Wetland breeding nurseries	Vegetative	559			7	54	235	241	22		
	Reproductive	80					1	1	10	15	53
International nursery entries	Vegetative	198			1	10	53	104	27	3	
	Reproductive	32						1	5	7	19
Heat-tolerant lines	Vegetative	44			1	14	21	8			
	Reproductive	26					3		3	2	18
Rice-sorghum hybrid	Vegetative	2				1	1				
	Reproductive	4								1	3

[a]Decimal score for vegetative stage based on 1 = plant has no or slight leaf rolling, remains green with few leaf tips drying and no stunting; to 9 = tube-like leaf rolling, all leaves dried, and severe stunting Reproductive stage score based on 1 = no heading delay, full panicle exsertion, normal panicle size, 91-100% spikelet fertility, mostly well-filled grain and slight leaf rolling, to 9 = half-exserted panicle, panicle size reduced by half, 0-10% spikelet fertility, mostly empty grain, and tight leaf rolling or no heading until after moisture is replenished

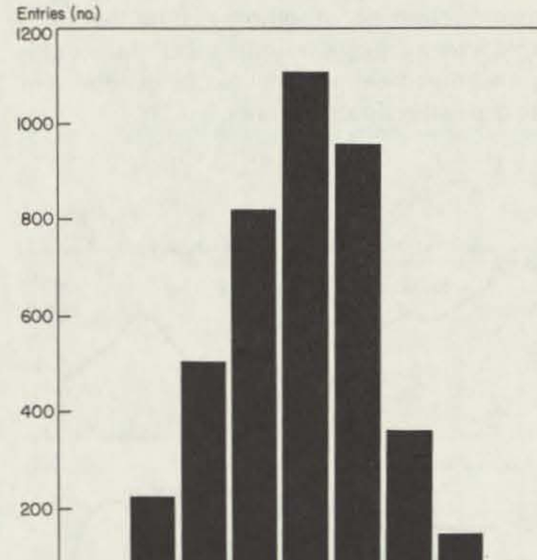
Table 5. Summary of drought resistance scores of 914 varieties and lines grown under rainfed-wetland culture and rated at 2 growth stages, 1980 dry season, IRRI, Plant Breeding Department.

Type of entry	Stage scored	Entries (no)	Entries (no.) with decimal[a] score of									Entries (no) not headed at end of test
			1	2	3	4	5	6	7	8	9	
Lines in collaborative rainfed-wetland trials	Vegetative	63	6	23	12	6	7	8	1			
	Reproductive	50			1	1	4	8	11		25	13
Lines in replicated rainfed-wetland yield trial	Vegetative	200	5	21	69	55	20	19	11			
	Reproductive	166			5	4	10	23	43	3	78	34
Lines for irrigated culture in replicated yield trial	Vegetative	400	5	95	155	113	23	3	6			
	Reproductive	394		1	1	12	30	58	155	28	109	6
International Rainfed Lowland Rice Observational Nursery entries	Vegetative	251		11	65	99	31	11	9	24	1	
	Reproductive	221			3	8	8	22	46	3	131	30

[a]Decimal score for vegetative stage based on 1 = plant has no or slight leaf rolling, remains green with few leaf tips drying and no stunting, to 9 = tube-like leaf rolling, all leaves dried and severe stunting Reproductive stage score based on 1 = no heading delay, full panicle exsertion, normal panicle size, 91-100% spikelet fertility, mostly well-filled grain, and slight leaf rolling, to 9 = half-exserted panicle, panicle size reduced by half, 0-10% spikelet fertility, mostly empty grain, and tight leaf rolling or no heading until after moisture is replenished



1. Distribution of the 4,187 entries screened at the IRRI drought screening greenhouse, 1976-80.



2. Distribution by drought score of the 4,187 entries tested for the period 1976-80 at the IRRI drought screening greenhouse.

end of 1980. Of 4,187 entries tested, 2,435 were germplasm bank accessions. Figures 1 and 2 illustrate the number of entries successfully screened each year and the frequency of entries falling in each of the SES scores 1 to 9. The entries that scored 1 are generally from dryland ecological backgrounds. Some of those that scored 2 and 3 are from wetland environments, and others are hybrids. Table 6 lists selected entries that had 3 or more replications and scores of 2.0 to 3.0 as a representative sample.

DROUGHT RESISTANCE IN RAINFED DRYLAND RICE

Agronomy and Plant Breeding Departments

Dryland rice yield test *(Agronomy).* The 1980 wet season dryland rice yield test consisted of the 27 entries in the 1980 International Upland Rice Yield Nursery; 36 selections from the 1977, 1978, and 1979 field drought screenings; 10 entries from the 1979 yield test; and 8 other rices, including traditional and other varieties used as checks in field drought screenings.

The test was conducted at IRRI, in two Batangas farmers' fields, and at two Philippine Bureau of Plant Industry (BPI) experiment stations. Two seedings (1-month interval) were made at IRRI and at the Batangas sites to determine the effect of delayed seeding on dryland rice. The first seeding above and the only seeding at the BPI stations coincided with the start of the planting season in each area.

Table 6. Selected entries with scores[a] of 2.0 to 3.0. IRRI, 1980.

Entry	Score	± SE
IAC1131	2.0	0.5
Holamaldiga	2.0	0.5
IRAT10	2.0	0.5
Ram Kajara	2.0	0.0
IR7777-7-1-1	2.0	0.4
IRAT13	2.2	0.6
IR5853-118-5	2.3	0.3
Maleba L	2.3	0.3
Sikodok	2.3	0.3
TR1	2.3	0.3
Naung Tu	2.5	1.5
BR166-2B-8	2.5	1.5
IRAT8	2.5	0.5
IR3260-P91-100	2.5	0.5
Gogo Putih	3.0	0.4
CR141-3138-2-234	3.0	0.0
CR410-1-3-4	3.0	0.5
Dacca 14	3.0	0.5
DD118	3.0	0.0
Dova H	3.0	0.0
ARC11430C	3.0	0.0
IAC5544	3.0	0.5
Intan	3.0	0.0
PN677-1	3.0	0.0
Nam Sagui 19	3.0	0.5
Paedi Kalibungga	3.0	0.0
1021 (Guatemala)	3.0	0.0
IR8608-79-3-2	3.0	0.0

[a]Scores are the mean of 3 or more replications (± SE).

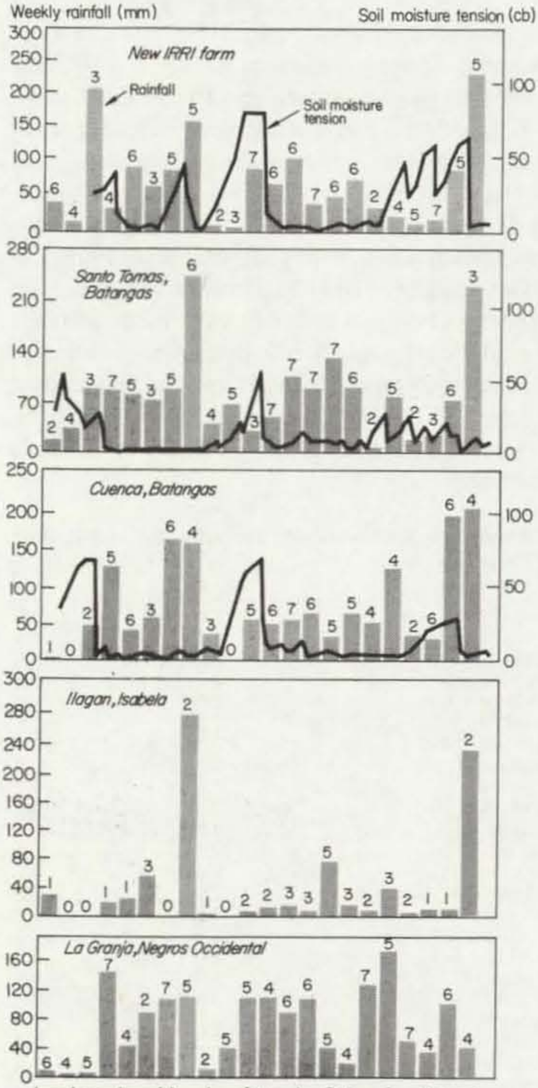
Daily rainfall (mm) and solar radiation (g cal/cm² daily) were monitored at all sites. Soil moisture tension (SMT) in centibars (cb) was recorded at IRRI and the two Batangas sites. Figure 3 shows SMT for 3 sites and rainfall for all sites. The rainfall in 4 of the 5 test sites (Ilagan was the exception) was relatively high for June-October 1980. The distribution, however, was erratic. A 2-week dry spell at IRRI and Cuenca in late July and early August caused the SMT to rise above 50 cb for a period of from 7 to 9 days. SMT at IRRI was above 80 cb for 7 days.

The limited rainfall at Ilagan caused prolonged soil moisture stresses, various degrees of wilting and leaf desiccation, and delayed and nonuniform heading.

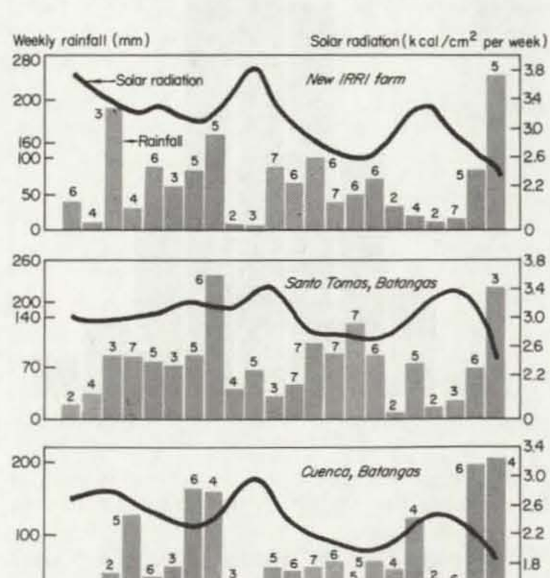
Solar radiation data for IRRI and the Batangas sites are seen in Figure 4.

For comparison with standard varieties of varying growth durations, the entries were grouped into the early-maturing and the medium- and late-maturing, consisting of 39 and 42 entries including check varieties.

Fourteen of the early-maturing rices are presented in Table 7. Twelve performed better than IR36 and M1-48, the early-maturing checks. Yields of 17 medium- and late-maturing rices are in Table 8. IR43, IR9560-2-6-3-1, and IR9669 Sel were earlier identified as tolerant of imposed soil moisture stresses of 5 and 10 bars SMT during dry season drought screenings. Another six from the list in Table 8 were drought-resistant selections, indicating that high yield potential can be incorporated into drought-resistant varieties.



3. Weekly rainfall and number (on bars) of rainy days per week at 5 Philippine sites for dryland rice yield trials, with corresponding soil moisture tension at IRRI and 2 Batangas sites. 1980 wet season.



4. Solar radiation and weekly rainfall at IRRI and two Batangas (Philippines) sites used in dryland rice yield trials. Numbers on bars are rainy days per week. 1980 wet season.

Table 7. Grain yield of early-maturing rices in dryland yield trials at 4 Philippine sites[a]. 1980 wet season.

Designation	Grain yield (t/ha)						
	IRRI	Santo Tomas		Cuenca		La Granja	Mean
	3 Jun	23 May	25 Jun	15 May	20 Jun	10 Jun	
IR5931-110-1	2.9**	4.6**	3.6**	4.5*	3.5**	3.9	3.8
B733C-167-3-2	2.8*	4.9**	3.2*	4.6**	3.3*	3.8	3.8
IR9782-111-2-1-2	2.5	4.7**	4.0**	5.0**	3.0	2.6	3.6
IR5716-18-1	2.2	3.8	2.9	4.1	3.1	3.4	3.3
IR5929-12-3	1.9	3.7	3.0	3.9	2.8	3.6	3.2
IR2061-522-6-9	2.1	4.1*	3.5**	3.4	2.9	3.2	3.2
IET4094 (CR156-5021-207)	2.6	3.8	2.3	4.1	3.3*	3.3	3.2
KMP34	1.9	4.0	2.6	3.5	3.2*	3.8	3.2
IR7473-118-2-2-3	2.1	4.1*	2.3	3.6	3.0	3.2	3.1
IR8085-48-2	1.7	3.9	2.7	3.3	3.5**	3.7	3.1
IR8608-3-2-2-3	2.4	3.7	3.4*	3.2	3.1	2.9	3.1
IR9828-36-3	1.7	4.0	2.8	3.7	3.1	3.3	3.1
IR36 (check)	2.2	3.3	2.3	3.5	2.6	3.2	2.9
M1-48 (check)	1.4	2.2	1.0	2.3	2.3	3.3	2.1

[a]Ilagan data not included because of crop failure; Santo Tomas and Cuenca had 2 seedings each. * and ** indicate significantly different from IR36 (check) at 5% and 1% levels.

Table 8. Grain yield of medium- and late-maturing rices in dryland yield trials at 4 Philippine sites[a]. 1980 wet season.

Designation	Grain yield (t/ha)						
	IRRI	Santo Tomas		Cuenca		La Granja	Mean
	3 Jun	23 May	25 Jun	15 May	20 Jun	10 Jun	
IR43	2.8**	4.9**	3.4**	5.0*	3.7*	3.6	3.9
IR9560-2-6-3-1	2.5**	4.5**	3.9**	4.3	3.9**	2.6	3.6
IR9669 selection	2.3**	4.7**	3.0**	3.9	3.9**	2.9	3.5
C171-136	2.6**	4.5**	2.2*	4.4	3.6*	3.8	3.5
B2433B-KN-10-1-1-1	2.3**	3.5	2.2*	5.6**	3.7*	2.8	3.4
Gama 318	2.5**	3.8	2.5**	4.4	3.6*	3.8	3.4
IR8098-41-3	2.8**	4.5**	2.9**	4.4	2.9	2.2	3.3
IR9101-124-1	2.1*	4.1*	3.0**	4.2	3.0	3.1	3.3
IET1785	2.8**	4.6**	2.8**	3.6	3.2	2.9	3.3
KN96	3.2**	3.8	1.9	3.8	3.3	3.9	3.3
IR5643-178-1	1.9	3.5	3.0**	4.4	2.8	3.7	3.2
IR5677-22-5-2	2.4**	4.3**	2.5**	4.1	3.8*	2.7	3.2
IR9995-96-2	2.3**	3.4	2.5**	4.9*	3.3	2.7	3.2
IR52	2.3**	3.8	1.9	4.3	3.2	3.2	3.1
B448-50-2-2-5-1-1	2.2*	4.2*	2.0*	4.6	3.0	2.6	3.1
C166-135	1.8	4.0*	1.9	4.3	3.0	3.5	3.1
IR45	2.0	3.7	2.3**	3.8	3.2	2.9	3.0
C22 (check)	1.6	3.2	1.1	4.0	3.0	3.9	2.8

[a]Ilagan data not included because of crop failure; Santo Tomas and Cuenca had 2 seedings each. * and ** indicate significantly different from C22 (check) at 5% and 1% levels.

Yield data for the two seedings at Santo Tomas and Cuenca indicate a generally lower yield in later seedings (Table 7, 8) because of reduced tillering and shorter panicles. Soil moisture stress in early August coincided with the active vegetative stage of the second seeding at both sites. In addition, disease pressure was heavier on the later seeded crops. Expected favorable effects of the solar radiation on the later seeded rices were masked by the combination of soil moisture stress and disease pressures.

A summary of agronomic characteristics for entries reported in Tables 7 and 8 is given in Table 9.

Drought at Ilagan delayed heading and, consequently, maturity of all the entries. Rices that had better scores than the drought-resistant checks IR442-2-58 and Salumpikit were IR9560-2-6-3-1, IR9995-96-2 (both identified earlier at IRRI as drought resistant), and M1-48.

A review of the yield trials since 1976 showed that IR43, IR2061-522-6-9, IR9669 Sel, and Gama 318 were consistently among the highest yielders (Table 10).

Field evaluation of promising dryland lines *(Plant Breeding).* Eighty varieties and lines were evaluated in a farmer's field in Batangas Province, on a fertile, wet site at IRRI, and on a well-drained, low-soil-fertility site at IRRI.

Table 9. Summary of grain yield and other agronomic characteristics of early-, medium-, and late-maturing rices in dryland yield trials at IRRI, Santo Tomas, Cuenca, and La Granja, Philippines. 1980 wet season.

Designation	Av grain yield (t/ha)	Growth duration (DS[a])		Plant ht (cm)	Panicles (no./m²)	Important diseases[b]
		Mean	Range			
Early-maturing						
IR5931-110-1	3.8	117	111-132	101	263	Bl, LSm, ShB
B733C-167-3-2	3.8	120	114-134	109	257	LSm, NBLS, ShB
IR9782-111-2-1-2	3.6	114	109-126	76	314	Bl, LSm, NBLS, ShB
IR5716-18-1	3.3	122	112-143	92	244	LSc, NBLS, ShB
IR5929-12-3	3.2	115	105-131	107	213	LSm, NBLS, ShB
IR2061-522-6-9	3.2	116	109-130	95	268	Bl, LSc, NBLS, ShB
IET4084 (CR156-5021-207)	3.2	120	112-133	82	258	Bl, NBLS, ShB
KMP34	3.2	116	107-132	82	267	LSm, NBLS, ShB
IR7473-118-2-2-3	3.1	118	110-136	90	226	LSm, NBLS, ShB
IR8085-48-2	3.1	122	117-138	88	242	LSc, NBLS, ShB
IR8608-3-2-2-3	3.1	112	105-126	82	247	LSm, NBLS, ShB
IR9828-36-3	3.1	116	109-130	74	267	LSm, NBLS, ShB
IR36 (check)	2.9	114	109-131	69	273	Bl, LSc, NBLS, ShB
M1-48 (check)	2.1	121	114-132	118	161	ShB
Medium- and late-maturing						
IR43	3.9	126	117-142	82	254	NBLS, ShB
IR9560-2-6-3-1	3.6	131	124-151	81	251	LSc, LSm, NLBS, ShB
IR9669 selection	3.5	132	124-149	82	233	BS, LSc, LSm, NBLS, ShB
C171-136	3.5	126	119-141	109	222	NBLS, ShB
B2433B-KN-10-1-1-1	3.4	136	129-154	104	257	Bl, LSc, ShB
Gama 318	3.4	129	123-145	95	251	Bl, NBLS, ShB
IR8098-41-3	3.3	129	123-142	93	241	LSc, LSm, NBLS, ShB
IR9101-124-1	3.3	124	115-141	80	260	NBLS, ShB
IET1785	3.3	127	122-143	79	270	LSm, NBLS, ShB
KN96	3.3	128	123-147	105	241	Bl, LSc, NBLS, ShB
IR5643-178-1	3.2	126	119-145	82	240	LSc, LSm, ShB
IR5677-22-5-2	3.2	132	124-146	84	252	Bl, LSc, NBLS, ShB
IR9995-96-2	3.2	132	122-147	91	233	BS, NBLS, ShB
IR52	3.1	124	120-134	90	261	Bl, LSm, NBLS, ShB
B44B-50-2-2-5-1-1	3.1	133	125-154	97	222	Bl, LSc, ShB
C166-135	3.1	128	124-143	111	209	LSc, ShB
IR45	3.0	130	122-147	80	272	LSc, NBLS, ShB
C22 (check)	2.8	126	117-143	117	205	Bl, LSc, ShB

[a]DS = days after seeding. [b]BL = leaf blast, LSc = leaf scald, LSm = leaf smut, NBLS = narrow brown leaf spot, ShB = sheath blight, BS = brown spot.

Table 10. Grain yield of rices that performed well for at least 2 years in wet season dryland yield tests at 4-5 Philippine sites.

Entry	Grain yield[a] (t/ha)			
	1977	1978	1979	1980
Early-maturing rices				
IR2061-522-6-9	3.5	3.2	2.3	3.2
IR5716-18-1	—	—	2.3	3.3
IR7473-118-2-2-3	—	—	2.0	3.1
IR9828-36-3	—	—	2.0	3.1
B733C-167-3-2	—	3.2	2.5	3.8
IET4094 (CR156-5021-207)	—	3.3	2.3	3.2
IR36 (check)	3.6	3.5	1.9	2.9
M1-48 (check)	2.2	2.8	1.7	2.1
Medium- and late-maturing rices				
IR43	3.6	3.3	2.8	3.9
IR52	—	3.5	2.5	3.1
IR9560-2-6-3-1	—	—	3.2	3.6
IR9669 selection	3.5	3.6	3.2	3.5
C166-135	—	—	2.6	3.1
Gama 318	3.5	3.4	2.8	3.4
IET1785	—	3.2	2.6	3.3
C22 (check)	3.4	2.8	2.2	2.8

[a]A dash (—) means not tested.

There was no serious drought spell throughout the crop season in the farmer's field at Batangas. However, severe lodging caused by typhoons at ripening and a high incidence of sheath blight lowered the yield of the susceptible entries. Leaf folders also damaged some entries.

The highest yields obtained at Batangas were from IR6115-1-1-1, C1064-5, and IR43 (Table 11). The coefficient of variation was computed at 18.8% and the average site yield was 2.8 t/ha.

Of three agronomic traits, the number of days from seeding to maturity was positively correlated with grain yield ($r = 0.28^{**}$), while plant height was negatively correlated ($r = -0.41^{**}$). Late-maturing lines lodged heavily because of a series of heavy downpours at the flowering-to-ripening stage of 120- to 130-day-old varieties. Panicle number did not appear to affect the yielding ability of the varie-

Table 11. Grain yield and other agronomic traits of selected lines grown at a farmer's field, Santo Tomas, Batangas Province, Philippines, 1980 wet season.

Line	Plant ht (cm)	Panicles (no.)	Maturity (days)	Grain yield (t/ha)
IR3179-25-3-4	111	36	120	3.6 c
IR3839-1	90	40	109	3.8 abc
IR3858-6	124	34	121	3.5 c
IR3880-10	120	38	120	3.4 c
IR3880-17	125	39	118	3.7 bc
IR5420-1-1-2	117	40	116	3.6 c
IR5873-9-1	128	38	120	3.4 c
IR5873-13-2	123	35	118	3.4 c
IR5929-12-3	106	37	113	3.4 c
IR5931-110-1	107	36	114	3.9 abc
IR5931-113-1	122	34	118	3.8 abc
IR5982-7-6-1	88	39	120	3.3 c
IR6023-10-1-1	130	37	120	3.4 c
IR6115-1-1-1	95	38	120	4.0 abc
IR9669 selection	92	40	126	3.8 abc
C1064-5	114	32	120	4.5 ab
IR36 (check)	70	45	110	2.0 d
IR43 (check)	88	38	123	4.6 a

ties ($r = 0.31^{**}$) at this site.

The crop grown on the fertile, wet site at IRRI received evenly distributed rainfall from seeding to harvest and had no serious drought spell. Adverse weather in October caused severe lodging in almost all the plots. High incidences of sheath blight and leaf folder were noted, especially in the middle of the field. The highest yield obtained was only 3.0 t/ha from C1064-5, the lowest was 0.5 t/ha from IR12740-24-1. The average yield was 1.7 t/ha and the coefficient of variation was 23.9%, the highest among the three test sites.

Correlation coefficients showed that plant height was negatively correlated ($r = -44^{**}$) with yield, and panicle number was positively correlated ($r = 0.48^{**}$). Growth duration was not significantly correlated with yield ($r = -0.05$ ns).

At the well-drained, low-fertility site at IRRI, the crop suffered from moisture stress at 60-70 days after seeding, which coincided with the panicle initiation stage of the early- and medium-maturing entries. A 7-day dry spell during the last week of September affected the ripening and heading stage of the late and very-late entries.

The yield ranged from 0.08 t/ha to 2.5 t/ha with an average yield of 1.3 t/ha. The coefficient of variation was 19.3%. Table 12 shows the grain yield and three other agronomic traits of selected lines and varieties. The highest yielders were IR6115-1-1 and C1064-5. IR36, IR45, and IR9669 selection, which were slightly affected by the early short dry spells, recovered and produced a yield higher than

Table 12. Grain yield and other agronomic traits of selected lines grown at a well-drained and low-fertility site at IRRI, 1980 wet season.

Variety or line	Plant ht (cm)	Panicles (no.)	Maturity (DS[a])	Grain yield (t/ha)
IR36 (check)	61	45	120	2.0 abc
IR43 (check)	79	40	122	2.0 abc
IR45 (check)	77	44	129	1.5 cde
IR3839-1	81	46	115	2.1 ab
IR5931-110-1	95	43	118	1.9 bcd
IR5931-113-1	102	48	118	1.5 bcde
IR6023-10-1-1	96	42	122	1.3 de
IR6115-1-1-1	90	40	123	2.5 a
IR9669 selection	84	44	126	2.0 abc
IR12740-24-1	128	33	145	0.5 f
C1064-5	94	35	118	2.5 a
Kinandang Patong (check)	144	34	120	1.1 e

[a]Days after seeding.

that of the traditional upland variety Kinandang Patong, but their heading was markedly delayed. Other high yielding lines, which also have high levels of drought resistance and recovery ability, generally gave higher yields without delay in heading or maturity, or both —IR3839-1, IR5931-110-1, and IR6115-1-1-1.

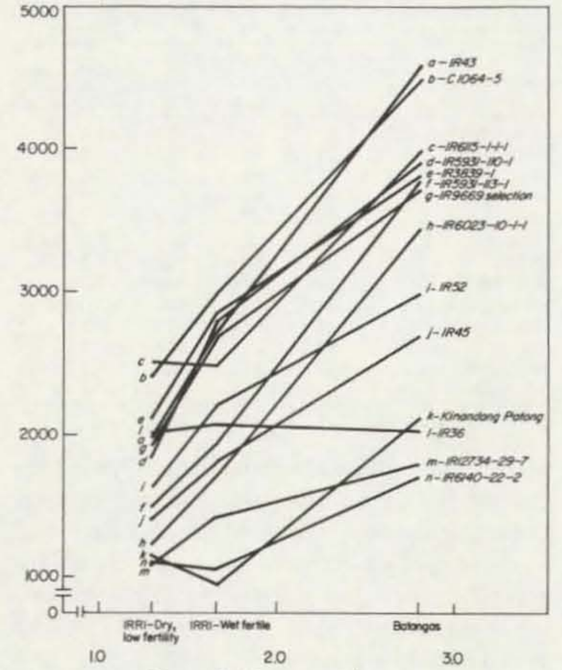
Correlation coefficients showed that panicle number was positively correlated with yield ($r = 0.62^{**}$), but plant height and yield were negatively correlated ($r = -0.38^{**}$). No correlation ($r = 0.07$ ns) was observed between growth duration and grain yield.

Analysis of variance for each test site showed highly significant variation among varieties and lines for the four characters studied (plant height, panicle number per unit area, number of days to maturity, and grain yield). Variances among sites were heterogeneous for three characters, but plant height showed independent response at each site. Figure 5 shows some selected lines representing the different yield responses of the entries at different test sites. The new IR lines showed a higher yield potential and more stable yields than the named varieties, mainly because of the high levels of drought resistance being incorporated. Rainfall varied from 1,184 mm at the well-drained site to 1,221 mm at the wet, fertile site at IRRI farm, and 1,396 mm in the farmer's field in Batangas.

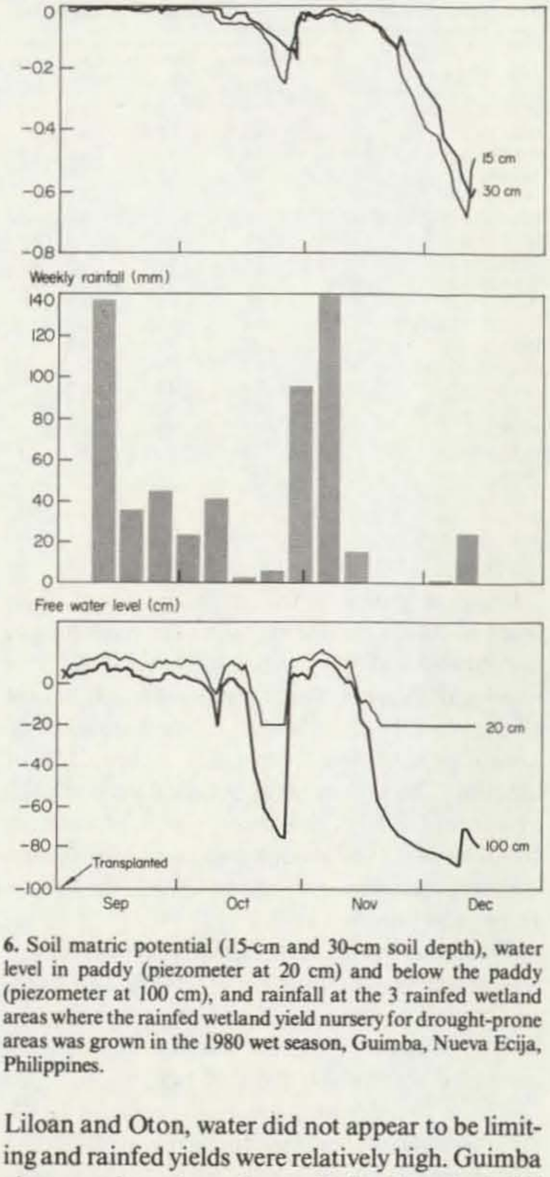
DROUGHT RESISTANCE IN RAINFED WETLAND

Agronomy, Plant Breeding, and Irrigation Water Management Departments

Rainfed wetland yield nursery for drought-prone areas *(Agronomy).* A rainfed wetland yield nursery



5. Yield performance of selected varieties and lines across 3 sites, dryland culture, 1980 wet season.

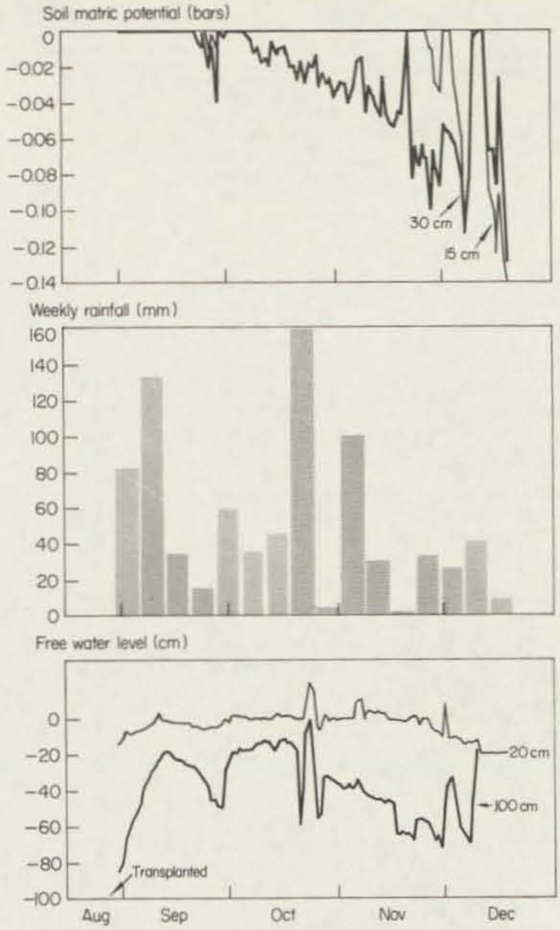


6. Soil matric potential (15-cm and 30-cm soil depth), water level in paddy (piezometer at 20 cm) and below the paddy (piezometer at 100 cm), and rainfall at the 3 rainfed wetland areas where the rainfed wetland yield nursery for drought-prone areas was grown in the 1980 wet season, Guimba, Nueva Ecija, Philippines.

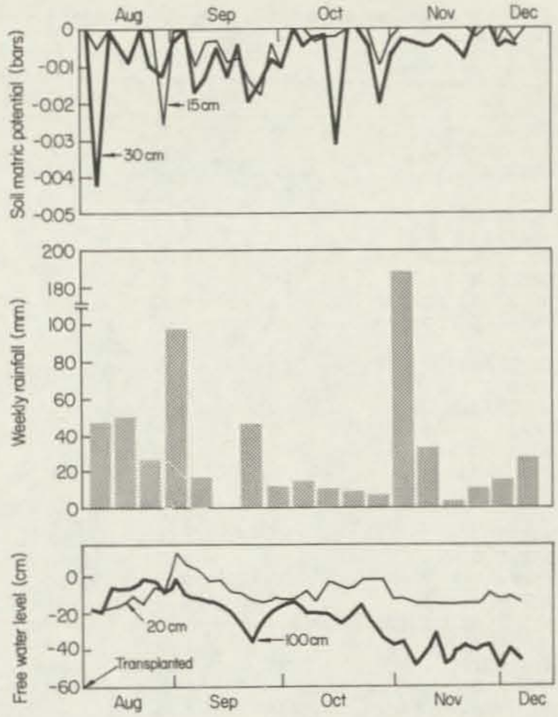
of selected entries from the Genetic Evaluation and Utilization (GEU) program and International Rice Testing Program (IRTP) was first grown at Guimba, Nueva Ecija, in 1979. In 1980 other sites at Liloan (Cebu) and Oton (Iloilo) were added. Crop management practices included 60-30-30 kg NPK/ha added basally. Insect and disease incidence were minimal, but at Guimba the leaf folder and whorl maggot occurred at the vegetative stage. Hand weeding was done as needed. Crop weather was favorable at all sites.

In 1980 the free water level in the paddy above the hardpan was measured. In addition, the free water level below the paddy was recorded. Figures 6-8 give an indication of the soil water conditions and show the three hydrologically related variables rainfall, soil matric potential, and free water level at the sites. At Guimba, both short-term water deficits such as those that occurred 16-27 October and the soil drying and decline of free water levels after the final storm of the monsoon season about 5 November are well illustrated (Fig. 6). Table 13 shows the yield at these sites for the 32 entries and IR8, which was the farmer's variety at Liloan. At Liloan and Oton, water did not appear to be limiting and rainfed yields were relatively high. Guimba also experienced a rather well-distributed rainfall and high water level conditions except at the end of the season. As previously reported the higher yields for Guimba were associated with the very early maturity groups.

Evaluation of rice yield under two water regimes *(Plant Breeding and Irrigation Water Management).* Yield performance of 20 IRRI lines, 4 Indonesian varieties and lines, 14 breeding lines from Thailand, and 2 Philippine varieties was tested under two water regimes at 3 sites — IRRI, and Gapan and Guimba, Nueva Ecija province.



7. Soil matric potential (15-cm and 30-cm soil depth), water level in paddy (piezometer at 20 cm) and below the paddy (piezometer at 100 cm), and rainfall at the 3 rainfed wetland areas where the rainfed wetland yield nursery for drought-prone areas was grown in the 1980 wet season, Oton, Iloilo, Philippines.



8. Soil matric potential (15-cm and 30-cm soil depth), water level in paddy (piezometer at 20 cm) and below the paddy (piezometer at 100 cm), and rainfall at the 3 rainfed areas where the rainfed wetland yield nursery for drought-prone areas was grown in the 1980 wet season, Liloan, Cebu, Philippines.

Gapan data are not included because, although the crop had no visible moisture stress, many susceptible entries were damaged by tungro.

IRRI. The IRRI trial was transplanted 29 July in a rainfed-wetland area and in an irrigated area. Total rainfall from transplanting to harvest was 1,161.6 mm. Short dry spells of 4-5 days occurred during the last week of September and the second week of October, which coincided with the heading time of the early-maturing entries but no pronounced symptoms of crop moisture stress were observed.

The highest yields obtained from the rainfed plots were 4.3 and 4.8 t/ha from IR9217-58-2 and IR13149-19-1. The mean yield from the rainfed test was 2.8 t/ha. Light infection of about 10-15% of rice tungro virus slightly affected the yields of susceptible plants, especially the breeding lines from Thailand.

Analysis of variance of plant height, panicle number, number of days to head, and grain yield showed highly significant variation among varieties grown in rainfed plots.

In the fully irrigated plots, the highest yield obtained was 5.4 t/ha from IR9852-22-3. The mean yield of the irrigated plots was 3.5 t/ha.

A highly significant correlation coefficient between the yield of rainfed plots and the yield of irrigated plots was obtained (0.83**). The coefficient of variation was 20.4% for rainfed plots and 16.6% for the irrigated plots.

Among the varieties that had no significant yield difference between the two water regimes were IR52 (3.7 vs 3.9 t/ha), IR4432-28-5 (3.6 vs 3.9 t/ha), IR9217-58-2-2 (4.3 vs 4.6 t/ha), and IR13149-19-1 (4.8 vs 4.2 t/ha).

Table 13. Grain yield of 33 entries in the rainfed wetland yield nursery for drought-prone areas: Guimba, Nueva Ecija; Oton, Iloilo; Liloan, Cebu, Philippines, 1980.

Entry	Maturity[a]	Grain yield[b] (t/ha) Guimba	Oton	Liloan	Rank (across 3 sites)
IR5853-198-1-2	E	3.34 a	2.38 hijklm	4.24 abcdefg	8
IR4707-14-3-1	E	3.22 ab	2.74 efghijkl	3.39 cdefg	11
IR5629-64-3	E	2.98 abc	3.23 cdefgh	4.00 abcdefg	5
IR54	E	2.96 abc	2.75 efghijkl	4.26 abcdef	7
IR9129-192-2	VE	2.79 abcd	4.13 ab	4.97 ab	1
IR4707-140-1-3	E	2.74 abcde	2.93 efghij	3.02 efg	19
IR14753-72-1	E	2.69 abcdef	3.09 cdefghi	4.18 abcdefg	10
IR2823-103-5-1	M	2.63 bcdef	3.15 cdefgh	4.19 abcdefg	9
IR4570-83-3-3-2	E	2.60 bcdef	0.85 p	3.46 cdefg	30
IR7149-35-2-3-2	VE	2.60 bcdef	4.13 ab	3.28 defg	6
IR43	E	2.39 cdefg	2.54 ghijklm	4.08 abcdefg	16
IR2307-437-1-2	E	2.38 cdefg	2.67 fghijkl	3.97 abcdefg	15
IR52	E	2.33 cdefgh	3.35 bcdefg	4.75 abc	4
IR9209-26-2	VE	2.30 cdefgh	3.83 abcd	4.69 abcd	3
MR7	E	2.18 defghi	2.55 ghijklm	4.06 abcdefg	18
IR13426-19-2	E	2.10 defghij	1.90 lmn	3.74 bcdefg	25
IR9129-161-2	VE	2.09 defghijk	3.51 abcdef	5.24 a	2
IET1444	E	2.06 efghijk	3.90 abc	3.99 abcdefg	12
IR36	E	2.00 fghijkl	3.21 cdefgh	4.43 abcde	14
IR3304-23	E	1.87 ghijkl	2.26 ijklmn	2.82 fg	29
IR3941-25-1	E	1.81 ghijklm	3.92 abc	4.12 abcdefg	13
IR26	E	1.79 ghijklm	3.05 defghij	3.47 cdefg	24
IR9764-45-2-2	E	1.73 ghijklm	0.97 p	4.53 abcd	28
IR5931-81-1-1	E	1.71 ghijklm	2.21 jklmn	2.86 fg	31
IR5931-110-1	E	1.63 hijklmn	2.59 ghijklm	4.41 abcde	21
Gama 318	M	1.54 ijklmn	2.04 klmn	3.87 abcdefg	26
IR3858-6	E	1.45 jklmnop	3.58 abcde	3.88 abcdefg	17
B2039C-Kn-7-2-5-3-1	M	1.38 klmnop	2.59 ghijklm	4.48 abcde	22
BG35-2	VE	1.29 lmnop	4.25 a	2.79 g	23
IR5716-45-1	E	1.16 mnp	2.98 efghijk	3.35 cdefg	27
IR5440-1-1-3	E	0.99 np	1.57 np	2.93 fg	32
IR7790-18-1-2	VE	0.83 p	1.81 mn	2.82 fg	33
IR8	M			2.88 fg	20

[a]E = early, VE = very early, M = medium. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

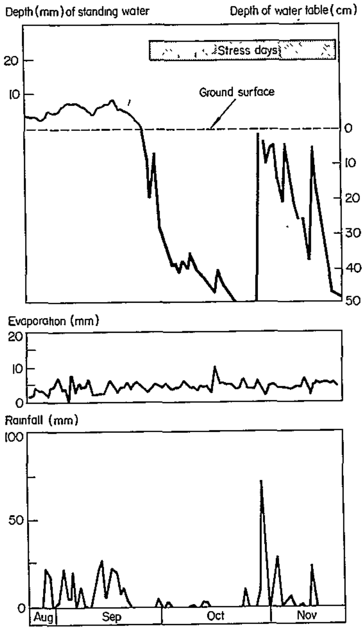
IR13149-19-1 produced more panicles in rainfed plots than in the irrigated plots. Panicle number was positively and significantly correlated with yield under both water regimes (Table 14). A significant negative correlation between yield and plant height and between yield and the number of days to head was also observed in both water regimes.

Guimba, Nueva Ecija. Most rice fields at Guimba are rainfed. The experimental site was on high ground and the irrigated treatment was not flooded at all times because of pump failure. The irrigated field had dry periods in 28 September-5 October, and 15-27 October, but there was no visible sign of moisture stress among the entries because there were light rains at those periods. The highest yield was 5.6 t/ha from IR46; the lowest yield was 3.1 t/ha from Intan and IR3351-38-3-1.

Figure 9 shows the weekly rainfall distribution, evaporation, depth of water table, and stress days at the rainfed Guimba site. There was a series of dry spells from 21 September to 23 October. The water table remained at the 35-50 cm depth. Light showers fell when the crop was 70-98 days old. Most entries showed visible symptoms of moisture stress. At maturity, IR30, IR34, IR36, IR5420-1-1-2, and Nam Sagui 19 lodged because the basal leaves and culms dried up. The yield of IR36, which recovered quickly after light showers, was not seriously reduced.

Table 14. Correlation coefficients of 3 plant characters with yield of 40 varieties at 2 water regimes at 2 sites. Philippines, 1980.

Site, water regime	Correlation coefficient: Yield and plant ht	Yield and panicle no.	Yield and no. of days to heading
IRRI farm			
Rainfed	-.66**	.50**	-.43**
Irrigated	-.60**	.49**	-.23
Guimba, Nueva Ecija			
Rainfed	-.55**	.52**	-.39*
Irrigated	-.42**	.25**	-.50**



9. Daily rainfall distribution, daily evaporation, water table depth, and stress days at the farmer's rainfed-wetland field, Guimba, Nueva Ecija, Philippines, 1980 wet season.

The highest yields obtained from the rainfed field was 3.9 t/ha from B1141C-KN-43-1-8; the lowest was 0.9 t/ha from BKN7130-1132-1. The check varieties BPI-76 (n.s.) and Intan yielded 2.4 and 1.4 t/ha. Intan was severely affected by drought but recovered when the rains came during the last week of October. Its heading was uneven and maturity was delayed, however.

Table 15 shows the grain yield and three agronomic traits of selected varieties and lines at the drought-prone site of Guimba.

Among the better performers, IR46 gave a more stable yield across 3 sites, producing 3.8, 4.0, and 3.1 t/ha at IRRI, Gapan, and Guimba.

The correlation coefficient between yields of rainfed and of irrigated plots was highly significant. Panicle number was positively correlated with yield at the rainfed plot but no significant correlation was observed at the irrigated plot (Table 14). Shorter plant height and earlier heading were significantly correlated with higher yields.

ROOT STUDIES

Agronomy, Plant Breeding, and Plant Physiology Departments

Inheritance of root characteristics in aeroponic culture *(Plant Breeding and Agronomy).* In past field experiments, the length, thickness, and number of roots were shown to be associated with drought resistance and recovery ability. In 1980 a new aeroponics system was used to investigate the inheritance of different components of the root systems and their relationships with the aboveground shoots in a number of crosses involving tall-dryland and semidwarf-wetland varieties. Rice seedlings were symmetrically spaced on the lid of an aeroponics tank and the roots were suspended in the air. Water and nutrients were continuously supplied in a uniform mist inside the tank.

Diallel analysis of an eight-parent set of crosses showed that the F_1 plants frequently excelled the deep-rooted dryland parents in maximum root length. Three dryland varieties had an excess of dominant alleles for deep roots, and one dryland and one semidwarf carried an excess of recessive alleles for long roots (Fig. 10). On the other hand, crosses involving the shallow-rooted variety IR20 showed the predominance of shallow roots controlled by an excess of dominant alleles present in IR20.

Root thickness was measured at three positions on the thick roots, and the data from three sampling sites were generally positively correlated. Thickness of the root tips appeared to be the significant element in varietal differences. Again, many F_1 plants showed a predominance of roots that were thinner than those of the thin-rooted semidwarf parents. An excess of dominant alleles controlled thin roots of IR20, IR841-67-1, and MGL-2. Only one African variety, OS4, contained dominant alleles for its thick root tips. In the two other

Table 15. Grain yield and other agronomic traits of selected lines and check varieties under 2 water regimes (rainfed, irrigated) at drought-prone Guimba, Nueva Ecija, Philippines, 1980 wet season.[a]

Variety or line	Rainfed rice			Yield[b] (t/ha)	
	Plant ht (cm)	Panicles (no.)	Days to heading	Rainfed	Irrigated
IR36	84	14	79	3 02 ns	4 87 ns
IR46	92	14	88	3 09 ns	5.62*
IR48	100	10	103	2 83 ns	3 69 ns
IR52	94	14	82	3.13 ns	4 66 ns
IR9852-22-3	94	12	88	3.15 ns	4.41 ns
IR13146-41-3	92	11	90	3 09 ns	4.18 ns
IR13426-19-2	88	13	88	3 34 ns	4 07 ns
B1141C-KN-43-1-8	103	12	87	3 95 ns	4 14 ns
KKN7409-SRN-245-2	102	13	84	3 16 ns	3.34[c]
SPR7421-3-1-2	92	12	86	3.02 ns	3 72 ns
KKN7205-39-3-SKN-1-1	107	11	87	3 02 ns	4.28 ns
BPI-76 (nonsensitive check)	116	8	86	2 44	3.97
Intan (check)	126	10	108	1 44	3 08

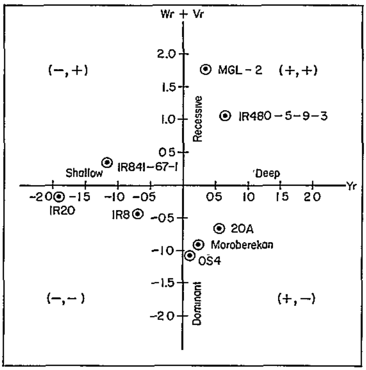
[a]Av of 2 replications. [b]* = means were significantly different from BPI-76 (nonsensitive check) at the 5% level. [c]From one observation only.

dryland parents, Moroberekan and 20A, recessive alleles controlled thick root tips (Fig. 11).

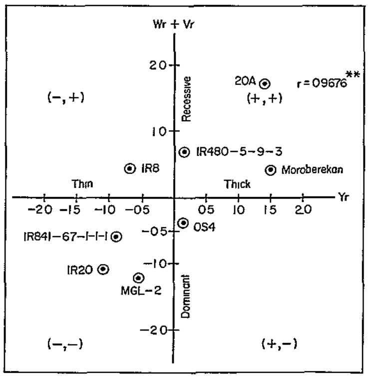
The semidwarfs generally have more roots than the dryland varieties. Most of the F_1 plants surpassed the semidwarfs in root number, indicating an overdominance of high root number. High root number was controlled by dominant alleles in two parents: IR8 and the Indian dryland variety MGL-2. Low root number may be due to recessive alleles in three dryland varieties and to dominant alleles in one semidwarf.

In terms of dry weight of roots, the F_1 plants frequently surpassed the heavy-rooted parents. Among different parents, high root weight was controlled by recessive alleles in three parents (IR8, IR480-5-9-3, and MGL-2) and by dominant alleles in two African dryland varieties (Moroberekan and 20A).

Among the F_1 populations, root length was positively correlated with plant height and root thickness. Root thickness was positively correlated with plant height, dry weight of the roots, and root-to-shoot-weight ratio. Root number was positively correlated with tiller number, and the dry weight of



10. Standardized deviation graph between *Yr* (parental measurement) and *Wr* = *Vr* (order of dominance) of maximum root length in an eight-parent diallel cross. IRRI, 1980.



11. Standardized deviation graph between *Yr* (parental measurement) and *Wr* + *Vr* (order of dominance) of root thickness (tip) in an eight-parent diallel cross. IRRI, 1980.

roots and shoots. However, there was no correlation between root number and root length, root number and plant height, and root number and thickness.

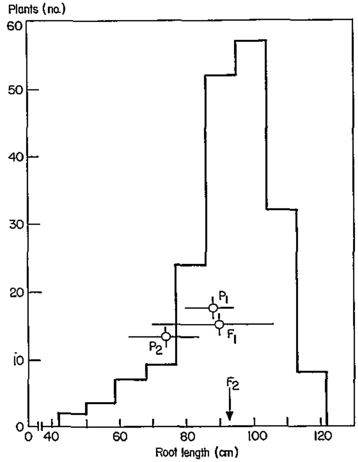
Heritability estimates (in the narrow sense) were moderately high for root length (0.61) and for root-tip thickness (0.62) and moderately low for root number (0.44) and root weight (0.43). On the other hand, the estimates were high for plant height at 50 days after seeding (0.75), and moderately high for root-to-shoot-weight ratio (0.53) and tiller number (0.63).

The distribution of F_2 plants in three crosses indicated that the prospects for obtaining F_2 plants with long and many roots (Fig. 12) are better than those for very thick roots (Fig. 13).

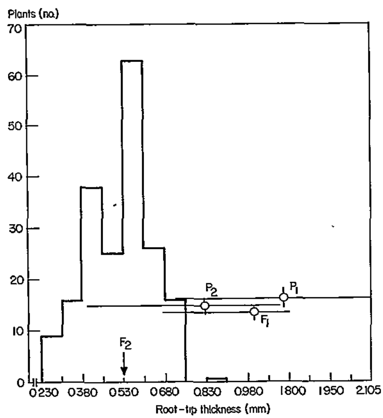
These findings may partly explain the difficulty in recombining deep and thick roots with a moderate number of roots in semidwarf-dryland crosses when deep and thick roots were controlled by various combinations of dominant and recessive alleles in different parents. Association of traits appeared to be mostly in the undesired directions. Moreover, F_1 partial sterility, restricted F_2 segregation, and aberrant recombination of other traits in such wide crosses was noted.

Effect of pH on root growth *(Plant Physiology).* Effect of pH on root growth of 5 varieties was studied in solution culture. Root elongation was extremely impaired at pH 3.0; no varietal difference was observed (Fig. 14). Within a pH range of from 3.5 to 6.0, root lengths were not much affected by pH. A slight reduction in root length at pH 6.0 was attributed to possible iron deficiency because chlorosis was observed in leaves.

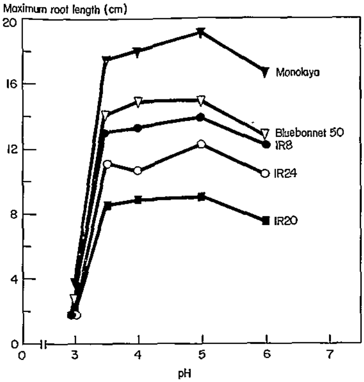
Comparison of three screening techniques for aluminum toxicity tolerance *(Plant Physiology).* Among available screening techniques for tolerance for aluminum toxicity — relative root length, root regrowth, and hematoxylin staining — relative root length technique was the simplest and most reliable. Seedlings were grown in culture solution with and without aluminum (30 ppm) for 2 weeks. Relative root length (ratio of root length at 0 ppm Al to that at 30 ppm Al) was taken as a measure of aluminum toxicity tolerance. Ratios were greater than 0.85 for tolerant varieties, less than 0.60 for susceptible varieties, and between 0.60 and 0.85 for intermediate varieties. When tolerant varieties are



12. Distribution and means of parents and F_1 and F_2 plants by maximum root length classes in the cross of OS4 (P_1) by IR8 (P_2). Solid horizontal lines show the range of parents and F_1 plants about the means (dotted circles). IRRI, 1980.



13. Distribution and means of parents and F_1 and F_2 plants by root-tip thickness classes in the cross of OS4 (P_1) by IR8 (P_2). Solid horizontal lines show the range of parents and F_1 plants about the means (dotted circles). IRRI, 1980



14. Effect of pH on root elongation of 5 varieties grown in culture solution IRRI, 1980

Table 16 Aluminum toxicity tolerance of 70 varieties based on relative root length. IRRI, 1980.

Varieties with given reaction to aluminum toxicity		
Tolerant	Intermediate	Susceptible
Agulha	Ardito	Bombilla
Amarelao	Batataes	C4-63
Bengue	Bosque Sel 693	Cera 4
Bico Branco	Canairo Acc No 3307	Cica 4
Bluebonnet 50	Canairo Acc No. 10753	IR5
Cateto	Catibao Dourado	IR8
Catito Dourado	Dalila	IR20
Colombia I	Dawk Mali	IR22
CI 2011	Huk Do	IR26
CI 2012	IR24	IR28
CI 2013	IR36	IR29
Dourado Agullia	IR48	IR30
E425	IR52	IR32
IAC-1	IR442-2-58	IR34
IAC-3	Khao Lo	IR38
IAC-9	Mantoya	IR40
ICA-162	Moroberekan	IR42
Iguape Catito	Palawan	IR43
Monolaya	Perola	IR44
M1-48	Secano	IR45
OS4	Starbonnet	IR46
OS6	Succa	IR50
Prolific	20A	
Pratao Prococe		
Tres Meses		

to be screened, visual comparison of roots facilitates screening; measurement of root length is not necessary.

The root regrowth technique required two measurements of root length and was tedious.

The hematoxylin staining technique, used successfully in wheat, is simple and fast but when applied to rice it does not give a clear separation between tolerant and susceptible varieties. Examination of stained root segments under a microscope gave a much better separation but was time-consuming.

Aluminum toxicity-tolerant and susceptible varieties *(Plant Physiology).* The tolerance of 70 varieties for aluminum toxicity was tested by the relative root length technique (Table 16). Most dryland varieties are tolerant of aluminum toxicity, and wetland varieties are susceptible. Thus, deep rooting habit and aluminum tolerance appear to be interrelated.

Histochemical technique for diagnosis of aluminum toxicity *(Plant Physiology).* A typical and consistent symptom of aluminum toxicity in rice is impaired root growth indicated by shortened root axis, less branching, and brittle root material. Leaves do not normally show any specific symptoms. Impaired root growth, however, is not always caused by aluminum toxicity. Thus, some direct means by which aluminum toxicity can be diagnosed — soil pH, exchangeable aluminum, and percent aluminum saturation — are commonly used. Species and varietal differences in aluminum tolerance, however, make it difficult to identify aluminum toxicity for a particular soil based on soil analysis alone.

Histochemical examination of the root tip region of the rice plant gave a clear indication of aluminum toxicity. A cross section of the near-tip region of a root was stained by hematoxylin and examined under a microscope. Blue stains in cortical cells indicated aluminum deposition. Aluminum deposition coincided with significant reductions in root growth by high levels of aluminum. The results indicate that histochemical examination of root cross sections can be used to diagnose aluminum toxicity in growing crops.

Relation between soil analysis and plant tests for aluminum toxicity *(Plant Physiology).* Eight acid soils were collected from the Philippines, Thailand, and Brazil. Among them, three had high percentages of aluminum saturation. There was good agreement in aluminum saturation (%) between

Table 17. Relation between soil analysis and plant tests[a] for aluminum toxicity of rice-growing soils. IRRI, 1980.

Soil	pH	Exchangeable Al (meq/100 g soil)	Al saturation (%)	Root growth test	Histochemical test
Adtuyon, Philippines	5 0	1.4	–	–	–
Bantug, Philippines	4 7	0.7	4	–	–
Luisiana, Philippines	4 5	0 4	3	–	–
Malinao, Philippines	3 5	7.7	64	+	+
Camaca, Brazil	4 4	6.0	81	+	+
Klong Luang, Thailand	4.7	0 7	3	–	–
Muang, Thailand	5.5	0 1	1	–	–
Ongkarak, Thailand	3 4	9 2	49	+	+

[a]The negative sign implies normal root growth and negative response to hematoxylin test; the plus sign indicates highly impaired root growth and positive response to hematoxylin test

root growth tests in the glasshouse and the histochemical test using hematoxylin (Table 17).

Luisiana soil of the Philippines is often suspected of being aluminum toxic but examination, indicated it is low in aluminum saturation (%), negative in root growth and histochemical tests, and not aluminum toxic. In Thailand, deepwater rice is sown and grown for about 2 months in dryland soils. Acid sulfate soils are considered aluminum toxic under those conditions. A preliminary study indicated that only Ongkarak soil (pH 3.4) is aluminum toxic.

SOIL-PLANT-WATER RELATIONSHIPS

Agronomy Department

Drought tolerance under limited rooting depth. Testing for drought tolerance at shallow rooting depth and the ability to recover from drought stress was continued in the greenhouse.

A total of 105 entries (GEU elite lines and selected entries from the previous season's test) were evaluated for drought tolerance at the vegetative stage. Three entries, including the indicator plant Leb Mue Nahng, were seeded into dry soil in steel drums with effective rooting depth of 45 cm. The soil in the drums was watered regularly until 30 days after seeding, then the soil was allowed to dry naturally. 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 3 weeks later.

The average soil moisture contents for both seasons were 8.2 and 12.7% at 20- and 30-cm soil depths. Table 18 shows the entries that performed better than Leb Mue Nahng (the tolerant check) and their corresponding drought tolerance and recovery scores during the dry season screening.

Table 18. Drought tolerance ratings at vegetative stage, and drought recovery scores of promising GEU elite lines and selected entries. IRRI greenhouse, 1980 dry season.

Variety or line	Drought tolerance rating[a]	Drought recovery rating[a]
Khao Dawk Mali	7	1
Ketan Cere	5	1
PN 677-2	5	1
IR15318-2-2-2-2	6	1
IR8192-31-2-1-2	6	2
Chungta 312 Hao + Binastian	6	2
IR3839-1	7	2
IR4568-86-1-3-2	7	2
Nam Sagui	7	3
Cauvery	5	3
IR14632-22-3	7	4
IR9852-22-3	6	5
IR5929-12-3	8	6
IR8192-166-2-2-3	8	6
Leb Mue Nahng (tolerant check)	9	9

[a]Scored with the 1976 Standard Evaluation System for Rice

Among the entries tested in the wet season, IR14753-120-3, IR13540-56-3-2-1, and IR9729-67-3 showed relatively high levels of drought tolerance and good recovery (Table 19). Two IR9209 lines also appeared promising. IR9411-5-3-3, IR13426-19-2, and IR6023-10-1-1, which were apparently dead, were able to recover; IAC5544 which had a better drought score of 7 performed almost as well when rewatered. Results indicate that the degree of drought recovery is independent of the ability to resist drought.

Measurement of leaf water potentials of rice. Comparisons of rice leaf water potentials by isopiestic psychrometer, Merrill soil psychrometer (single junction, #75-1), dew-point method, and pressure chamber were made to identify the most reliable technique for future research. Pressure chamber measurements were highly correlated ($r = 0.98^{**}$) with those of the isopiestic psychrometer, a method considered accurate for measuring tissue

Table 19 Drought tolerance ratings at vegetative stage, and drought recovery scores of promising GEU elite lines and selected entries. IRRI greenhouse, 1980 wet season.

Variety or line	Drought tolerance rating[a]	Drought recovery rating[a]
IR14753-120-3	7	3
IR13540-56-3-2-1	7	4
IR9729-67-3	7	4
IR2909-262-1-3-1	6	5
IR17494-32-1-1-3-2	6	5
IR5260-1	6	5
IR9209-181-3-5	7	6
IR19759-29-2-1-3	6	6
IR9764-45-2-2	8	6
IR13429-299-2-1-3	8	7
IR9411-5-3-3	9	7
Cauvery	6	7
IET1444	7	7
IR9852-22-3	8	7
IR13426-19-2	9	7
IAC5544	7	8
IR6023-10-1-1	9	8
Leb Mue Nahng (tolerant check)	9	9

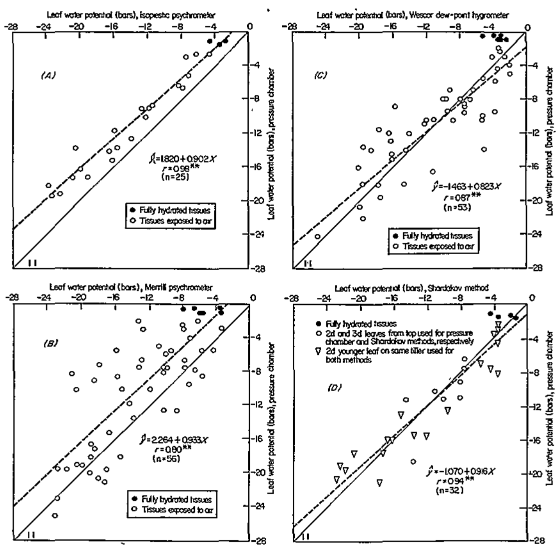
[a]Scored with the 1976 Standard Evaluation System for Rice.

water potentials (Fig. 15a). Agreement between the Merrill psychrometer and the pressure chamber was poor with correlation coefficient $r = 0.80^{**}$, the lowest among 4 comparisons (Fig. 15b). Pressure chamber values were less positive than dew-point determinations at leaf water potentials > -8 bars and the opposite trend was true at potentials < -8 bars (Fig. 15c). Comparison of the Shardakov dye method and pressure chamber gave the best agreement with the second highest correlation coefficient ($r = 0.94^{**}$) and the data falling on the 1:1 line (Fig. 15d).

The sampling variance of the pressure chamber readings was the lowest ($s^2 = 0.12$) and that of the Merrill psychrometer ($s^2 = 8.2$) was the highest among the five methods used to measure leaf water potentials of fully turgid leaves (Table 20). The Merrill psychrometer gave the lowest mean ($\bar{x} = -7.3$) leaf water potential of fully hydrated leaves.

It was concluded that the pressure chamber provides reliable estimates of leaf water potential of rice.

Use of a line source sprinkler system to evaluate drought response of rices at various nitrogen fertility levels. Drought response of rice at various nitrogen fertility levels was studied with a line source sprinkler system. Treatments consisted of seven levels of water application, four cultivars, and three nitrogen rates replicated four times. Each subplot (14 × 3 m) was subdivided into 7 consecutive indi-



15. Comparison of the different methods of measuring leaf water potential in rice. IRRI, 1980.

Table 20. Table of means, sampling variances (s^2), and coefficients of variations (CV) for different leaf water potential measurements on fully hydrated leaves.[a] IRRI, 1980.

Method	n	Mean (bars)	s^2	CV (%)
Merrill psychrometer	14	−7.3 c	8.20 c	39.2
Pressure chamber	13	−1.0 a	0.12 a	34.5
Shardakov method	8	−2.8 b	0.86 b	33.7
Wescor psychrometer	6	−3.5 b	0.87 b	26.5
Isopiestic psychrometer	4	−3.6 b	0.58 b	21.4

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

vidual plots or positions of 8 rows each (positions 1, 2, . . . 7) where position 1 received the highest application rate and 7 the lowest. The center of each plot was 1 to 13 m from the line source sprinkler at 2-m increments starting from the nearest plot.

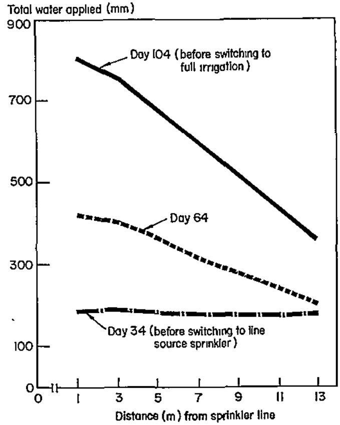
IR20, IR36, IR52, and Kinandang Patong were hand-drilled in 25-cm rows parallel to the sprinkler line at the rate of 100 kg/ha for IR20, and at a rate adjusted to give about equal seed numbers for the other cultivars. Nitrogen at 0, 60, and 120 kg/ha was basally applied at seeding together with 30 kg each of P_2O_5 and K_2O/ha.

Four sets of sprinklers spaced 12.2 m apart were used to establish the seedlings to day 34. Starting on day 40, irrigation was with a single sprinkler line (6.1 m between sprinklers) to give variable water supply across the plots. Water applied at each irrigation schedule was measured from several sets of catch cans installed at specific places in the field. Tensiometers and neutron access tubes were also installed to monitor soil water changes at different soil depths.

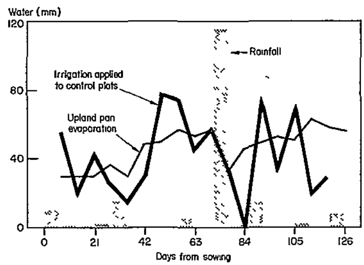
Leaf water potential by pressure chamber technique, visual scoring for degree of leaf rolling and drought tolerance, and measurements of other parameters were done at desired growth stages. Grain yield and dry matter production were sampled from the four middle rows of each plot.

Test results. A linear decrease in water supply farther from the line (Fig. 16) permitted visual evaluation of some traits at a particular irrigation level. The amount of water applied to control plots (1 m from the sprinkler line) was adequate (Fig. 17) and was necessary to minimize horizontal seepage except in case of too much rain. Inadequate water could have resulted in water stress in the control plots.

Visual scores on the degree of leaf rolling and drought tolerance showed that water stress was



16. Total water applied (including rainfall) measured at different distances from a line source sprinkler. IRRI, 1980 dry season.



17. Weekly rainfall, pan evaporation (upland farm), and maximum irrigation applied to control plots by a line source sprinkler. IRRI, 1980 dry season.

more evident in the three positions farthest from the sprinkler line. The effect of drought stress was least on Kinandang Patong and greatest on IR20 (Table 21). Increasing the nitrogen level from zero to 60 and 120 kg N/ha increased the degree of water stress especially in plots farthest from the sprinkler line.

Measurement of leaf water potential (LWP) on day 64 showed that the application of 120 kg N/ha

Table 21. Effect of nitrogen level and water applied on leaf rolling and drought tolerance scores IRRI, 1980 dry season.

Nitrogen applied (kg/ha)	Distance (m) from the sprinkler line	Leaf rolling score[a]					Drought tolerance score[b]				
		IR20	IR36	IR52	Kinandang Patong	Mean	IR20	IR36	IR52	Kinandang Patong	Mean
0	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	5	1.0	1.0	1.0	1.0	1.0	1.3	1.3	1.3	1.0	1.2
	9	1.5	1.3	1.8	1.3	1.5	2.0	2.3	2.0	1.8	2.0
	13	3.0	2.5	2.8	2.3	2.7	3.0	2.8	3.0	2.0	2.7
60	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	5	1.0	1.0	1.0	1.0	1.0	1.3	1.0	1.0	1.0	1.1
	9	2.0	2.0	2.0	1.8	2.0	2.3	2.3	2.3	1.5	2.1
	13	3.8	3.3	3.0	2.3	3.1	3.8	3.5	3.0	2.0	3.1
120	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	9	2.5	2.3	2.5	1.8	2.3	2.8	2.5	2.8	1.8	2.5
	13	4.5	3.8	4.3	2.8	3.9	4.8	3.5	4.5	2.3	3.8
Mean		1.9	1.8	1.9	1.5		2.1	1.9	2.0	1.5	

[a]Based on scale of 1-5: 1 = no rolling, 5 = tightly rolled [b]Scored with the 1980 Standard Evaluation System for Rice.

Table 22. Effect of nitrogen level and distance from the sprinkler line on leaf water potential. IRRI, 1980 dry season.

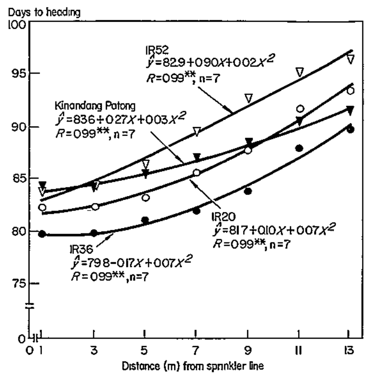
Nitrogen applied (kg/ha)	Leaf water potential[a] (bars) at indicated distance from sprinkler line		
	3 m	7 m	11 m
0	−13.7 a	−15.3 a	−19.0 b
60	−13.4 a	−15.2 a	−22.0 ab
120	−13.8 a	−17.2 a	−23.1 a

[a]Av of 4 varieties. Separation of means in a column by Duncan's multiple range test at the 5% level

Table 23. Leaf water potential of 4 varieties at different nitrogen levels and at a distance of 11 m from the sprinkler line. IRRI, 1980 dry season.

Variety	Leaf water potential[a] (bars)		
	0	60 kg N/ha	120 kg N/ha
IR20	−23.0 a	−30.3 a	−29.0 a
IR36	−21.5 ab	−21.6 b	−23.4 ab
IR52	−17.0 ab	−19.4 b	−23.6 ab
Kinandang Patong	−14.6 b	−16.9 b	−16.3 b

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



18. Effect of distance from the sprinkler line on days to heading of 4 varieties (mean of 3 nitrogen levels). IRRI, 1980 dry season

decreased LWP when the distance from the sprinkler line was 11 m (Table 22). At all levels of N, Kinandang Patong significantly gave higher LWP than IR20 (Table 23). IR36, IR52, and Kinandang Patong were not significantly different although Kinandang Patong had the highest numerical value.

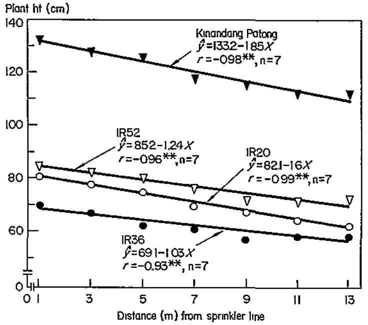
There was a curvilinear increase in the number of days to heading and a linear decrease in plant height with increase in the distance from the sprinkler line (Fig. 18, 19). Total dry matter production at harvest was also affected (Fig. 20). The effect on Kinandang Patong was less pronounced perhaps because water stress had little effect on that variety.

The yield-water-fertilizer relationships of the four cultivars revealed different production surfaces (Fig. 21, 22). The following equation provided a good fit in predicting the yield for various combinations of water and fertilizer applied:

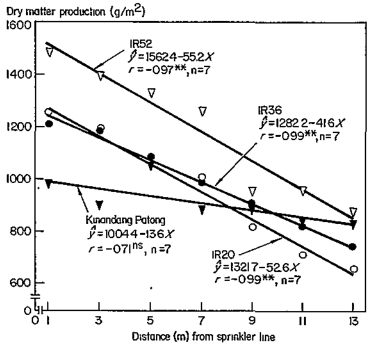
$$\hat{Y} = a + b_1N + b_2W + b_3N^2 + b_4W^2 + b_5NW$$

were $\hat{Y}$ = grain yield (g/m²), N = nitrogen level (kg N/ha), and W = water applied (mm). The multiple correlation coefficients were highly significant for all cultivars tested.

Predicted maximum yields of 562, 802, and 837

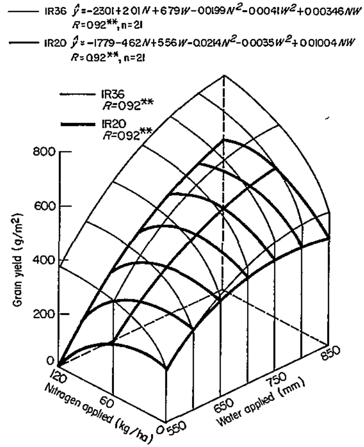


19. Plant height at harvest of 4 rice varieties at different distances from a line source sprinkler (mean of 3 nitrogen levels). IRRI, 1980 dry season

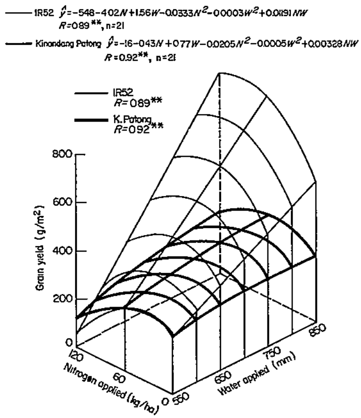


20. Total dry matter production at harvest of 4 rice varieties at different distances from a line source sprinkler (mean of 3 nitrogen levels). IRRI, 1980 dry season

g/m^2 were obtained with IR20, IR36, and IR52 at 120 kg N/ha and with 850 mm water. Kinandang Patong attained a maximum yield of 342 g/m^2 at 60 kg N/ha with the same amount of water applied. However, with no N fertilizer application, Kinandang Patong gave the highest predicted yield of 255 g/m^2 with 550 mm water; its yields at 0 kg N/ha were almost constant irrespective of water applied.



21. Response surfaces of IR29 and IR36 varieties at different water and nitrogen levels IRRI, 1980 dry season.



22. Response surfaces of IR52 and Kinandang Patong varieties at different water and nitrogen levels IRRI, 1980 dry season.

At a combination of 120 kg N/ha and 550 mm water, IR36 was superior to the other cultivars.

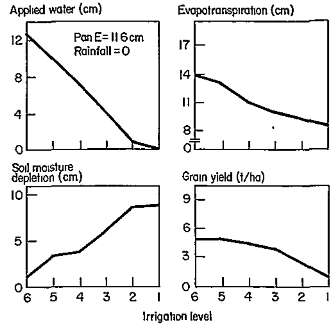
The line source sprinkler system proved useful in assessing the effects of different moisture levels on rices with various plant types. Although main moisture effect could not be tested statistically because of systematic arrangement of water treatments, interactions between several variables could be evaluated.

Line source sprinkler experiments at reproductive stage. *Water stress at flowering stage.* The 1979 annual report indicated the great sensitivity of the flowering stage of rice to water stress. That report also gave an initial evaluation of the line source sprinkler (LSS) system as a drought-screening method. During the 1980 dry season the use of the LSS system at the flowering stage was investigated.

The study was initiated with particular attention to quantifying the soil, plant, and atmospheric conditions during the stress period. The LSS was used to create a gradient of soil moisture just before flowering. The maximum water application (near the line) decreased progressively to a dry-farming condition (15 m from the line). Eight plot positions (8 = wettest, near the sprinkler; and 1 = driest, far from the sprinklers) were sampled across the gradient. Irrigation was sufficient in the wetter positions (8 and 7), and they are omitted in the following section.

The 15-day cumulative evapotranspiration (ET) values of 14 cm at irrigation level 6 and 13 cm at level 5 resulted in similar yield of 5 t/ha (Fig. 23). Those ET values were 20% and 15% more than pan evaporation, respectively. However, yield reductions of 8 to 81% (levels 4 to 1) were obtained when ET values were 6 to 27% less than pan evaporation, respectively, indicating sensitivity of the flowering phase to water stress. Figure 24 shows that grain yield is linearly related to evapotranspiration, and spikelet sterility strongly influenced grain yield when optimum ET requirement was not met.

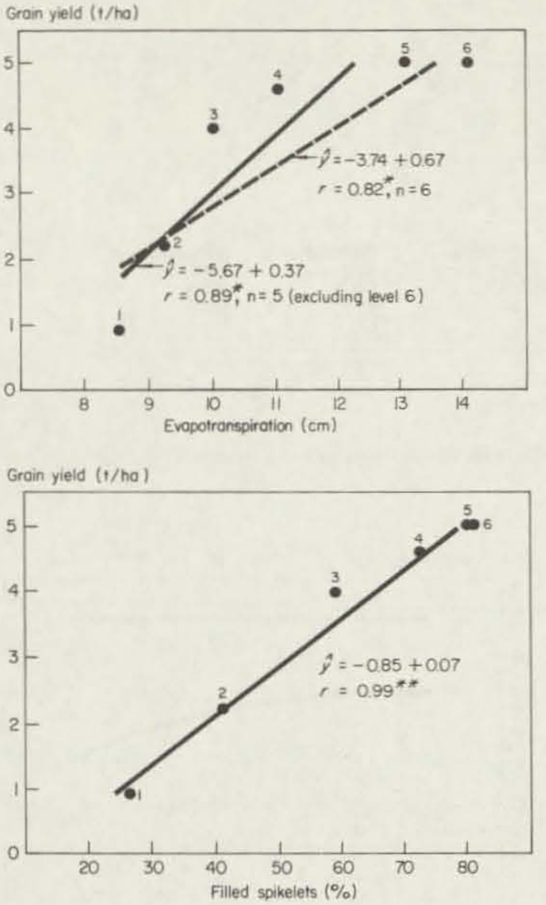
Flowering and other growth processes are directly controlled by plant water status, which is a result of both atmospheric evaporative demand and soil water stress. The midday leaf water potential under 6 irrigation levels decreased from -9 to -25 bars on 22 April (Fig. 25), a trend similar to that of ET and grain yield in Figure 23. Due to higher irradiance and vapor pressure deficit on 22 April,



23. Evapotranspiration (applied water plus depletion assuming negligible drainage and upward flow) and grain yield of IR36 under six irrigation levels. Pan E refers to total evaporation during the treatment period 8-23 April. IRRI, 1980 dry season.

leaf water potentials for levels 6 and 5 were slightly more negative than those of 9 April. However, for levels 4 to 1 increased differences in leaf water potential between the two dates is an indication of the intensity of water stress due to reduced capacity to rehydrate during the dark period when evaporative demand was low.

Root length density of IR36 decreased exponentially with depth (Fig. 26). Of the total root length density in the 75-cm soil profile, 70 to 80% was found in the upper 30-cm soil layer. Available soil water in the 90-cm profile is the water potential in the profile plus water applied. For levels 4 to 1, it is worth noting that 60 to 70% of the total water extraction occurred in the upper 30-cm soil layer. Evidently, as the surface layers dried, additional water uptake in the subsoil depended on the portion of the root system in that layer. As illustrated in level 1 (Fig. 27), depth and density could play a major role in further uptake that could reduce stress at a very sensitive growth stage. Further increase in root length density occurred between flowering and crop maturity. The increase in root density was greater in levels 3 to 1 where the plants experienced a relatively higher degree of stress. Since stress-induced sterility reduced the productivity of the spikelets, assimilates could have been rechanneled for further root growth. For levels 6



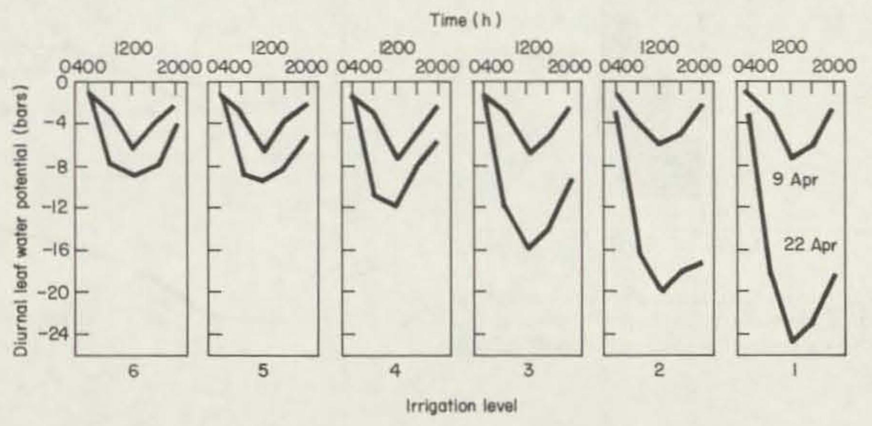
24. Relationship between grain yield and evapotranspiration, and grain yield and sterility of IR36. IRRI, 1980.

and 5, the green leaf area index dropped from 5 to 3 because of senescence; the reduction from 5 to 1.2 (Fig. 28) was due to the confounding effect of water stress. The drop in green leaf area index paralleled the decline in leaf water potential in Figure 25.

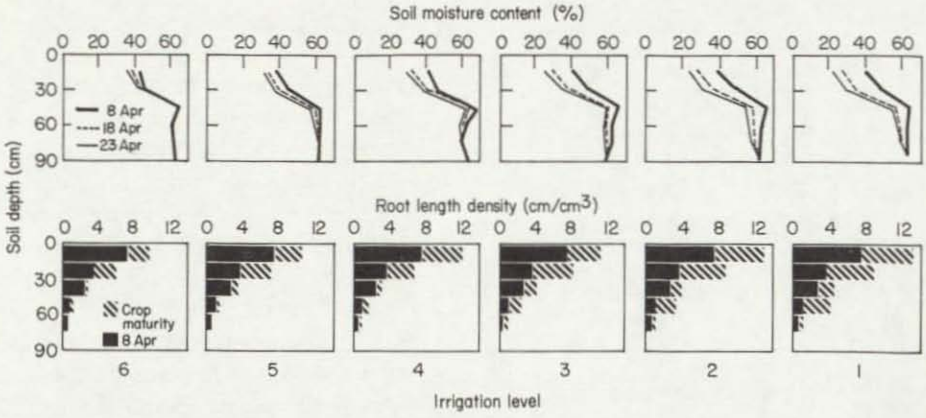
Effect of water stress on panicle emergence. Water stress of varying intensity was created across six plots using a continuously variable water application method (line source sprinkler) at the heading and flowering stages of IR36 rice. The objective was to investigate the effect of water stress on panicle exsertion rate and final exsertion percentage of the panicles, and the relation of those parameters to spikelet sterility and yield.

Water stress reduced the rate of panicle exsertion; however, the reduction was not significant because the water stress experienced by the plants on 14 April or during the early flowering period was slight (−5 to −7 bars) (Fig. 29). Reduction of panicle growth was significant when moderate water stress (-7 to -12 bars) occurred at the maximum flowering period (17 Apr). Figure 29 shows that the effect of water stress on panicle exsertion rate was influenced by the growth stage of the plants. Late panicles were observed to have lower growth rates even at stress levels of -5 to -7 bars. Panicle exsertion was also inhibited, but not significantly, at late flowering stage (22 Apr).

The rate of panicle exsertion affected the degree of final exsertion, which, in turn, contributed to spikelet sterility. Panicles with extremely low exser-



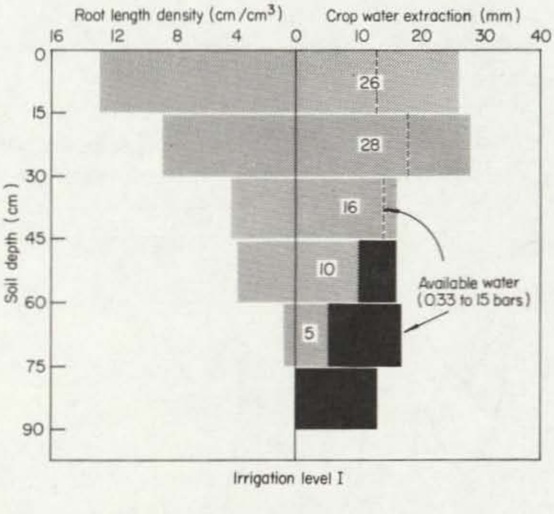
25. Trends in diurnal leaf water potential of IR36 under the highest soil moisture content at level 6 to the lowest at level 1. IRRI, 1980.



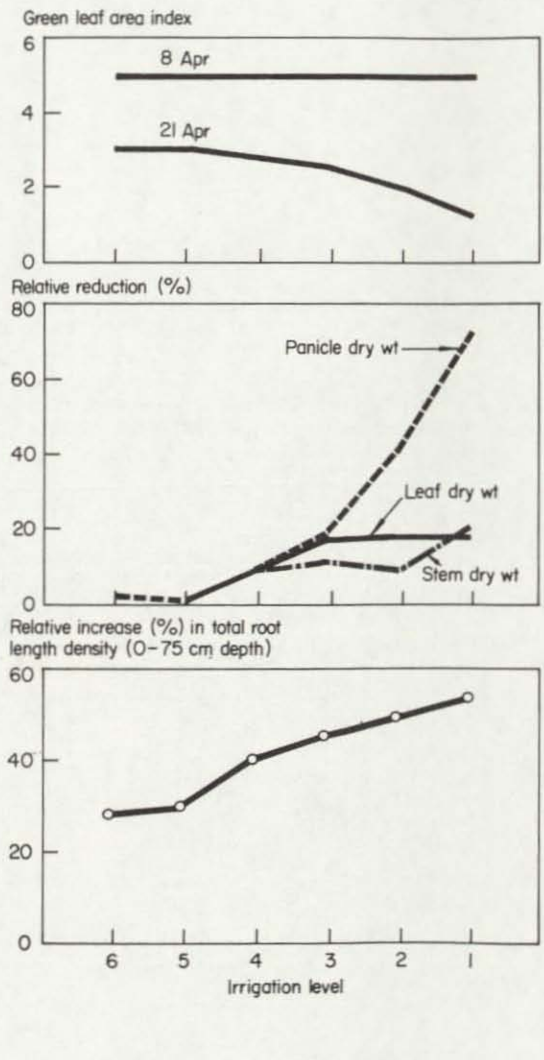
26. Volumetric moisture content and root length density of IR36 at various depths under 6 irrigation levels. IRRI, 1980.

tion rates were the least exserted at maturity (Fig. 30).

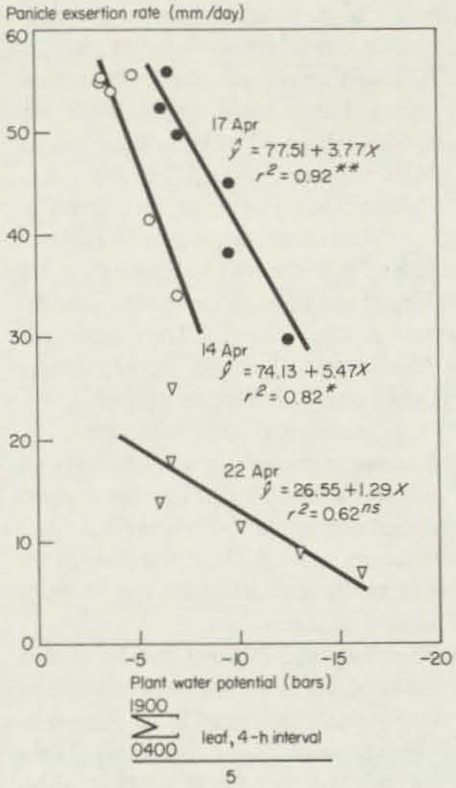
This study has shown that one potential cause of spikelet sterility in rice is poor panicle exsertion. Water stress of varying intensity affected the sterility of rice by causing poor panicle exsertion. Poorly exserted panicles were associated with as high as



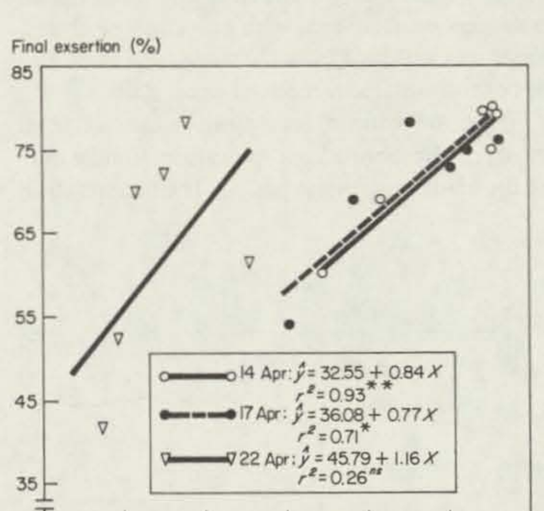
27. Root length at harvest, cumulative water extraction beyond the range of available water in the upper 45 cm soil, and extraction within the range of available water in the subsoil. IRRI, 1980.



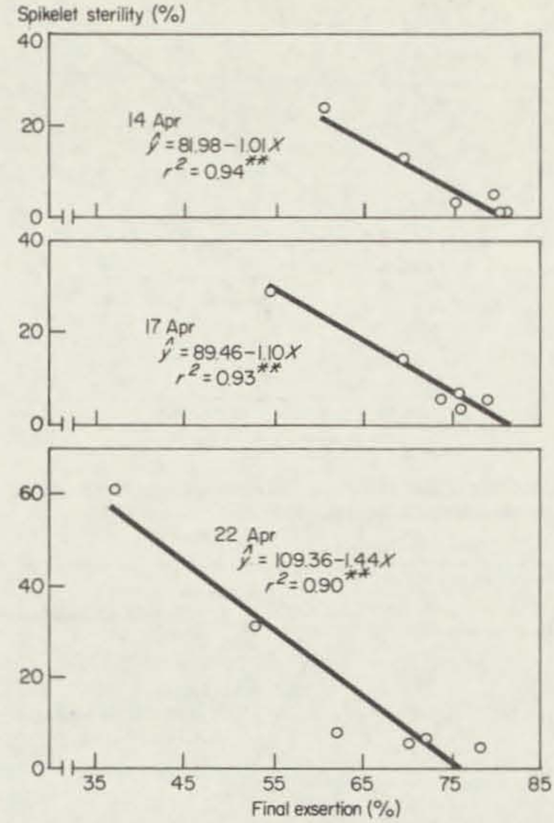
28. Green leaf area index, percentage of reduction in plant parts, and percentage of increase in root length density under 6 irrigation levels for IR36. IRRI, 1980.



29. The effect of water stress on panicle exsertion rate in IR36. IRRI, 1980 dry season.



30. The relationship between exsertion rate and degree of final exsertion of the panicle in IR36. IRRI, 1980 dry season.

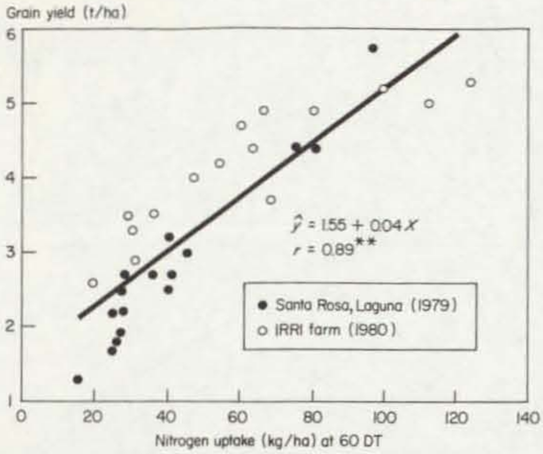


31. Percentage of spikelet sterility attributed to poor panicle exsertion in IR36. IRRI, 1980 dry season.

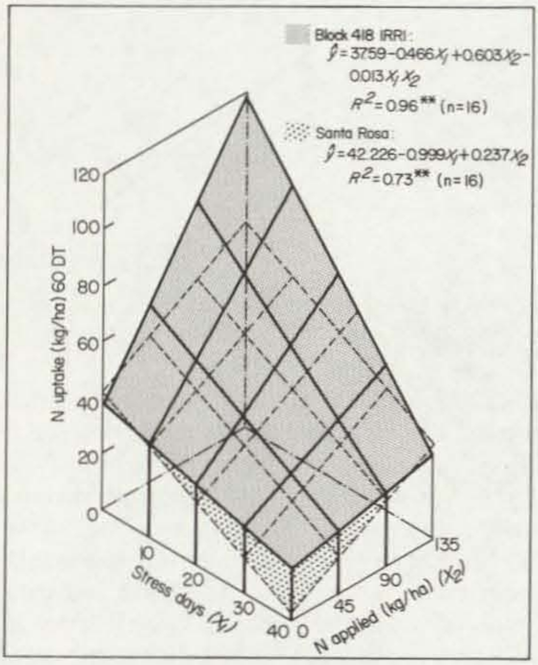
20%, 30%, and 60% sterility when stress occurred at early, maximum, and late flowering stages (Fig. 31).

Effect of water stress on nitrogen uptake and yield. A field trial similar to that reported in the 1979 annual report estimated the nitrogen uptake and yield of rice in simulated rainfed wetlands. Fertilizer rates (0, 45, 90, and 135 kg N/ha) as in 1979 were applied, but water-deficit (stress days) treatments were reduced by 5 days in each water regime (scheduled at 0, 10, 20, and 40 stress days) because of rains in March 1980. Data points were therefore fitted into a regression to estimate the effects on yield and nitrogen uptake based on 0, 5, 15, and 35 actual stress days. As in the previous experiment at Santa Rosa, Laguna, seepage from flooded treatments to stress plots were minimized by plastic sheets buried 40 cm deep.

Regression analysis on nitrogen uptake and yield is shown in Figure 32. In general, the yield



32. Grain yield as a function of nitrogen uptake. DT = days after transplanting. Philippines, 1980.



33. Multiple linear regression showing the combined effects of stress days and applied nitrogen on nitrogen uptake of rice. DT = days after transplanting. Philippines, 1980.

was higher at IRRI (1980) than at the Santa Rosa site (1979). For both sites, however, use of data points in the regression showed that yield was greatly influenced by the nitrogen uptake of rice.

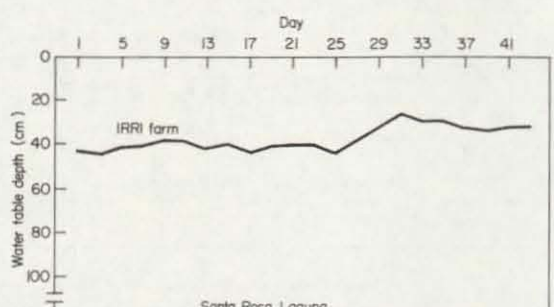
Figure 33 shows the multiple linear regression on nitrogen uptake as a function of water stress and nitrogen applied in the two sites and years.

The response of nitrogen uptake to the combined effects of water stress and applied nitrogen was linear. Nitrogen uptake was affected by increasing water stress, but a more severe result was observed at Santa Rosa. The magnitude of the stress at IRRI was very much less than that observed in Santa Rosa. The water table depth for the duration of stress treatments in both places is shown in Figure 34. In the IRRI wetland field, the water table depth and upward movement of water from it are within the root zone. Thus, even after the crop experienced 35 stress days, nitrogen uptake and yield were still relatively high.

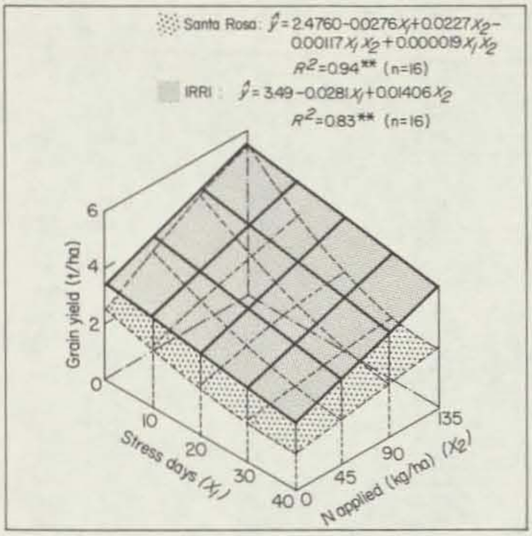
Multiple regression on the effect of stress days and applied nitrogen on yield is shown in Figure 35. Grain yield was affected by the number of stress days and applied nitrogen at both sites. But water table depth at a site can significantly influence the yield response to the combined effects of water stress and applied nitrogen.

Transpiration rate and nutrient uptake of rice. A greenhouse experiment determined the effect of water stress on nutrient uptake of IR36. Pregerminated seeds were sown in plastic containers (32 cm × 24 cm × 10 cm). Nitrogen [$(NH_4)_2(SO_4)$], phosphorus (solophos), and potassium (muriate of potash) were added at a rate of 200:30:30/1-ha furrow slice. Twenty-eight days after seeding, all containers were covered with polyethylene sheets. Water was withheld from the stress treatment, but the control treatment received water daily.

Figure 36 illustrates transpiration rate and total nitrogen, phosphorus, and potassium uptake during the 18-day treatment period. The transpiration



34. Water table depth throughout the stress period at 2 Philippine sites, 1980.



35. Multiple regression showing the combined effects of stress days and applied nitrogen on grain yield at 2 Philippine sites, 1980.

rate of water-stressed plants was significantly lower (by as much as 60%) than that of the control plants on the 11th day. The stressed plants accumulated nitrogen, phosphorus, and potassium more slowly than the well-watered plants. Toward the end of the stress period, uptake of the nutrients was only about 60 to 70% of that by the control plants.

As the soil dries, nutrient availability diminishes. Transpiration and nutrient availability are factors that could affect nutrient uptake at low soil moisture content and, consequently, the response to drought.

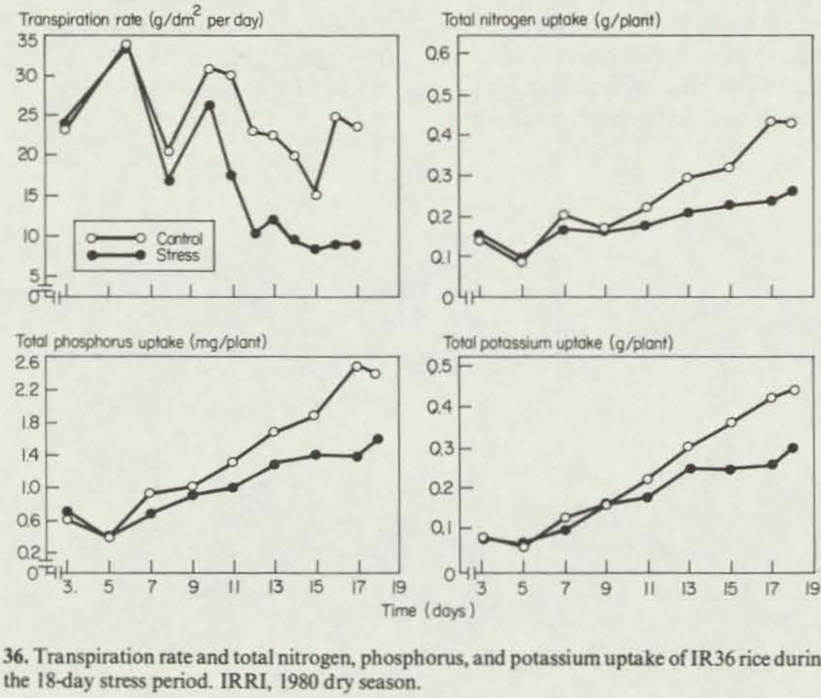
IRRI-INDIA COLLABORATIVE OBSERVATIONAL TRIAL

Plant Breeding and Agronomy Departments

A collaborative drought resistance observational trial with India was planted during the 1980 wet season. Twenty-two entries were grown in a soil of low fertility and good drainage at IRRI.

Table 24 shows the yield and agronomic traits of the 22 entries. Correlation coefficients showed a positive significant correlation (r = 0.48) between plant height and yield, although the value was rather low. Panicle number was not significantly correlated with yield (r = –0.33 ns). The highest yielders did not necessarily have the highest panicle number per unit area.

A significant negative correlation between number of days to full head and yield (r = -0.52) and between percentage of spikelet sterility and yield (r



36. Transpiration rate and total nitrogen, phosphorus, and potassium uptake of IR36 rice during the 18-day stress period. IRRI, 1980 dry season.

Table 24. Yield and other agronomic traits of 22 varieties and lines grown at IRRI, 1980 wet season.

Variety or line	Plant ht (cm)	Panicles (no./m²)	Days to heading	Spikelet sterility (%)	100-grain wt (g)	Yield[a] (t/ha)
CRM-13-3241	56.5	280	55	37.5	1.6	1.16 bc
CR-214-J5-52-102	53.2	259	82	41.9	1.6	0.44 ef
D6-2-2	120.2	154	74	29.4	2.8	0.98 cd
Bala	72.6	184	63	21.4	1.7	1.16 bc
CR222 MW 10	64.7	214	78	40.9	2.2	0.62 def
Annapurna	64.7	270	71	58.4	2.0	0.49 ef
CR245-1	105.9	202	60	25.2	1.9	1.14 bc
OR165-28-14-B	66.3	175	69	41.5	1.9	0.60 def
IAC25	104.6	94	70	26.6	2.7	0.62 def
KS109	67.4	182	70	46.5	2.4	0.51 ef
IR12787-3	84.3	161	94	45.9	2.0	0.81 cde
MR262	66.9	231	77	50.5	1.8	0.34 f
N22	106.9	211	61	10.5	1.8	1.66 a
Kalakari	104.2	141	63	12.4	2.9	1.87 a
Brown Gora	116.0	158	68	10.7	2.7	1.49 ab
OR165-18-1	70.2	187	61	41.4	2.0	0.61 def
Black Gora	119.5	146	66	6.6	2.9	1.70 a
IR10001-1-2	105.1	163	95	18.6	1.9	0.70 def
CO 13	121.0	170	83	47.6	2.0	0.52 ef
IR6115-1-1-1	55.3	258	85	48.1	1.9	0.64 def
CR143-2-2	81.3	146	68	16.6	2.1	1.57 a
OR165-85-12	66.2	202	65	29.5	1.8	1.09 c

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

= -0.86**) was observed.

The crop experienced a series of moisture stress from 18 September to 17 October, the longest of which was about 9 days. Occasional rains fell during this period. The crop was about 64 days from seeding at the start of stress. Some entries that headed during this period had high spikelet sterility.

Among the entries that did not show any sign of stress and had high spikelet fertility were Kalakari, Black Gora, N22, IAC25, Brown Gora, and Bala. They headed during the dry period despite the stress. Indian breeders reported earlier that those varieties had higher levels of drought resistance at reproductive growth stage. Their deep root system enabled them to use available soil moisture at deeper soil horizons.

No significant correlation was obtained between 100-grain weight and yield.

Kalakari, Black Gora, N22, and CR143-2-2 were the highest yielders with 1.6-1.9 t/ha. The lowest yield (0.3 t/ha) was from MR262 of India.

Genetic evaluation and utilization (GEU) program

Adverse soils tolerance

Soil Chemistry and Plant Breeding Departments

The main activities in 1980 were screening for soil toxicities and nutrient efficiency, breeding for salt and alkali tolerance, testing of promising rices in farmers' fields, and identification of breeding lines and multiple stress tolerance.

Table 1 summarizes the results of the 1980 screening tests. Most of the 3,211 rices that gave tolerant scores came from the salt tolerance hybridization program.

SALINITY

Soil Chemistry Department

Mass screening. Of the 8,462 rices screened, 3,068 were rated as tolerant. Outstanding among them were 17 from the world collection, IR46, IR52, IR54, IR4563-52-1 (a drought-tolerant line), and 18 hybrids, which had one of the salt-tolerant rices Pokkali, Nona Bokra, or IR2153-26-3 as a parent.

Yield trials. In a dry season field test of 28 rices on an artificial saline soil with an EC_e (electrical conductivity of the saturation extract) of 8.4 mS/cm, the yields ranged from 0.9 t/ha for IR1561-228-3 to 2.6 t/ha for IR13646-2, a progeny of Nona Bokra. Salt tolerance conferred a yield advantage of about 2 t/ha. IR46, IR5657-33-2, IR9860-56-1, and IR13426-19 yielded more than 2 t/ha. In the wet season the EC_e was 7.3 mS/cm and the yields ranged from 1.4 t/ha for IR48 to 3.1 t/ha for IR52.

Promising salt-tolerant rices were tested in farmers' fields representative of a wide range of soil, climatic, and hydrological conditions. The yields with salient environmental conditions are given in Table 2 and the mean yields in Table 3.

Four salt-tolerant hybrids gave yields exceeding 2.5 t/ha, averaged for the environmental conditions in 8 Philippine farmers' fields on coastal saline soils, in the wet and dry seasons.

Table 1. Summary of screening tests for adverse soil tolerance. IRRI, 1980.

	Varieties (no.)	
	Screened	Tolerant
Salinity	8462	3068
Alkalinity	2035	24
Peat soil	27	4
Acid sulfate soil	583	43
Aluminum and manganese toxicities	15	5
Phosphorus deficiency	670	39
Zinc deficiency	527	16
Iron deficiency	86	12

IRSATON at IRRI. Of 73 rices tested in the 1980 wet season on an artificial saline soil with an EC_e of 8 mS/cm, 19 were rated as tolerant. Among them were IR42, IR52, and five rices from the salt tolerance hybridization program.

Varietal reactions to increasing salt concentration. Greenhouse and field experiments in 1980 studied the effects of increasing salt concentration on the growth, yield, and mineral nutrition of four rices.

Beyond a threshold salt concentration, growth and yield decreased according to the equation

$$Y = 100 - B\,(EC_e - A)$$

where Y = relative yield, EC_e = electrical conductivity of the saturation extract, A = threshold salinity in mS/cm, and B = percentage of yield decrease per unit of EC_e beyond A. The values of A and B in the greenhouse experiment follow:

Rice	*A (mS/cm)*	*B (%)*
IR28	2.5	13.2
IR34	2.5	11.3
IR42	5.0	8.1
IR9884-54	2.5	7.7

In the field experiment, A for all 4 varieties was 5.0 mS/cm and B values were 6.0, 6.1, 2.5, and 5.5 for IR28, IR34, IR42, and IR9884-54-3.

Yield reduction caused by increasing salt concentration was least in IR42 (Table 4). The yield decrease with increasing salinity was in the order IR28 > IR34 > IR9884-54-3 > IR42. IR42 gave the highest yield at all salt concentrations.

The four varieties differed markedly in their capacity to absorb nutrients under salt stress. Increasing the salt concentration depressed the concentrations of potassium and calcium in the straw and the K-Na and K-Ca ratios. IR42, the most tolerant variety, had a higher K-Na ratio than any other variety. Increasing salinity increased the concentration of sodium and chloride in the plants, but the effect was least in IR42. Apparently IR42 has a salt-exclusion mechanism.

ALKALINITY

Soil Chemistry Department

Mass screening. Sixteen out of 1,962 rices screened in the greenhouse were found to have alkali toler-

Table 2 Summary of tests of 12 varieties and lines on coastal saline soils in farmers' fields in the Philippines, 1980 dry and wet seasons

Site	Salt source	EC_e[a] (mS/cm)	Soil pH	Soil organic content (%)	Other soil problems	Yield range (t/ha)	Best yielders	Remarks
					Dry season			
Lubao, Pampanga	Creek	14	6.9	1 7	—	—	—	Intrusion of strongly saline water killed the plants
Mexico, Pampanga	River	11.7	7.0	0.7	Zinc deficiency	1.0-4.3	IR10168-3	Plants were harvested before high salinity.
Samal, Bataan	Creek	4 3	6.5	1 5	—	0.9-4.4	IR50 IR9884-54 IR10206-29	Salinity was low
Taal, Batangas	River	4.6	7 1	1.4	Zinc deficiency Boron toxicity	—	—	Frequent deep flooding.
Sinacaban Misamis Occidental	Seepage	7 6	4.1	4.0	Iron toxicity	1.6-3 9	IR4630-22 IR5657-33 IR4432-28-5	Rains depressed salinity but tungro reduced yields
					Wet season			
Cebu, Cebu	Creek		7.4	3 9	Zinc deficiency Boron toxicity	4 5-6.6	IR9884-54 IR42	Low salinity.
Minalin, Pampanga	Creek	9.2	5 8	1 6	Zinc deficiency	0 8-3.6	IR9884-54	Rains depressed salinity
Bani, Pangasinan	Creek	8 0	6 1	0.8	—	1.1-2.6	IR5657-33 IR52, IR42, IR9884-54	Drought depressed growth.

[a]Electrical conductivity of the saturation extract

Table 3. Summary of 1980 yield trials on Philippine coastal saline soils.

Variety or line	Trials (no.)	Yield (t/ha)	
		Range	$\bar{X}$
IR36	5	0 9-2 2	1 7
IR50	3	1 8-4.4	2.9
IR4432-28	5	1.6-3 4	2.5
IR4595-4	5	0.5-1.6	1 1
IR4630-22	4	1 4-3.9	2.1
IR5657-33	4	2.0-3 7	2 5
IR9884-54	3	2.1-4.2	3 3
IR10167-87	4	1 0-3.2	2.6
IR10206-29	5	1 8-4.0	2.4
IR2058-78	4	1 6-2 4	1 9

ance. IR36 and two hybrids with alkali-tolerant Pokkali as one parent were among them.

Yield trials. Of 21 alkali-tolerant rices tested on an artificial sodic soil (pH 8.6, SAR 20), IR36, IR38, IR52, and IR9715-7-2 had Standard Evaluation System for Rice (SES) scores of less than 3.5 and yields higher than 3 t/ha.

IRSATON at IRRI. IR46 and 4 IR lines were among the 8 rices that gave tolerant scores in a test of 73 rices on an artificial sodic soil.

ACID SULFATE SOIL CONDITIONS

Soil Chemistry Department

The main nutritional disorder of wetland rice on acid sulfate soils is iron toxicity. Rices were scored

Table 4. Effect of 5 salt concentrations on the yield of rices at IRRI, 1980 dry season.

Salt added (%)	EC_e[a] (mS/cm)	Grain yield[b] (t/ha)			
		IR28	IR34	IR42	IR9884-54-3
0	0 8	4 7 ab	5 3 a	6 4 ab	5.7 b
0.1	4.9	4 9 a	5 4 a	6 6 a	6.1 a
0 2	7.7	4 3 b	4.5 b	6.1 bc	4.9 c
0.3	9 7	3 7 c	3 9 c	5.7 c	4 7 cd
0.4	11.0	3.1 d	3 4 d	5.7 c	4.3 d

[a]Electrical conductivity in the saturation extract, 1 wk after salt addition. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

in greenhouse and field mass-screening tests, and the performance of promising rices was observed in field yield trials on a Sulfaquept with an aerobic pH of 3.5.

Greenhouse screening. A total of 320 rices were screened in the greenhouse. They included elite lines and some hybrids from Mahsuri (an iron-toxicity tolerant variety) and IR5657-33-2 (a salt-tolerant line). Fifty were rated as tolerant.

Field screening. Of 190 lines tested in the field, 25 were tolerant. Iron toxicity in the wet season was severe, and of 73 rices tested only IR29385-1-1, IR29385-1-12, and IR29385-1-13 gave tolerant scores.

Yield trials. Yield trials confirmed that plant growth was poorer in the wet season than in the dry (Table 5) and that tolerant rices gave higher yields than the sensitive ones at two sites with acid sulfate soil (Table 6). The marked yield reduction in the wet season was due to severe iron toxicity induced by strong soil acidification during the dry spell preceding the wet season planting.

Tolerant IR46, IR4683-54-2, and IR1349-43-2 yielded more than 6 t/ha in the dry season and more than 3.3 t/ha in the wet season without lime, the usual amendment. Tolerance for iron toxicity conferred a yield advantage of about 2 t/ha over varieties that lacked the trait.

Table 5. Influence of season on the performance of 6 rices on an acid sulfate soil, Malinao, Albay, Philippines, 1980.

Designation	Grain yield (t/ha)	
	Dry season	Wet season
IR36	5.2	2.5
IR42	5.9	3.6
IR44	6.3	2.9
IR46	6.4	3 3
IR52	5.4	3.6
IR4683-54-2	6.7	3.6
Mean	6.0	3.2

Table 6. Performance of 15 rices at 2 sites on an acid sulfate soil, Malinao, Albay, Philippines, 1980 wet season.

Designation	Grain yield[a] (t/ha)	
	Site 1	Site 2
IR54	3.9 a	2 8 abc
IR48	3.6 ab	2.7 abcd
IR4683-54	3.6 ab	3.1 ab
IR42	3.6 ab	3.2 a
IR52	3.6 ab	2 4 abcd
IR13149-43	3.6 ab	2 7 abcd
IR2797-105-2	3 4 ab	2.0 cde
IR46	3.3 abc	2.2 abcde
IR44	2.9 abcd	2.9 abc
IR20	2 8 abcd	1.8 de
IR36	2.5 bcde	2.1 bcde
IR50	2.4 bcde	2.0 cde
IR13168-143-1	2.0 cde	1.5 e
IR8	1.8 de	0 f
IR9129-136-2	1.4 e	1.5 e

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

Varietal reactions to soil amendments. To ascertain whether varietal tolerance could be a partial substitute for soil amendments, the effects of lime (5 t/ha) and manganese dioxide (100 kg/ha) on iron toxicity symptoms and yield of IR26 and IR43 were studied in a replicated factorial experiment on an acid sulfate soil at Malinao, Albay, in the 1980 dry season.

On the basis of iron toxicity symptoms at 4 and 8 weeks after transplanting, the best treatment was IR43 (a moderately tolerant variety) with lime and manganese dioxide; the poorest was IR26 (a susceptible variety) without soil amendment (Table 7). On the basis of grain yield, the best treatment had IR43 and manganese dioxide with or without lime. The poorest had IR26 without soil amendment. IR43 showed a response of 2.2 t/ha to manganese dioxide alone. IR26 gave a response of 1.2 t/ha to lime. IR43 produced 6.2 t/ha with only manganese dioxide, but IR26 with both soil amendments produced only 4.8 t/ha.

Varietal tolerance may be a substitute for lime on acid sulfate soils.

PEAT SOIL PROBLEMS

Soil Chemistry Department

Rice on peat soils shows zinc deficiency symptoms. On such a soil (pH 5.4, O.M. 46%, available Zn 0.3 mg/kg soil) at Famy, Laguna, Philippines, 27 rices that were tested in a replicated experiment in the 1980 dry season differed in performance with and without zinc in the presence of N-P-K fertilizer. IR28, a moderately susceptible variety, yielded 0.9 t/ha; IR34 and IR8192-31-2 (both zinc-deficiency tolerant) yielded 2.6 and 2.4 t/ha without zinc.

If grain yield in the absence of zinc stress (i.e. in the presence of applied zinc) is a criterion of tolerance for the peat soil conditions of the experimen-

Table 7. Effects of lime and manganese dioxide on the severity of iron toxicity symptoms 4 and 8 weeks after transplanting, and on grain yield of 2 rice varieties on an acid sulfate soil. Malinao, Albay, Philippines, 1980 dry season.[a]

Treatment			Iron toxicity score[b]		Yield (t/ha)
Lime	Manganese dioxide	Variety	4 wk	8 wk	
No	No	IR26	5 8 d	6.0 a	3 6 d
No	Yes	IR26	4 8 cd	5 2 ab	3.9 d
No	No	IR43	4.8 cd	5.5 ab	4.0 cd
No	Yes	IR43	3.5 ab	4.2 bc	6.2 a
Yes	No	IR26	5.2 cd	5.8 a	4.3 cd
Yes	Yes	IR26	4.2 bc	4.8 ab	4 8 bc
Yes	No	IR43	3.5 ab	4 2 bc	5.3 b
Yes	Yes	IR43	3.0 a	4.0 c	6.2 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Scored by the 1980 Standard Evaluation System for Rice.

tal site, then IR42 and IR8192-31-2, each with a yield of 3 t/ha, may be considered the most tolerant of the 27 varieties tested.

In a similar test of 10 varieties on an organic soil (pH 5.2, O.M. 20.6%, available Zn 0.2 mg/kg) at Morong, Rizal, 8 responded positively to added zinc, 4 of them significantly. The yields of IR8192-31-2 (2.9 t/ha) and IR34 (2.5 t/ha) without zinc, confirmed their tolerance for zinc deficiency on peat soils. In the presence of zinc, the highest yielders — IR54 with 3.4 t/ha and IR8192-31-2 with 3.1 t/ha — showed their tolerance for excess organic matter.

The zinc-efficient rices IR34, IR42, IR54, IR5983-13-1, and IR8192-31-2 performed best on peat soils. They had a yield advantage of 1.5 to 2.0 t/ha over zinc-sensitive modern varieties.

BORON TOXICITY

Soil Chemistry Department

Of 25 rices tested on a boron-toxic soil in the greenhouse, the following were found tolerant on the basis of symptoms and grain yield: IR5716-18-1, IR9129-209-2, IR8608-189-2, IR9764-45-2, BR51-282-8.

In solution culture IR8, IR20, IR26, IR42, and IR46 showed toxicity symptoms at 2.5 mg boron/liter in the medium, but only IR36 and IR46 suffered a significant yield reduction.

On a boron-toxic soil in the 1980 dry season, IR50 scored 2.9 by the 1980 Standard Evaluation System for Rice and yielded 6.1 t/ha. IR54 scored 4.5 and yielded 5.6 t/ha.

ZINC EFFICIENCY

Soil Chemistry Department

Mass screening. Of 527 rices tested in 1980 on a zinc-deficient soil (pH 7.0, organic C 4.9%, available Zn 0.1 mg/kg soil) in a farmer's field, 16 had tolerant scores. Among them were IR34 and IR54.

Yield trials. Selected rices were grown to maturity with and without zinc in a replicated experiment in the field used for the mass screening. Among the IR varieties, IR54 gave the highest yield: 4.5 t/ha with zinc and 4.4 t/ha without zinc. IR5 gave the lowest yield (2.3 t/ha) without zinc and the highest response to zinc (1.4 t/ha). IR8192-31-2, a tolerant line, yielded 4.4 t/ha without zinc, but IR5983-13-1, a sensitive line, yielded 2.3 t/ha. The wet season yield trial was damaged by floods, insects, and virus diseases. Despite that, IR54 and IR8192-31-2 yielded 2.6 and 2.7 t/ha without zinc, compared with 1.8 t/ha for IR5983-13-1.

Varieties with tolerance for zinc deficiency yielded 1 to 1.5 t/ha more than varieties that lack it. Tolerant IR34 maintained its superiority to sensitive IR26 in different soil and weather conditions (Table 8).

PHOSPHORUS EFFICIENCY

Soil Chemistry Department

Varietal differences in phosphorus efficiency were studied by mass screening in the greenhouse and yield trials with and without phosphate fertilizer on a phosphorus-deficient Tropaquult.

Mass screening. Of the 570 rices tested in culture

Table 8. Performance of sensitive IR26 and tolerant IR34 on zinc-deficient soils at 4 Philippine sites[a] in 2 seasons, 1980.

Designation	Grain yield (t/ha)						
	Dry season			Wet season			Mean
	Bay	Gen. Santos	Morong	Bay	Gen. Santos	Famy	
IR26	3.1	0.8	2.0	2 4	0.0	2 0	1.72
IR34	4.3	2.1	2.5	2 0	2 2	2 6	2.62

[a]Soil properties:

Site	pH	Organic carbon (%)	Available zinc (mg/kg)
Bay	7.0	4.9	0.1
Gen. Santos	7.9	3 8	0.1
Morong	5.2	11.8	0.2
Famy	5.4	26.4	0.3

solution, 34 were rated phosphorus efficient. Nine were 1980 elite lines.

Yield trials. Thirty-one rices were grown with and without 25 kg P/ha as single superphosphate in the 1980 dry and wet seasons.

In the dry season, IR40, IR48, IR52, IR54, and IR9129-209 gave yields exceeding 4 t/ha without phosphate fertilizer and produced a mean response of only 7.5% when phosphate was added. In the wet season, despite insect damage, tungro, and typhoons, IR40, IR52, IR54, and IR9129-209 maintained their superiority over the others with yields of 2.7 to 3.5 t/ha. IR6115-1-1 was the poorest performer in both seasons (Table 9).

Phosphorus-efficient modern rices enjoyed a yield advantage of about 1.5 t/ha over inefficient modern rices on the phosphorus-deficient Tropaquult.

Table 9. Performance of selected rices on a phosphorus-deficient Tropaquult at IRRI, in the 1980 dry and wet seasons.

Designation	Dry season		Wet season	
	Yield (t/ha)	Rank	Yield (t/ha)	Rank
IR54	4.7	1	2.7	6
IR52	4.6	2	3.1	2
IR48	4.2	3	2.1	22
IR40	4.1	4	2.8	5
IR9129-209-2	4.0	7	3.5	1
IR5	2 9	25	1.6	27
IR6115-1-1	2.2	31	1.5	31

AEROBIC SOIL CONDITIONS

Soil Chemistry Department

Dryland rice suffers from aluminum and manganese toxicities on acid soils and from iron deficiency on neutral and alkaline soils. To observe varietal reactions to those stresses, 15 selected rices were grown in a replicated yield trial on Luisiana clay (pH 4.9, organic C 2.5%, total N 0.22%), Maahas clay (pH 6.5, organic C 2.0%, total N 0.12%), and Maahas clay limed to a pH of 7.5. The soils were fertilized with 50 kg N/ha and 25 kg P/ha. The seeds were dry-sown at a seeding rate of 3 g/m in furrows 20 cm apart in 3-m × 4-m plots replicated 3 times. The plots were irrigated when

Table 10. Grain yield of 15 selected rices on 3 dryland soils. IRRI, 1980 dry season.

Designation	Grain yield[a] (t/ha)			
	Luisiana clay	Maahas clay	Limed Maahas clay	Mean
IR36	5.4 ab	4.1 a	1.6 abc	3.70
IR43	5.2 ab	3 4 abcd	3.3 abc	3.97
IR45	4 5 abcd	2.7 def	3 0 abc	3.40
IR52	5 5 a	3.9 ab	2.9 abc	4.10
IR1750-F5B-5	4.2 cde	3.0 cde	1.5 bc	2.90
IR1754-F5B-22	5 3 ab	3.6 cde	3.6 ab	4 70
IR2061-522-6	5.2 ab	3.0 cde	3 7 a	3.97
IR2061-628-6	4.7 abcd	3.3 bcd	2.6 abc	3.53
IR3839-1	4.7 abcd	3 3 bcd	1 5 bc	3.17
IR3880-29	4.8 abc	2.9 cde	2 2 abc	3.30
IR5179-2	3.5 e	3.0 cde	2.2 abc	2.90
IR8072-31	3.9 de	2.4 ef	1 3 c	2 53
IR8085-48	4.5 bcd	2.0 f	0.0 d	2.17
IET 1444	3.5 c	2 9 cde	3.0 abc	3.13
M1-48	3 5 c	2.4 ef	1.4 c	2.43
Mean	4.56	3 06	2 25	

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

necessary. The plants were scored visually on general appearance and foliar symptoms 8 and 12 weeks after sowing.

The main foliar symptoms were manganese toxicity on the strongly acid soil and iron deficiency on the limed Maahas clay. On Maahas clay no clear symptoms of a nutritional disorder were discernible.

Table 10 shows striking soil and varietal influence on grain yield. The mean yield decreased as soil pH increased. Within a soil there were marked varietal differences, and there were variety × soil interactions. IR43, IR52, IR1754-F5B-22, and IR2061-522-6 did uniformly well on all three soils. IR36 and IR8085-48 fared well on the strongly acid soil but poorly on the alkaline soil. The poorest performer was M1-48, apparently because of its poor plant type.

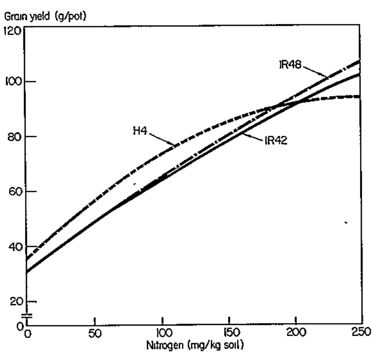
Several IR rices can yield more than 3 t/ha on irrigated acid dryland soils.

NITROGEN DEFICIENCY

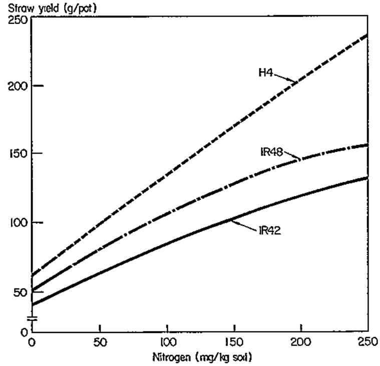
Soil Chemistry Department

Three rice varieties were grown on Maahas clay (pH 6.6, total N 0.16%) in 16-liter pots in the presence of 0, 50, 100, 150, 200, and 250 mg N/kg soil as urea, 25 mg P/kg soil as triple superphosphate, and 50 mg K/kg soil in the 1980 dry season.

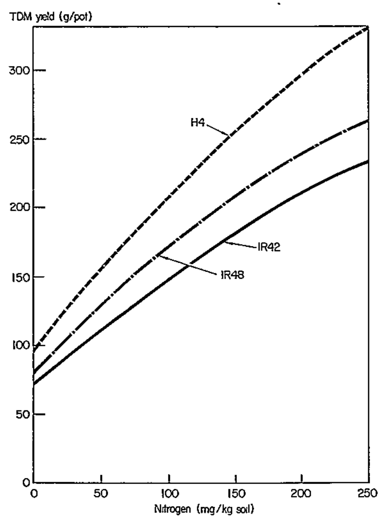
Figures 1, 2, and 3 indicate that H4 (a tall traditional variety) was the best producer of straw and total dry matter at all levels of nitrogen and the best grain producer from 0 to 150 mg N/kg soil. But the modern varieties IR42 and IR48, although not



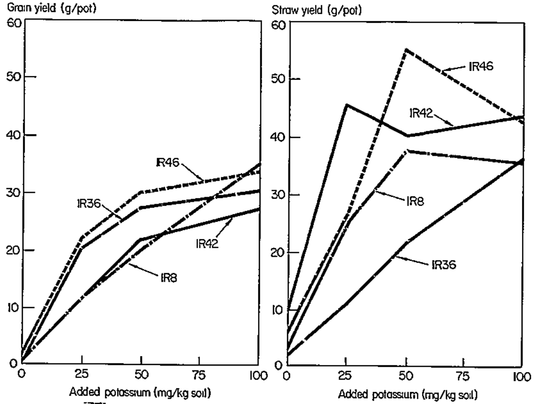
1. Grain yield as a function of nitrogen level IRRI, 1980 dry season.



2. Straw yield as a function of nitrogen level. IRRI, 1980 dry season



3. Total dry matter (TDM) yield as a function of nitrogen level. IRRI, 1980 dry season.



4. Effect of increasing potassium levels on a straw and grain yield of rice on a potassium-deficient soil. IRRI, 1980 wet season

high dry matter producers, yielded more grain than H4 at the highest level of nitrogen. IR48 produced more total dry matter than IR42 at all nitrogen levels.

Grain yield was a highly significant quadratic function of the nitrogen level for all three varieties, but the coefficients differed as seen below:

Variety	*Regression*	*R*
H4	$\hat{Y} = 35.3 + 0.4639X - .000918\,X^2$	1.00**
IR42	$\hat{Y} = 30.9 + 0.3407X - .000234\,X^2$	0.99**
IR48	$\hat{Y} = 30.7 + 0.3636X - .00025\,X^2$	1.00**

POTASSIUM EFFICIENCY

Soil Chemistry Department

Potassium deficiency is widespread in soils of the Philippine provinces of Zambales and Nueva Ecija, but on some soils rice does not respond to potassium fertilizer because of potassium fixation by vermiculite and beidellite. On such soils potassium-efficient rices may be useful.

To observe varietal reactions to potassium deficiency, 23 rices were grown in the greenhouse on a potassium-deficient soil (pH 7.0, exchangeable K 0.7 mmol/kg) in the presence of adequate amounts of nitrogen and phosphorus fertilizers. The plants were screened visually 2 weeks after transplanting. Of the 10 IRRI varieties tested, IR45, IR48, and IR54 showed no deficiency symptoms.

To study varietal differences in efficiency of potassium use, four modern rices were grown on a potassium-deficient soil (pH 6.0, exchangeable K 0.3 mmol/kg) in the presence of 0, 25, 100, and 150 mg K/kg of added potassium and with adequate nitrogen and phosphorus in the greenhouse.

Figure 4 shows that IR42 was a more efficient user of potassium for straw production at low potassium levels than IR36, but the opposite was true for grain production. Efficiency of potassium use for grain production was in the order IR46 > IR36 > IR42.

PRACTICAL IMPLICATIONS OF ADVERSE SOILS TOLERANCE IN RICE

Soil Chemistry Department

Mass screening and yield trials have revealed the existence of striking varietal differences in tolerance for soil toxicities and nutrient deficiencies. Some tolerant rices are hybrids generated for specific problems such as salinity and alkalinity. Most tolerant rices are IR varieties or IR lines that have good agronomic characteristics and pest resistance. Tolerance for an adverse soil condition confers on a cultivar a yield advantage of 1-2 t/ha. Some of the 1980 findings are summarized in Table 11. Use of modern soil-stress-tolerant varieties with

Table 11. Performance of some tolerant and sensitive IR varieties on unamended problem soils. 1980 dry and wet seasons.[a]

Problem	Tolerant		Sensitive		Difference
	Designation	Yield (t/ha)	Designation	Yield (t/ha)	
Salinity	IR42	3.3	IR26	1.4	1.9
Alkalinity	IR36	3 3	IR45	1.3	2.0
Acid sulfate soil	IR46, IR42	3.6	IR26	1.2	2 4
Peat soil	IR42	3.0	IR28	1.1	1.9
Phosphorus deficiency	IR54	3.7	IR36	2 6	1.1
Zinc deficiency	IR34	2.6	IR26	1.7	0.9

[a]Yield data are averages for soils and seasons.

good cultural practices can lead to yields of 3-4 t/ha on adverse soils without costly soil amendments.

BREEDING FOR ADVERSE SOILS TOLERANCE

Plant Breeding Department

Breeding for adverse soils tolerance continued with the objective of transferring tolerance to breeding lines with high yield potential and other desirable characteristics. Tolerance for salinity and-alkalinity received priority. Early-generation and advanced breeding lines were screened for tolerance for salinity (4,000) and alkalinity (1,200). Advanced-generation breeding lines were screened additionally for tolerance for iron toxicity, potassium deficiency, and zinc deficiency to identify those with multiple stress tolerance.

More than 3,000 entries were screened for multiple stress tolerance (Table 12).

More than 3,700 advanced-generation breeding lines ranging from F_4 through F_8 were grown; 54 lines were promoted for yield testing and more than 650 lines were advanced for further selection.

A number of crosses with diverse tolerance sources for different adverse soil stresses were made. The tolerance sources were hybridized with IR36 (male sterile) to permit the formation of intermating composite populations. Recurrent selection practiced on such composites grown under increasing levels of adverse soil stresses could favor the accumulation of genes for tolerance, leading eventually to enhanced levels of stress tolerance.

Table 12. Sources of breeding materials screened for tolerance for adverse soil stresses. IRRI, 1980.

Stresses	No. from each source[a]					Total (no.)
	HB	PN	RYT	OYT	GEU elite	
Salinity	—	3985	—	49	—	4034
Alkalinity	—	86	—	—	—	86
Iron toxicity	—	288	—	—	—	288
Phosphorus deficiency	—	83	—	—	—	83
Zinc deficiency	—	50	—	—	—	50
Salinity and zinc deficiency	—	—	—	789	—	789
Salinity and alkalinity	—	—	1200	—	—	1200
Salinity, alkalinity, and zinc deficiency	375	—	—	—	—	375
Salinity, iron toxicity, and phosphorus deficiency	—	183	—	—	—	183
Salinity, iron toxicity, phosphorus deficiency, and zinc deficiency	—	610	—	—	—	610
Salinity, alkalinity, iron toxicity, phosphorus deficiency, and zinc deficiency	—	—	—	—	163	163
Grand total	—	—	—	—	—	7861

[a]HB = hybridization block, PN = pedigree nurseries, RYT = replicated yield trial, OYT = observational yield trial, GEU = Genetic Evaluation and Utilization.

Genetic evaluation and utilization (GEU) program

Deepwater and flood tolerance

Plant Physiology, Agronomy, and Plant Breeding Departments and Thailand-IRRI Cooperative Deepwater Project

BREEDING PROGRAM AT IRRI

Plant Breeding and Plant Physiology Departments

More than 11,700 rainfed-wetland breeding lines and varieties were screened for submergence tolerance. Crosses numbering 740 were made with rainfed wetland rice and the F_1 planted during the wet season.

Plants selected in 1980 screening were multiplied and retested. From 1978-79 screening, 132 lines were selected for seed increase, grain yield, and plant type evaluation. The best of those lines will be added to the International Rice Deep Water Observational Nursery.

Among the varieties tested for submergence tolerance, 39 came from the tidal swamp rice collection of Ecuador. No variety had elongation ability, but Brasilero, Cafuringa 1, Chato Rayado, and Donato were highly tolerant of submergence.

Elongation ability of 4,271 lines and varieties was also tested and 92 lines from 1978-79 screening were selected for seed increase.

EFFECT OF WATER LEVELS ON TILLERING

Plant Physiology Department

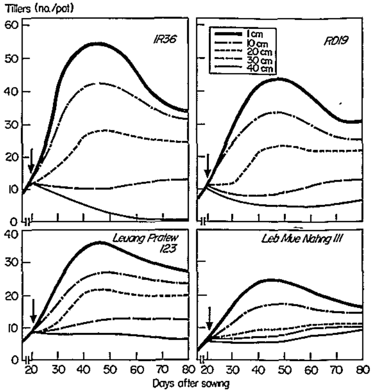
Tillering of 4 rice varieties with different plant types and elongation abilities was studied at 5 water levels 20, 30, and 40 days after sowing (DS).

Tiller number increased with time to a certain point, and then decreased. The maximum tillering stage of the 4 rice varieties was about 50 DS (Fig. 1). IR36 showed earliest tiller emergence and had the most tillers per pot. The faster rate of primary tiller production resulted in a faster rate of secondary and tertiary tiller production.

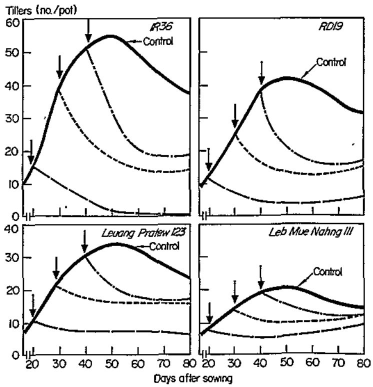
Deep water reduces tiller number but the modification of tiller production is not clearly understood. Deep water significantly reduced the tiller number of all varieties except Leb Mue Nahng 111 (LMN 111).

At 20 DS, generally considered to be the active tillering stage, deep water delayed the production of primary tillers, which, in turn, resulted in the production of less secondary tillers. At 10-40 cm depths, no tertiary tillers were produced and at 30-40 cm depths no secondary tillers were produced. Similar results were obtained when water treatment was started at 30 and 40 DS. For crop production a 10-cm water depth can be used as a critical water level for IR36; Leuang Pratew 123 (LPT 123), and RD19.

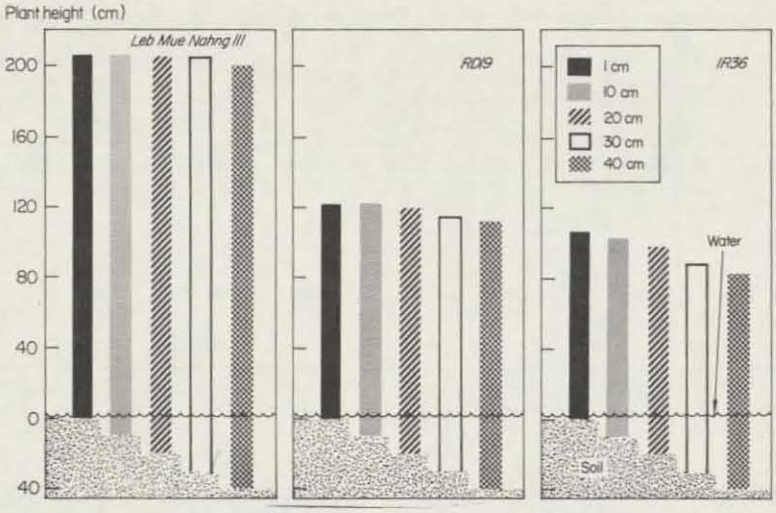
Seedling age and tiller reduction. Regardless of the variety, younger seedlings were more affected by deep water (40 cm) than older seedlings (Fig. 2).



1. Tiller number per pot at different growth stages of 4 rice varieties subjected to 5 water levels at 20 days after sowing. The arrow marks the start of the water treatment. IRRI greenhouse, 1980.



2. Tiller reduction of 4 rice varieties subjected to 40-cm water depth at 20, 30, and 40 days after sowing. The arrows mark the start of the water treatment. IRRI greenhouse, 1980.



3. Plant height of LMN 111, RD19, and IR36 at 80 days after sowing as affected by 5 water levels. IRRI greenhouse, 1980.

However, at 20-cm water depth, tiller number per pot 80 DS was similar in the plants that were treated at 20, 30, and 40 DS.

The advantage of using older seedlings is clear at the 40-cm water depth. IR36 had almost no surviving tillers when the 40-cm water treatment was started at 20 DS, but when treatment started at 40 DS the reduction was only 50%. The advantage of older plants at the time of increase in water depth was also apparent in RD19.

Occurrence of nodal tillers. Nodal tillering was observed in LMN 111 and RD19; there was some in IR36 but none in LPT 123. Nodal tillering was noted as early as 30 days after water treatment at 20, 30, and 40 cm water. However, deeper water seemed to produce more nodal tillers. The varieties with nodal tillering ability tended to have better nodal rooting ability.

Importance of internode elongation. Internode elongation was poor in IR36. IR36 plants were flowering at 80 DS and the elongated internodes were part of the flowering process.

LMN 111 had good elongation ability. In RD19 elongation occurred only if necessary for survival; in LMN 111, it occurred when the plants were above the water level.

The semidwarf characteristic of IR36 remained the same in medium-deep water (30-40 cm) when only plant height above the water level was considered (Fig. 3). Similarly, RD19 remained intermediate in plant height. LMN 111 was tall regardless of the water depth.

The treatments clearly showed that plants with intermediate height and elongation ability make a good plant type for medium-deep water.

SUBMERGENCE TOLERANCE

Plant Physiology and Plant Breeding Departments

In tests at different times, at different sites, and by different workers, FR13A, Kurkaruppan, and a few other traditional rice varieties exhibited a high degree of submergence tolerance, thus suggesting that the trait is gene controlled.

In a study to find optimum seedling age and submergence duration for genotypic differentiation of varieties, 9 treatment combinations involving seedling ages of 5, 7, and 9 days and also 5, 7, and 9 days of submergence were used in greenhouse tanks. The treatment combination of 7-day-old seedlings submerged for 7 days was found to be the most effective for maximizing genotypic variance (Table 1). However, the treatment combinations 7- or 9-day-old seedlings submerged for 9 days appeared to be more effective in differentiating entries showing above average tolerance, thus suggesting the necessity of longer submergence period in screening of pedigree lines in breeding programs. The study also confirmed earlier results with Kurkaruppan, FR13A, and Thavalu (Acc. 15314).

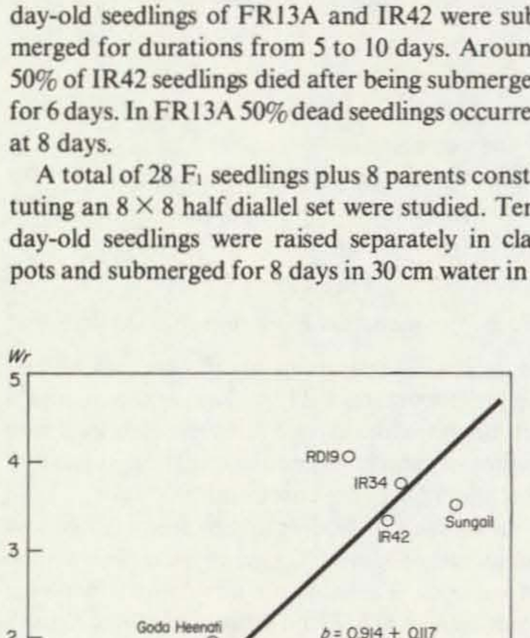
Table 1. Mean survival percentage in 8 rice varieties under 9 different seedling age-submergence duration combinations.[a] IRRI, 1980.

Variety	Survival[b] (%)									Overall mean
	5-5	5-7	5-9	7-5	7-7	7-9	9-5	9-7	9-9	
IR5	96.0 ab	83.5 ab	70.0 b	58.5 b	26.5 b	4.5 cd	87.5 ab	4.5 b	0.0 b	47.9
IR38	52.5 c	40.0 c	18.0 cd	46.0 b	4.5 bc	0.0 d	57.5 bc	4.5 b	0.0 b	24.8
IR42	79.5 bc	50.5 bc	4.5 d	8.5 c	0.0 c	3.0 cd	50.5 c	0.0 b	0.0 b	21.8
IR3464-75-1-1	77.0 bc	46.5 c	34.0 bc	46.0 b	12.5 bc	0.0 d	71.5 abc	17.0 b	0.0 b	33.9
RD19	64.0 c	54.5 bc	37.5 bc	54.5 b	17.0 bc	0.0 d	92.0 ab	8.5 b	0.0 b	36.9
Thavalu	100.0 a	100.0 a	100.0 a	96.0 a	73.0 a	20.0 bc	67.0 abc	58.5 a	0.0 b	68.3
FR13A	96.0 ab	75.5 abc	63.0 b	100.0 a	79.5 a	50.5 b	88.0 ab	59.0 a	9.0 b	68.9
Kurkaruppan	74.0 bc	91.0 a	63.0 b	100.0 a	92.0 a	87.5 a	95.5 a	78.5 a	54.5 a	81.8
Overall mean	79.9	67.7	48.8	63.7	38.0	21.0	76.0	29.0	8.0	48.0

[a]The first of 2 numbers joined by a hyphen indicates seedling age; the second is number of days of submergence. [b]Av of 2 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

High submergence tolerance in FR13A was further indicated from another study in which 10-day-old seedlings of FR13A and IR42 were submerged for durations from 5 to 10 days. Around 50% of IR42 seedlings died after being submerged for 6 days. In FR13A 50% dead seedlings occurred at 8 days.

A total of 28 F_1 seedlings plus 8 parents constituting an 8 × 8 half diallel set were studied. Ten-day-old seedlings were raised separately in clay pots and submerged for 8 days in 30 cm water in a greenhouse tank. The F_1 seedlings involving FR13A and Kurkaruppan showed submergence tolerance equal to or higher than that of their respective tolerant parents. That indicates tolerance was dominant over susceptibility.



4. Array variance (Vr) - covariance (Wr) graph in an 8 × 8 diallel cross for rice submergence tolerance (scored on a 1-9 scale).

The array of variance and covariance indicated the highest concentration of dominant alleles in FR13A, followed by FR43B and Kurkaruppan. RD19, IR34, and IR42 showed concentration of recessive alleles in that order (Fig. 4). The wide distance between dominant and recessive groups along the regression line suggests possible involvement of one or more major genes.

Both general combining ability and specific combining ability effects were highly significant. However, general combining ability (indicating additive gene action) was more important than specific combining ability (indicating nonadditive effects). This observation suggests high possibility of recovering recombinants having adequate level of submergence tolerance in the homozygous state.

Three components — b_1, b_2, and b_3 — of the nonadditive effects were highly significant. The significance of b_1, which indicates unidirectional dominance, showed that population dominance was manifested as a simple difference between the average of F_1 progenies and average of their parents. The presence of gene asymmetry (b_2) indicated that parents made different contributions to their progenies in respect of genes displaying dominance. The significance of b_3 showed that not all crosses had significant deviation from the midparent and indicated possible epistatic action.

Another study of the inheritance of submergence tolerance analyzed the segregation pattern and estimated the genetic parameters of the crosses involving FR13A, Kurkaruppan, Thavalu (Acc. 15314), Goda Heenati, IR36, and B2433b-Kn-10-1-1-1. Tests in the greenhouse submerged 10-day-old seedlings in a tank for 7 days at a depth of 30 cm above the soil. Water temperature was kept constant at 30° C and the light intensity 400 lux at the tray level.

Segregation analyses indicated that at least three dominant genes were involved in control of tolerance for submergence. Two had duplicate gene action, and the third was complementary to any of the first two. Estimation of the genetic parameters showed that additive and nonadditive gene effects were important in the inheritance of submergence tolerance. Dominance and nonallelic interactions were present in all the crosses analyzed, and nonallelic interactions were mostly of the duplicate type. Estimates of broad sense heritability were low to moderate, indicating that a large portion of the phenotypic variance was due to nongenetic effects.

Another study used the crosses Khao Dawk Mali/IR42 and Thavalu 15314/IR42. The mode of segregation for submergence tolerance at seedling stage of the F_2 population, based on percentage of survival of 10-day-old seedlings submerged for 7 days, indicated the dominant nature of submergence tolerance. Tolerance seems to have resulted from the complementary gene action of two independent loci.

EFFECT OF NITROGEN LEVEL AND SEEDLINGS PER HILL ON YIELD

Plant Physiology Department

To investigate the effect of basal nitrogen and number of seedlings per hill on tillering ability and yield performance of IR42 in medium-deep water, 20-day-old seedlings were transplanted with 0, 40, 80, and 120 kg N/ha at the rate of 2, 5, and 10 seedlings/hill. Water level at 30 days after transplanting (DT) was increased at the rate of 5 cm/day and was kept at 50 cm until full flowering.

An earlier study had shown that nitrogen fertilizer increased the grain yield of rice in deep water. The increase was associated with an increase in tiller number before water depth rose. The result was greater plant height and more panicles at harvest. In 1980, both basal nitrogen application and increased number of seedlings per hill resulted

Table 2. Grain yield of IR42 grown in medium-deep (50 cm) water as affected by 4 levels of nitrogen fertilizer and number of seedlings per hill. IRRI, 1980 wet season.

Nitrogen level (kg/ha)	Grain yield (t/ha)			
	2 seedlings/hill	5 seedlings/hill	10 seedlings/hill	Mean[a]
0	2.45	2.74	3.13	2.77 b
40	3.11	3.33	3.65	3.36 ab
80	3.67	3.82	3.96	3.81 a
120	3.83	3.96	3.91	3.90 a
Mean[a]	3.27 b	3.46 ab	3.66 a	

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

in more tillers per unit area and in taller plants, which produced more crop canopy above the water, higher leaf area index, more dry matter, and ultimately higher grain yield.

Generally, grain yields increased with increase in nitrogen level and increase in seedlings per hill (Table 2). The advantage of using more seedlings per hill was clear in plots without or with low levels of nitrogen fertilizer (40 kg N/ha), but not so clear in plots with high levels of nitrogen fertilizer. The results imply that the effect of basal nitrogen fertilizer application can be achieved, to a certain extent, by increasing the number of seedlings per hill.

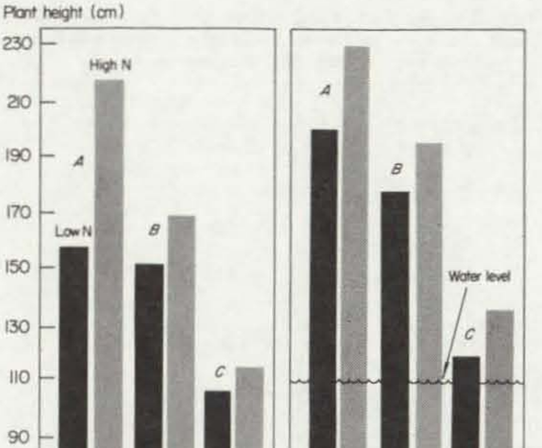
VARIETAL DIFFERENCE IN NITROGEN UPTAKE AND UTILIZATION

Plant Physiology Department

A study with 10 varieties of diverse plant types elucidated the phenomenon of nitrogen uptake and utilization in relation to water depths and nitrogen level. Nitrogen levels were 2 and 6 g ammonium sulfate in each pot with 4 kg soil. The water levels were 30 cm (medium-deep) and 110 cm (deep).

Three types of plant-height response were evident in the varieties tested (Fig. 5). Type A, which includes the traditional tall floating rice varieties such as Kalar Harsall, LMN 111, and Chenab Sel. 64-117, showed a marked difference in plant height with higher nitrogen level in both medium-deep and deep water. At flowering the plant parts above the water ranged from 120 to 130 cm in medium-deep water and 50 to 130 cm in deep water.

Type B response is shown by improved deepwater rice lines such as RD19, BKN6986-167, and



5. Variation in plant height due to low and high nitrogen levels at medium-deep (30 cm) and deep (110 cm) water levels. The plant types are the traditional tall Kalar Harsall (A), improved BKN6986-167 (B), and modern intermediate tall IR442-2-58 (C).

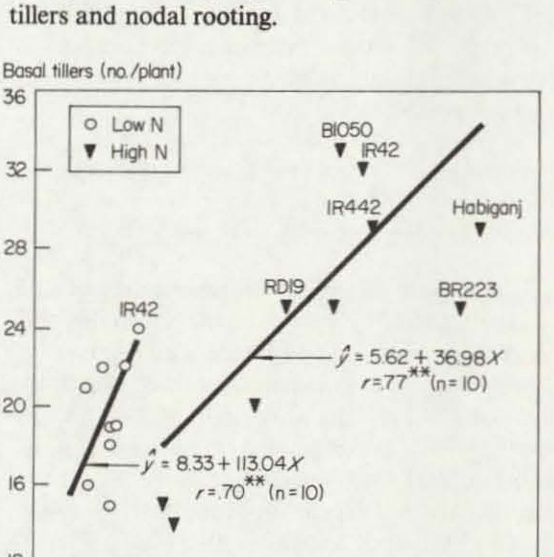
BR223-B-38. Plant height increased with increase in nitrogen level but not as much as in Type A.

Type C response was typified by IR442-2-58, B1050-Mr-18-2, and IR42. Those intermediate-height varieties have poor elongation ability. Addition of nitrogen gave only a small increase in plant height. The plant parts above the medium-deep water ranged from 70 to 110 cm, the optimum range under irrigated conditions. But in deep water, Type C was barely above water (10 cm), and additional nitrogen increased plant height but not sufficiently.

Varietal difference in nitrogen uptake and production of basal tillers before water treatment is seen in Figure 6. Varieties with high nitrogen uptake also had a high number of basal tillers. Improved varieties, such as IR42, IR442-2-58, B1050-Mr-18-2, BR223-B-38, and RD19, had high nitrogen uptake and high number of basal tillers at both nitrogen levels. The traditional varieties not only had poor ability to absorb nitrogen, they also had poor tillering ability. Habiganj Aman I, however, showed a different and better response in terms of tiller production and nitrogen uptake.

The results show that the basal tiller number in deepwater rice culture may be increased by increasing basal nitrogen and selecting varieties with not only high tillering ability but also ability to absorb nitrogen. Examples are B1050-Mr-18-2, IR42, RD19, BR223-B-38, and Habiganj Aman I. Such high tillering ability and nitrogen uptake were generally still apparent at flowering in medium-deep water, but the relationship changed in deep water — Kalar Harsall and Habiganj Aman I, which have greater elongation ability, gave the highest number of basal tillers. Although LMN 111 had relatively good elongation ability, it had the poorest tillering ability.

In medium-deep water, varieties planted with low nitrogen level did not produce any nodal tillers. But at high nitrogen, nodal tillers were produced in some entries. In deep water, Kalar Harsall, LMN 111, and IR442-2-58 had a good number (5 to 9) of nodal tillers, especially at high nitrogen (Table 3). Some entries either failed to produce any nodal tiller or produced few (1-3) even at high nitrogen. Generally high nitrogen increased nodal tillers and nodal rooting.



6. Relationship between nitrogen (N) uptake and basal tillers per plant of 10 entries at low and high N levels before water treatment. IRRI, 1980.

Table 3. Production of nodal tillers and nodal roots of 9 entries in deep water (110 cm) at low (2N) and high (6N) nitrogen levels at flowering. IRRI, 1979 wet season.

Entry	Nodal tillers (no.)		Nodal roots (no.)		Nodal root wt (g)	
	2N	6N	2N	6N	2N	6N
Kalar Harsall	0	5	98	119	3.6	14.4
Habiganj Aman I	1	1	68	68	5.6	5.7
Leb Mue Nahng III	0	9	157	210	5 2	20.4
Chenab Sel 64-117	2	2	25	53	0.9	2 2
B1050-Mr-18-2	0	0	61	100	0.4	1.9
BR223-B-38	0	1	98	102	2 3	9 5
RD19	0	3	87	118	1.1	6 3
BKN6986-167	1	3	107	156	0 8	5 3
IR442-2-58	0	5	10	17	0.1	0.5
Av	0.4	3.2	79	105	2 2	7.4

The traditional types tended to produce more nodal roots than the improved types. Among the improved types, BR223-B-38, RD19, and BKN6986-167 had good nodal rooting ability in terms of nodal root weight and number but high nitrogen failed to increase number or weight of nodal roots in either traditional (Habiganj Aman I), improved (B1050-Mr-18-2), or modern types (IR442-2-58). Hence, varietal difference in nodal rooting ability is vivid in all types of entries tested.

Varietal difference in nodal tillering ability was also distinct. Except in Kalar Harsall and LMN 111, higher nodal tillering did not lead to higher nodal rooting. Among the improved as well as modern entries, some had poor nodal tillering ability but high nodal rooting ability or vice versa. Wider screening for these two attributes may lead to the selection of varieties with higher nodal tillering and nodal rooting ability, which may be recombined in breeding for wider adaptability for deep water.

Higher nitrogen consistently increased grain yield in all entries because of increased panicle number and spikelet number per panicle (Table 4). Among the varieties, Kalar Harsall, RD19, and BKN6986-167 had significantly higher grain yield than BR223-B-38 at high nitrogen, in medium-deep water. Kalar Harsall had the lowest yield at low nitrogen in medium-deep water. Variety × nitrogen interactions were not, however, significantly different in deep water. The increased yields of RD19 and BKN6986-167 with high nitrogen at both medium-deep and deep water were due to their increased panicle number and number of spikelets per panicle, which resulted in higher panicle weight, and consequently higher harvest index (HI). In a controlled experiment, higher HI may be used as a selection criterion for higher yield potential. The higher HI is related to the type B plant height response.

UPTAKE THROUGH NODAL ROOTS AND DISTRIBUTION OF ^{15}N-TAGGED AMMONIUM

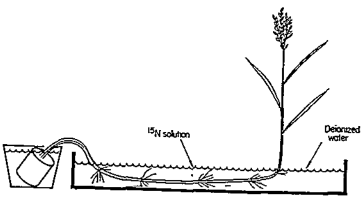
Plant Physiology Department

A study with ^{15}N, determined absorption of nitrogen through the upper nodal roots and its distribution in a deepwater rice plant. Two 20-day-old seedlings of Kalar Harsall, a deepwater variety, were transplanted as 1 hill in a pot containing 3 kg Maahas soil basally supplied with 2 g ammonium

Table 4. Grain weight, panicle number, number of spikelets per panicle, and harvest index of some entries[a] in medium-deep (30 cm) and deep (110 cm) water at low (2N) and high (6N) nitrogen levels/plant.[b] IRRI, 1979 wet season.

Entry	Grain wt (g)		Panicle no.		No spikelets per panicle		Harvest index	
	2N	6N	2N	6N	2N	6N	2N	6N
				Medium-deep water				
Kalar Harsall	9 d	24 a	8 cd	12 ab	57 f	95 cd	0 26	0 25
BR223-B-38	10 cd	20 b	9 c	13 ab	75 e	98 e	0.22	0.23
RD19	12 cd	26 a	7 cd	14 a	98 c	120 b	0.31	0.43
BKN6986-167	13 c	27 a	6 d	11 bc	90 d	130 a	0.35	0.26
				Deep water				
Kalar Harsall	19 a	29 a	14 bcd	18 a	74 f	120 b	0.39	0 21
BR223-B-38	14 a	26 a	12 cd	17 ab	75 f	77 ef	0 29	0.21
RD19	18 a	32 a	7 f	16 abc	104 d	110 cd	0 38	0.37
BKN6986-167	18 a	31 a	10 cdef	13 cde	116 bc	138 a	0.35	0 23

[a]Some entries damaged by disease or typhoons at maturity were discarded. [b]Separation of means in a column and under each water condition by Duncan's multiple range test at the 1% level CV (%) for grain weight, panicle number, and number of spikelets per panicle were 4, 12, and 4 in medium-deep water and 8, 15, and 4 in deep water.



7. Setup of the ^{15}N treatment using Kalar Harsall that has elongated and has been induced to "knee up."

sulfate. The plants were subjected to increasing water depth for 6-7 weeks to induce internode elongation and nodal root development and then allowed to "knee-up" on a galvanized iron tray containing 100 liters of water (Fig. 7). The soil in the pot remained flooded throughout the experiment but the pot was completely separate from the nodal root region submerged in the tray. Tagged ^{15}N ammonium sulfate was added to the tray. The nodal roots of some plants were excised as soon as they appeared, and another set of plants had their nodal roots intact and undisturbed.

Table 5 shows the amount of tagged N in different plant parts 3 and 96 days after fertilizer application in the nodal root region. The percentage of ^{15}N uptake, ^{15}N activity, was considerably greater in the nodal roots than in the other plant parts, suggesting nodal roots as the active sites for absorption of available nitrogen. Translocation of absorbed nitrogen was rapid. At 3 days after treatment, a large amount of ^{15}N was in the culm and green leaves, which were not submerged in the ^{15}N solution. Even the basal roots in the soil contained some ^{15}N.

Accumulation of ^{15}N progressively increased with the growth of the rice plant, and with the increasing absorption of total nitrogen. ^{15}N contributed 29 and 43% of the total nitrogen absorbed after 5 and 10 days of ^{15}N addition. At flowering (96 days after treatment), the amount of ^{15}N in total nitrogen uptake had increased to 53%. Most of the ^{15}N remained in the culms.

Among the plant parts, the nodal roots exhibited the highest percentage of ^{15}N activity at the initial stages, but subsequently the new nodal tillers, green leaves, and panicles became the primary sink of ^{15}N.

The amount of ^{15}N absorbed from the nodal root region was reflected in the dry matter weight of the rice plant. At flowering, the dry matter weight of the different plant parts and their total were remarkably higher in the ^{15}N plants than in the control plants. The presence of relatively greater amount of available nitrogen in the tray resulted in the greater number of late developed nodal and basal tillers.

Application of ^{15}N in the nodal root region increased basal root mass and absorption of soil nitrogen. The amount of nitrogen from the soil was 377 mg/plant in the ^{15}N treatment and 310 mg/plant in the control.

The removal of most of the nodal roots caused considerable decline in the absorption of ^{15}N. Absorption was only 33% of the total nitrogen uptake as against 60% in the intact treatment. With intact roots ^{15}N contributed as much as 72% of the total nitrogen in the grains, but cutting the nodal roots reduced the amount to 32%. The removal of most of the nodal roots reduced total ^{15}N absorption by 396 mg/plant and the total nitrogen uptake by 456 mg/plant, thus reducing dry matter weight by 19.9 g/plant.

The results demonstrated the importance for

Table 5. Uptake and distribution of tagged nitrogen (N) topdressed in the upper nodal root region of Kalar Harsall. IRRI, 1980.

Plant parts	3 days after ^{15}N treatment			96 days after treatment		
	Dry wt (g)	Tagged N uptake (mg)	Tagged N/ total N (%)	Dry wt (g)	Tagged N uptake (mg)	Tagged N/ total N (%)
Culm + leaves	40.6	73	21	60.9	264	53
New nodal tillers	0.0	0	0	7 8	62	55
Basal roots	4.7	3	8	5 8	6	16
Nodal roots	0 4	4	66	8.9	43	59
Panicle				6.4	50	61
Total	45.7	80	21	89.8	425	53

Table 6. Segregation of ratooning ability. IRRI, 1980.

Generation	Cross	Ratoon	Non-ratoon	Ratio	χ^2	*P*-value
F_2	Kalar Harsall/ Mingolo	55	121	1:3	3.67	0 10 – 0.50
F_4	CNL231-B-B/ Pankaj	430	1365	1:3	1.04	0.50 – 0.30

deepwater rice of the upper nodal roots in the absorption of nutrients from the floodwater. The importance of nodal rooting ability in screening for such a plant trait is clearly indicated.

DEEPWATER RICE WITH RATOONING ABILITY

Plant Physiology and Plant Breeding Departments

In some deepwater areas, there is a possibility of growing photoperiod-sensitive varieties in the dry season for harvest in April and followed by a ratoon crop. With the onset of the monsoon, the ratoon crop should grow vigorously and tolerate varying degrees of submergence from July to September. It could then be harvested in November.

Breeding for rice with ratooning ability. A variety for such areas should be photoperiod sensitive, cold tolerant, and responsive to fertilizer. It should have good ratooning ability with some degree of drought and submergence tolerance or elongation ability. Furthermore, the ratoon crop should possess resistance to virus diseases.

That plant type was studied by a single cross of Kalar Harsall, a photoperiod-sensitive deepwater rice with elongation ability, and Mingolo, a good ratooning variety. Another single cross of CNL231-B-B, which is suitable for waterlogged areas, and Pankaj, with good ratooning ability, was made to combine good ratooning ability with submergence tolerance. The F_1, F_2, and F_3 populations were grown by rapid generation advance and allowed to ratoon. Ratooning ability was scored as good, moderate, low, and no ratoon 15 days after harvest.

The ratooning ability of F_2 and F_3 populations varied with growth duration. The late-maturing segregants had greatest ratooning ability and a high correlation value ($r = 0.962^{**}$) was obtained between F_2 and F_3 ratooning ability classified according to growth duration. The elongation ability of Kalar Harsall, the F_3 bulk population, and the ratoons show that the hybrid had distinctly better elongation ability than the elongating parent both at early seedling stage and as ratoon plants.

Ratooning ability appeared recessive monogenic to nonratooning ability (Table 6). Selection for ratooning ability early in a breeding program is suggested.

EFFECTS OF GROWTH DURATION AND LIGHT INTENSITY ON RATOONING

Plant Physiology Department

Photoperiod-sensitive BPI-76 was grown in 16 hours photoperiod after which the plants were transferred to 10 hours photoperiod. The ability to ratoon was negatively correlated with the growth duration of the main plant ($r = -0.99^{**}$). The percentage of plants that produced ratoon tillers decreased from 100 to 0 as the growth duration increased from 117 to 177 days (Table 7). The shorter-duration plants produced ratoons on every plant and more ratoons per hill (Table 8). They also initiated ratoons earlier. Ratoons from the

Table 7. Number of BPI-76 plants that produced ratoons. IRRI, 1980.

Growth duration (days after sowing)	Plants (no.)	
	Total	Produced ratoons
117	5	5
137	5	4
157	4	2
177	5	0

Table 8. Number of ratoon tillers produced per treatment during the first 3 weeks after main crop harvest. IRRI, 1980.

Growth duration (days after sowing)	Ratoon tillers (no.)		
	1 wk	2 wk	3 wk
117	9	11	14
137	7	8	10
157	2	4	5
177	0	0	0

younger plants grew taller than those from the older plants.

Total carbohydrate content in ratoon plants was significantly correlated with growth duration (r = 0.88**). The total carbohydrate contents of the 177-day and the 157-day main plant stubble (37 and 41%) were significantly different from those of the 137- and 117-day plants (26 and 19%). However, the nitrogen content of the main plant stubble was negatively correlated with growth duration (r = 0.98**). The 117-day plants gave the highest value of 0.76% nitrogen, and the 177-day plants gave the lowest — 0.26% nitrogen.

Two types of ratoon tillers were observed. Basal ratoon tillers originated from the soil surface, and upper nodal ratoon tillers originated from 5 to 15 cm above the soil surface. BPI-76 had more basal ratoon tillers than upper nodal ratoon tillers regardless of growth duration.

Because there was a 48.4% reduction in total carbohydrate of the 117-day plants compared with the 177-day ones, the observed 100% regeneration in the former could not be attributed to the accumulated carbohydrate in the stubble. Regeneration, then, in the short-duration plants (117 and 137 days) may be largely due to the high nitrogen content of the stubbles.

Light intensity. Mingolo, a variety known for good ratooning ability, was grown under 10 hours photoperiod until heading. At 5 days after panicle exsertion, one lot was shaded 49%, and another lot 66%. A third lot was left unshaded. At 30 days after flowering, the plants were cut at 15 cm above the soil surface and left to ratoon.

Low light intensity during ripening did not affect the ability of the main plants to produce ratoon tillers (Table 9). Earliest production of ratoon tillers was apparent in the unshaded plants.

Ratoon tillers produced were 68.0, 62.0, and 55.5% of the main crop tillers for 0, 49, and 66% shading. The height of the ratoon plants was not affected by shading of the main crop.

Carbohydrate content of the main plant stubble was negatively correlated with degree of shading, and was highest at no shading and lowest at 66% shading. The nitrogen content of the main plant stubble was independent of shading.

The ratoon yield of plants with 49% shading did not differ significantly from that of the unshaded plants (Table 10). But, ratoon yield with 66% shading was significantly lower.

Table 9. Ratoon production in Mingolo subjected to different degrees of shading at flowering to harvest IRRI, 1980.

Treatment (% shading)	No. of tillers[a]				Yield (g/plant)	
	1 wk	2 wk	3 wk	Harvest	Main plant	Ratoon plant
0	6 a	6 a	9 a	7 a	32 8 a	11.9 a
49	4 ab	4 ab	7 ab	6 a	35.6 a	12.0 a
66	3 b	3 b	4 b	5 a	33.2 a	7.9 b

[a]Separation of means in a column by Duncan's multiple range test, 5% level.

Table 10. Grain yield of main and ratoon plants of Mingolo subjected to different degrees of shading from flowering to harvest of the main crop. IRRI, 1980.

Treatment (% shading)	Yield[a] (g/plant)	
	Main plant	Ratoon plant
0	32 75 a	11.94 a
49	35.58 a	12.02 a
66	33.23 a	7.88 b

[a]Separation of means in a column by Duncan's multiple range test, 5% level.

Number of panicles per hill in the ratoon crop did not significantly differ among the three treatments although panicle number tended to be higher with no or less shading. The 66% shading produced more unfilled spikelets in the ratoon crop than did the 0 and 49%. The 100-grain weight was not affected by shading of the main plant.

As in BPI-76, more ratoon tillers in Mingolo regenerated from the base than from the node, irrespective of shading treatment. The basal tillers outyielded the upper nodal tillers by 26.8%, showing the importance of selecting varieties for higher basal tillers.

FERTILIZER TRIALS

Agronomy Department

Increasing fertilizer nitrogen efficiency in deepwater rice. The first international trial on nitrogen fertilizer efficiency for deepwater rice was planted at IRRI during the 1980 wet season. Soil analysis is reported in Table 11; analysis of floodwater is in Table 12.

RD19 did not show any significant increase in grain yield with either 29 or 58 kg N/ha. However,

Table 11. Analysis of soil in deepwater tank 1. IRRI, 1980 wet season

Soil property	Analysis
pH	6.8
Organic matter (%)	1.94
Total nitrogen (%)	0.12
Exchangeable potassium (mg/100 g)	1.29
Available phosphorus (ppm)	12.0
Cation exchange capacity	40.0
Particle size	
Clay (%)	39
Silt (%)	32
Sand (%)	29
Texture	Clay loam
Taxonomic classification	Alfisol

foliar application of urea near the panicle initiation stage did not show any special advantage over all urea fertilizer applied as a basal dose (Table 13).

The most significant result was that RD19 elongated to 200 cm and produced 300 panicles/m^2. Both factors favor high grain yield under flooding regimes of 51 to 100 cm deep water.

Increasing fertilizer nitrogen efficiency in medium-deepwater rice. In the second International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) trial, IR42 was planted in medium-deep water with maximum water depth of 50 cm during the dry season.

Regardless of nitrogen source, application of fertilizer nitrogen increased grain yield by 1-3 t/ha (Table 14).

At 54 kg N/ha, deep placement of urea supergranules gave significantly higher grain yield than broadcast-incorporated prilled urea or sulfur-

Table 12. Measurements[a] of pH, temperature, ammonium nitrogen (NH_4–N) and urea-nitrogen of floodwater in deepwater rice tank 1 after fertilizer application. IRRI, 1980 wet season.

Days after fertilizer application	At basal fertilizer application				At foliar spraying		5-7 DBPI[b]	
	pH	Temperature (°C)	NH_4–N (ppm)	Urea-N (ppm)	pH	Temperature (°C)	NH_4–N[c] (ppm)	Urea-N (ppm)
1	6.3	26	0.45	1.31	8.6	22	nil	1.57
2	8.3	32	0.60	0.06	8.8	21	nil	0.67
3	8.6	33	0.43	0.06	8.9	21	nil	nil
4	6.4	31	0.20	0.06	8.8	22	nil	nil
5	6.4	35	0.27	0.06	8.9	20	nil	nil
6	6.6	27	0.28	0.18	9.0	20	nil	nil
7	7.7	36	0.43	0.31	8.9	20	nil	0.36
8	7.2	27	0.70	0.32	8.7	19	nil	0.15
9	7.2	28	0.56	0.40	8.5	19	nil	0.84

[a]Av of 8 plots, 4 samples/plot. [b]DBPI = days before panicle initiation. [c]Ranging from 0.21 to 0.30 ppm N

Table 13. Grain yield and some agronomic characteristics[a] of RD19 as affected by forms of nitrogen fertilizers and methods of application in deep water (100 cm deep). IRRI, 1980 wet season.

Nitrogen fertilizer treatment	Grain yield (t/ha)	Plant ht (cm) 30 DT	Plant ht (cm) at harvest	Tiller count (no./m²) 30 DT	Tiller count (no./m²) at harvest	Panicle count (no./m²) at harvest	Panicle length (cm)	Unfilled grains (%)	100-grain wt (g)
No fertilizer nitrogen	3.7 ab	76 b	200 a	189 b	300 ab	235 bc	24 a	21 a	3.3 ab
29 kg N/ha									
Urea supergranule placed 10-12 cm deep	3.7 ab	82 a	186 a	198 ab	245 b	191 c	26 a	29 a	3.2 ab
58 kg N/ha									
Prilled urea[b]	4.0 a	80 ab	197 a	210 ab	325 a	300 a	25 a	22 a	3.2 ab
Sulfur-coated urea[b]	3.8 ab	82 a	181 a	216 ab	267 ab	221 bc	25 a	23 a	3.1 b
1/2 prilled urea + 1/2 sulfur-coated urea[b]	3.6 ab	83 a	186 a	246 a	290 ab	220 bc	26 a	21 a	3.3 a
2/3 prilled urea[b] + 1/3 urea foliar spray at 5-7 DBPI[c]	4.0 a	81 a	196 a	213 ab	308 ab	261 ab	26 a	25 a	3.3 ab
2/3 sulfur-coated urea[b] + 1/3 urea foliar spray at 5-7 DBPI[c]	3.4 ab	84 a	202 a	195 b	302 ab	267 ab	26 a	25 a	3.2 ab
Urea supergranule placed 10-12 cm deep	3.2 b	82 a	193 a	231 ab	260 ab	202 bc	25 a	24 a	3.2 ab

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Av of 4 replications. [b]Broadcast and incorporated. [c]DBPI = days before panicle initiation. Urea solution was applied 73 days after transplanting.

Table 14. Mean grain yield of IR42 grown in 50-cm water, with various sources[a] and rates of nitrogen application. IRRI, 1980 dry season.[b]

Treatment		Grain yield (t/ha)	Nitrogen content (%) in straw
Form	Rate (kg/ha)		
No nitrogen	—	1.3 f	0 64 cd
Prilled urea	54 kg N/ha	2.6 e	0.50 d
Sulfur-coated urea	54 kg N/ha	3.2 de	0.45 e
Urea supergranule	54 kg N/ha	4.0 bc	0.52 de
Prilled urea	108 kg N/ha	4 3 abc	0.53 de
Sulfur-coated urea	108 kg N/ha	4.5 ab	0.56 de
Urea supergranule	108 kg N/ha	4 2 abc	0.82 b
Prilled urea	162 kg N/ha	4 8 a	0.57 de
Sulfur-coated urea	162 kg N/ha	4 2 abc	0.79 bc
Urea supergranule	162 kg N/ha	3.6 cd	1.05 a

[a]Broadcast and incorporated at planting, except urea supergranule, which was deep-placed at 10-12 cm soil depth. [b]Av of 3 replications. Separation of means at the same rate by Duncan's multiple range test at the 5% level.

coated urea. IR42 did not respond to a rate higher than 54 kg N/ha. In fact, deep placement of supergranules at 162 kg N/ha caused excessive lodging and significantly reduced the grain yield.

Plant height, and tiller and panicle numbers increased with increased nitrogen rates, but differences in these traits were not significant among nitrogen sources.

Nitrogen uptake. With deep placement of urea supergranules, nitrogen content in straw was considerably higher at 108 and 162 kg N/ha than at 54 kg N/ha. The increased content caused lodging, and no grain yield advantage was recorded in that treatment beyond 54 kg N/ha (Table 14).

In the 1980 wet season, complete soil analysis was made in the medium-deepwater experimental area (Table 15). Grain yield response to added nitrogen was significant for IR42 for all sources and rates of nitrogen fertilizers except one (Table 16).

Considerable lodging occurred in plots with deep-placed urea supergranules at 58 kg N/ha and yield increase from 29 to 58 kg N/ha in that treatment was not significant.

Table 15. Analysis of soil in medium-deepwater rice experimental area. IRRI, 1980 wet season.

Soil property	Analysis
pH, 1:1 without water	6.2
Organic matter (%)	1.88
Total nitrogen (%)	0.11
CEC (meq/100 g)	36.0
Exchangeable potassium (meq/100 g)	0 90
Available phosphorus (ppm)	11 0
Particle size	
Clay (%)	34
Silt (%)	30
Sand (%)	36
Texture	Clay loam
Taxonomic classification	Alfisol

Application of azolla as source of supplemental nitrogen in deepwater rice. A wet season experiment with azolla had water depth gradually raised to 100 cm and maintained at that level until maturity. Fresh azolla was inoculated in designated plots at the rate of 500 g/m^2 immediately after transplanting RD19. Azolla was allowed to grow for 1 month before incorporation into the soil. Following that, the water level was increased 5 cm/day.

Inorganic nitrogen rates used were 0, 29, and 58 kg N/ha. The azolla application did not improve grain yields more than inorganic fertilizer nitrogen did (Table 17). Without azolla, slow-release sulfur-coated urea (SCU) at 58 kg N/ha significantly increased yield over 0 or 29 kg N/ha with the highest yield of 5.2 t/ha. If increase in water level is gradual, grain yields of 5 t/ha can be obtained with modern varieties like RD19.

BREEDING PROGRAM IN THAILAND

Thailand-IRRI Cooperative Deepwater Project

Performance of RD19 in various yield trials. RD19 showed its potential in yield trials, and in farmers' fields (Table 18). The 3.9 t/ha at K67 was attained in a flood that peaked at 120 cm.

Average panicles per square meter calculated for 10 sites were 168 for RD19 and 112 for LMN 111. The lowest advantage of RD19 over LMN 111 was at low yield levels, which occurred where both entries were subjected to excessive flooding, or where RD19 had greater plant length.

Table 16. Mean grain yield and some agronomic characteristics of IR42 as affected by sources of nitrogen fertilizer and methods of application under medium water depth (50 cm). IRRI, 1980 wet season.[a]

Nitrogen fertilizer treatment[b]	Grain yield (t/ha)	Tiller count (no./m²) at harvest	Panicle count (no./m²) at harvest	Unfilled grains (%)
No fertilizer nitrogen	1.6 d	163 c	151 c	13 a
29 kg N/ha				
Urea supergranule placed 10-12 cm deep	2 4 bc	226 ab	203 ab	13 a
58 kg N/ha				
Prilled urea, broadcast and incorporated	2.9 ab	261 a	228 a	10 ab
Sulfur-coated urea (SCU), broadcast and incorporated	3 4 a	234 ab	214 ab	10 ab
1/2 prilled urea + 1/2 SCU, broadcast and incorporated	2 9 ab	254 a	222 ab	7 b
2/3 prilled urea broadcast and incorporated + 1/3 urea foliar spray at 5-7 DBPI	2.1 cd	226 ab	212 ab	12 ab
2/3 SCU broadcast and incorporated + 1/3 urea foliar spray at 5-7 DBPI	2.7 bc	194 bc	174 bc	11 ab
Urea supergranule placed 10-12 cm deep	2.7 bc	268 a	223 ab	8 b

[a]Separation of means in each column by Duncan's multiple range test at the 5% level Av of 4 replications. [b]DBPI = days before panicle initiation; urea solution was applied 55 days after transplanting 20-day-old seedlings.

Table 17. Mean grain yield of RD19 as affected by rates and forms of urea, with and without azolla in deep water (100 cm max water depth). IRRI, 1980 wet season.

Treatment		Grain yield (t/ha)[a]	
N form	N rate (kg/ha)	With azolla	Without azolla
No nitrogen	0	3.3 c	3.4 b
Prilled urea	29	4.2 b	3.3 b
Sulfur-coated urea	29	3 6 c	4.0 b
Supergranules	29	3.7 bc	3.5 b
Prilled urea	58	3 9 c	3.3 b
Sulfur-coated urea	58	4.7 a	5.2 a
Supergranules	58	4 4 b	4.0 b

[a]Av of 3 replications Separation of means in a column by Duncan's multiple range test at the 5% level.

Hybridization. Two hundred and sixty-nine crosses were made at the Bangkhen and Huntra Experiment Stations — 116 for elongation ability, 76 for submergence tolerance, 35 for combined elongation ability and submergence tolerance, and 12 for other purposes. Of the crosses, 190 had one or more photoperiod-sensitive parents and of those 69 had one or more glutinous parents.

Promising lines. A number of lines offer deep-water protection in improved plant types, and thus are suitable for either testing, possible release, or use as breeding materials. They include:

- *IR8234-OT-9-2,* a result of the cross Nam Sagui 19/IR1721-11-6-3//IR2061-213-2-16. It has semidwarf intermediate plant type, moderate resistance to submergence, resistance to bacterial blight, brown planthopper biotype 1, and ragged stunt.
- *BKNFR76045-35-1,* from the cross BKN6987-92-2/Rayada #7. It is only 100 cm tall, but elongates and survives floods as deep as 175 cm. It has some submergence tolerance at peak flood levels, and secondary flush of nodal tillers as the water recedes. It is photoperiod sensitive and is recommended mostly

Table 18. Performance of RD19 and Leb Mue Nahng 111 in tests at 14 sites, including 4 in farmers' fields, Thailand, 1980.[a]

	Site codes													
	SPR	K67	CNT	KLG	HTA	PSL	PJR	KLG	PJR	KSR	HTA	Wni[b]	Ant[b]	Nnk[b]
	Grain yield (t/ha)													
RD19	4.3	3.9	3 8	3 6	3.4	3 4	2 8	2 8	2.7	2.7	2.3	2 3	2.2	2.1
LMN 111	4.0	2.5	3 2	3 3	2 4	2 0	2 2	2 0	2 0	1.5	2.5	2.4	2.3	1.6
	Plant length (cm)													
RD19	115	—	147	123	142	143	—	131	163	112	148	173	158	—
LMN 111	182	—	230	178	214	213	—	227	196	178	220	247	164	—

[a]Dash indicates data not recorded [b]Farmer field tests

for crossing.

- *SPR7233-1-24-2-2-2-3,* from Leb Mue Nahng 111/C4-63, is a photoperiod-sensitive line with good elongation ability. It is recommended for medium-deep floating rice areas.
- *IR11185-R-07,* from IR2070-414/LMN 111 is a medium-tall floating rice type that survives a 180-cm flood without damage.
- *DWCT156-1-2-0-1,* a semidwarf type with elongation ability. It is insensitive to photoperiod, resistant to bacterial blight, shows little ragged stunt damage, and is susceptible to brown planthopper biotype 1.
- *BKNFR76035-106-01,* from IR4427-70-6/RD19//BKN6987-52-1. It is a photoperiod-sensitive semidwarf line. It has resistance to brown planthopper biotype 1 and to ragged stunt, good elongation for 100-cm flood, and is glutinous.
- *SPR7282-2-0-7,* from HTA1645/NSR6515-27. It is a photoperiod-sensitive floating rice type, moderately susceptible to bacterial blight and resistant to ragged stunt.
- *SPR7265-0-0-1-1-2,* from Seua Lahk/Sigadis, is a late-maturing, medium-stature, deepwater rice for moderate water depths. It has good resistance to ragged stunt.
- *HTA7406-115-0-0-4,* from RD7//RD1/KP32 is a medium-stature line with good elongation and good resistance to ragged stunt.

Screening for elongation ability and submergence tolerance. In 1980 3,321 pedigree lines, 536 yield trial and observation nursery entries, 85 F_2 populations, and 118 genetic stock entries, including the IRDWON, were screened for elongation ability. About 3,500 surviving F_2 plants and 4,000 surviving pedigree lines were selected for seed increase.

In addition 1,134 pedigree lines, 239 yield trial and observation nursery entries, 151 F_2 populations, and 128 genetic stock entries, including the IRDWON, were screened for submergence tolerance. From F_2 populations, about 5,000 surviving plants and 300 lines that showed good survival were transplanted.

Combining elongation ability with flash flood tolerance. Elongation ability and flash flood submergence tolerance may be needed in the same variety. To study the implications of such combination, crosses were made between elongating improved lines (mostly semidwarf) and the submergence-tolerant variety FR13A. F_2 populations were assigned to 3 treatments at 30 days after sowing — 10 days of flash flood, slowly rising water (3-5 cm/day), and flash flood followed by slowly rising water from day 54 to day 84. Survival percentages (Table 19) indicate that tolerance for temporary flash floods can combine with ability to elongate in gradually rising water. Verification started with F_3 progenies of plants surviving each treatment.

Table 19. Survival of six F_2 populations subjected to different excess water situations. Thailand-IRRI Cooperative Deepwater Project, 1980

F_2 population	Survival (%)		
	Flash flood at 30 days	Elongation at 30 days	Elongation (survivors of flash flood)
BKN6986-108/FR13A	90	12	26
DWCT156/FR13A	93	21	31
SPR7297-405/FR13A	87	12	16
BKN6988-52/FR13A	71	34	34
DWCT134/FR13A	86	12	21
BKN6986-161/FR13A	79	4	21
Av	84	16	25

Establishing the limits of submergence tolerance. Khao Dawk Mali 105, a popular, tall, traditional variety of Northeast Thailand with little tolerance for temporary submergence; FR13A, a variety from Orissa, India, with outstanding submergence tolerance; and IR8234-OT-9-2, a semidwarf promising line with significant submergence tolerance, but not as good as FR13A, were used to predict the potential of submergence-tolerant materials now being developed.

Seedlings were transplanted in a tank for 3 consecutive weeks. The tank was flooded and temporarily drained at 5, 14, and 21 days after flooding, just long enough to transplant sample plants into pots for recovery away from the tank.

In general, submergence survival was positively correlated with age of seedlings at submergence, and was negatively correlated with duration of submergence. FR13A did well in almost all combinations of treatments, with 50% survival deemed acceptable. IR8234-OT-9-2 survived short-duration flooding of 120 cm depth. Khao Dawk Mali 105 showed lack of tolerance for every treatment.

In another test, the ability to withstand a 10-day

Table 20. Submergence survival of 2 varieties at 3 transplanting schedules: 10, 5, and 0 days before flood. Thailand-IRRI Cooperative Deepwater Project, 1980

Variety	Submergence survival (%)		
	10	5	0
KDML	10	12	19
FR13A	91	93	91

Table 21. Number of 15-day-old plants before water-level increase and survival percentage when water reached 100-cm depth for 3 parents and 2 F_2 populations. Thailand-IRRI Cooperative Deepwater Project, 1980.

Entry	Plants (no.) at 15 days of age	Survival (%) at 100-cm depth
T442-57	657	0.0
Pin Gaew 56	404	0.0
Habiganj Aman 8	879	8.8
T442-57/Habiganj 8[a]	4528	2.7
Pin Gaew 56/ Habiganj 8[a]	2124	10.5

[a]And its reciprocal.

110-cm-deep flash flood shortly after transplanting time was assessed for Khao Dawk Mali 105 and FR13A. The results are in Table 20.

Selection for ability to elongate at early seedling age. To successfully elongate with rising water, floating rice usually must attain a minimum seedling age of about 6 weeks. Some floating rices from Bangladesh are able to elongate at the early age of 15 days. To get elongation at this early seedling age in a rice acceptable for Thailand, F_2 populations of Habiganj Aman 8/Pin Gaew 56 and Habiganj Aman 8/T442-57 were tested with 5 cm/day flooding increments starting at 15 days after seeding. The survival percentages are in Table 21. The low survival percentage for Habiganj Aman 8 is believed partly a consequence of not allowing time for lagging plants to reach the surface by maintaining the 100-cm water level for several days. The recovery of early elongating types from both hybrids was adequate.

Genetics of elongation ability of floating rice. The parents, F_1, F_2, and both backcrosses of a cross between Sigadis, a tall traditional Indonesian variety, and LMN 111, a Thai floating rice, were observed. Ten-day-old seedlings were planted in a deepwater pond. The water level was increased at 5 cm/day, starting 30 days after transplanting, until the water level reached 175 cm.

Table 22 gives the distribution of the maximum water depths at which plants were still partly above the water. From the F_1 and the backcross to Sigadis, it is evident that an essential gene for elongation ability is recessive.

The F_1 also shows a genotype not expressed by either parent. In view of the low segregation of the nonelongating phenotype in the F_2, this gene must be additional to the recessive one.

The implication of these findings for plant breeding is that one can expect an immediate recovery of around 25% of floating types in an F_2. Recovery of floating types from backcrosses or topcrosses to a nonfloating variety would be low or none.

Table 22. Water-level intervals at which various proportions (%) of the population were destroyed. Thailand-IRRI Cooperative Deepwater Project, 1980.

Populations	Percent of population				
	85 cm	85-115 cm	115-145 cm	145-175 cm	175 cm
Leb Mue Nahng 111	0	0	0	3	97
Sigadis	42	54	0	4	0
F_1 Leb Mue Nahng/Sigadis	11	22	11	56	0
Backcross F_1 F_1/Leb Mue Nahng	0	3	0	19	78
Backcross F_1 F_1/Sigadis	8	75	10	2	5
F_2 Leb Mue Nahng/Sigadis	1	8	22	32	37

Genetic evaluation and utilization (GEU) program

Temperature tolerance

Plant Physiology and Plant Breeding Departments and International Rice Testing Program

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Plant Physiology and Plant Breeding Departments and International Rice Testing Program

Breeding. At Banaue, Philippines, 16 F_2 populations were grown. Six populations gave 942 plant selections and 10 were bulked for rapid generation advance (RGA). Advanced lines (1,427) were also grown and 1,279 individual selections were made from them. All the lines planted at Banaue were tested for blast resistance at IRRI, and 223 lines that showed resistance were tested for cold tolerance at Chuncheon, Korea. From that test, 77 lines that showed cold tolerance were nominated for the International Rice Cold Tolerance Nursery (IRCTN).

Thirty-six of 102 selected breeding lines grown at Banaue had more than 5 t grain yield/ha; 12 lines yielded 5.8 t/ha or higher (Table 1). Most of the high yielding lines at Banaue had poor phenotypic acceptability at Chuncheon.

From an observational yield trial in Banaue, 76 lines that showed blast resistance were tested in the cold tolerance nursery at Chuncheon and 35 were selected for nomination to the IRCTN.

When planted in Banaue, the high grain yielders among the highly cold-tolerant lines were all intermediate in plant height (Table 2). All the crosses had Kn-1b-361 as the cold-tolerant parent. It is intermediate in plant height with relatively wide leaves.

Rapid generation advance for cold-tolerant rice. The RGA program processed more than 500,000 plants (involving 287 crosses) in 1980. Five RGA

Table 1. Characteristics of selected breeding lines grown at Banaue, Ifugao, Philippines, 1980 dry season.

Designation and cross	Phenotypic acceptability[a]		Days to flower	Height (cm)	Grain sterility (%)	Grain quality[b]			Yield (t/ha)
	Banaue	Chuncheon				Amylose	Alkali	Gel consistency	
IR8866-30-3-1-4 K78-12/IR2053-362-1-4	2	8	117	80	20	7	7	3	7.7
IR9202-5-2-2-2 IR2053-521-1-1/K116// Kn-1b-361	2	7	109	83	19	9	6	5	7.3
IR15579-135-3 K28-76-B-1/Kn-1b-214// Kn-1b-214	1	7	109	107	3	9	7	1	6.8
IR8866-48-3 K78-12/IR2053-362-1-4	3	7	118	79	11	9	7	1	6.5
IR8866-30-3-1-4-2 K78-13/IR2053-362-1-4	2	8	115	74	14	9	7	1	6.4
IR13045-175-1 IR3941-25-1/IR1416-131-5// Kn-1b-361	1	7	115	118	7	9	7	5	6.3
IR7167-33-2-3-3-1-3-2 China 1039/Kn-1b-361-Blk	2	7	109	96	4	9	7	3	6.1
IR9202-25-3-1 IR2053-521-1-1/K116// Kn-1b-361	1	5	110	108	6	9	5	5	6.0
IR7167-16-1-2-1-2 China 1039/Kn-1b-361-1-8-6-10	3	9	109	119	8	9	7	5	6.0
IR9202-21-3-2 IR2053-521-1-1/K116// Kn-1b-361	2	7	115	103	22	9	7	5	5.9
IR9202-33-4-2 IR2053-521-1-1/K116// Kn-1b-361	2	7	113	109	6	9	6	3	5.9
IR13045-104-1 IR3941-25-1/IR1416-131-5// Kn-1b-361	3	7	108	109	18	9	7	3	5.8

[a]In cold water nursery with 17°C irrigation water at Chuncheon, under natural conditions at Banaue. Scored by the 1980 Standard Evaluation System for Rice (SES). [b]Scored by 1980 SES.

Table 2. Characteristics of selected cold-tolerant breeding lines grown at Banaue, Ifugao, Philippines, 1980 dry season.

Designation and cross	Days to flower	Height (cm)	Grain sterility (%)	Yield (t/ha)
IR13155-4-1 BG90-2/Kn-1b-361//Kn-1b-361	107	113	13	5.5
IR9202-22-3-2 IR2053-521-1-1/K116//Kn-1b-361	113	105	6	4.9
IR15889-180-3 IR3941-39-2/Kn-1b-361	109	106	16	4.9
IR15889-112-3 IR3941-37-2/Kn-1b-361	108	110	13	4.8
IR9202-25-1-2-2 IR2053-521-1-1/K116//Kn-1b-361	108	103	14	4.8
IR13047-68-2 IR4405-115-1/IR1846-300-1//Kn-1b-361	112	122	17	4.6
IR13045-76-2 IR3941-25-1/IR1416-131-5//Kn-1b-361	108	104	31	4.4
IR15889-113-3 IR3941-37-2/Kn-1b-361//IR3941-25-1	106	108	28	4.0

bulk materials were included in the 1980 IRCTN. In Chuncheon, 23 RGA crosses were planted and individual plants were selected from 18 crosses.

Research on improving RGA methods, especially screening techniques, was started in 1980.

Selection for cold tolerance at seedling stage. The possibility of RGA screening for cold tolerance at the seedling stage of segregating F_3 matérials was studied in IR20654 (K78-13/IR5908-125-1) and IR22553 (Fujisaka 5/Kn-1b-361-1-8-6-9). Ten days after seeds were sown, the plants were subjected to 12° C cold water for 10 days and then scored for leaf yellowing; a score of 1 was best and 9 indicated almost dead or dead plants.

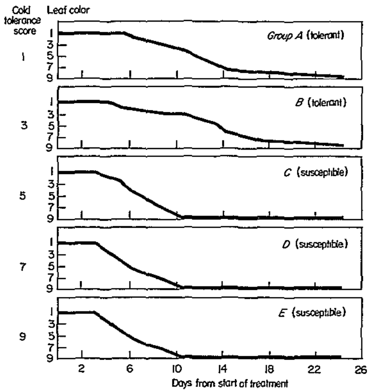
A number of F_3 plants had a score of 1 to 3 (4% in IR22553 and 14% in IR20654). Removal of the susceptible lines (score of 7 to 9) eliminated 87% and 58% of the F_3 plants in the two crosses studied. Cold water treatment at seedling stage generally delayed heading date but the delay was relatively short.

Selection for earliness. Delayed heading, or long growth duration, is a major effect of low temperature. With long growth duration, the rice plant initiates its panicle late (when temperatures are low). Late panicle initiation causes degenerate spikelets and sterility. Sterility also results when temperatures are low at flowering time.

Selection of F_2 plants that flower in 70 days or less reduced the population of IR22553 by 31% and that of IR20654 by 12%. Selection for earliness (< 70 days) in F_2 of IR22553 resulted in 94% of the F_3 population with growth duration of less than 70 days. For the IR20654 F_3 population it was 84%. These high values justify an early selection (at F_2) for short growth duration.

Selection for earliness, however, does not select for cold tolerance at seedling stage. If selection for earliness is made at F_2, a minimum population of about 2,000 plants should be maintained so that F_3 selections for cold tolerance at the seedling stage can be made.

Difference in leaf color and seedling height between cold-tolerant and susceptible varieties. Subjecting the 10-day-old seedlings to 12° C cold water showed that the tolerant varieties (group A) had green leaves after 5 days of cold water treatment. Group B had green leaves until 4 days and groups C, D, and E had green leaves until 3 days (Fig. 1). The change in color from green to yellow to brown was rapid for the susceptible varieties (groups C, D, and E) and most plants died after 10



1. Change in leaf color of varieties from different cold tolerance groups during treatment at 12° C water. Leaf color scores are by Standard Evaluation System for Rice, 1980. IRRI, 1980.

days. Seedlings from groups A and B had green leaves after 10 days.

Measurement of plant height — from the base of the plant to the highest portion of the plant that remained green or alive — on a different set of plants treated 10 days in cold water at 12°C showed that the susceptible groups generally had taller seedlings (20 cm) than the tolerant groups (12 to 15 cm) even before treatment (Fig. 2). The susceptible groups were mostly indica types.

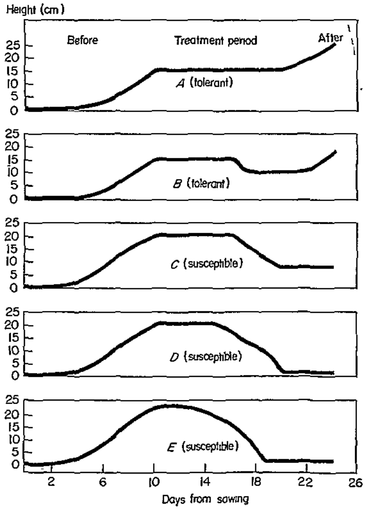
After the plants were removed from the cold water, the increase in height was most rapid in group A. Group B, which had light-green leaves, recovered from treatment after only 3 days; groups C, D, and E showed no recovery after 3 days and most plants in group E eventually died.

These patterns in plant growth or plant height substantiated the earlier suggested grouping based on color that separated those with a score of 1 and 3 from those with a score of 5, 7, and 9.

A detailed observation of some representative varieties showed further the complex response of varieties to low water temperature in terms of discoloration. Seedlings were subjected to low water temperature at the 2-leaf stage (second leaf fully expanded and the third leaf just coming out). Each leaf was scored on the degree of yellowing as the low water temperature treatment progressed. Group A showed no yellowing of any leaves; group B showed yellowing on the second leaf but became green again when returned to normal temperature.

The susceptible groups C, D, and E showed yellowing first in the second leaf; the more susceptible the plant, the earlier the yellowing of the second leaf or the destruction of the chloroplast. Continuous low water temperature affected the rapidly growing third leaf and, eventually, even the fully mature first leaf in groups D and E was also affected. In group C the third leaf recovered from yellowing when the plant was transferred to normal temperature; in group D the second and third leaves did not recover but remained alive; in group E the leaves died prematurely.

Adaptability of rice cultivars to different temperature patterns. The adaptability of the different varieties to low-temperature areas may depend upon the stage at which the low temperature occurs. This thesis was tested with 32 rice varieties of diverse origin (Table 3).



2. Height of representative varieties from different cold tolerance groups before, during, and after treatment at 12° C water. IRRI, 1980.

Table 3. Varieties, origin, growth duration, and latitude of origin, and varietal reactions to tests for adaptability to temperature patterns. IRRI, 1980.

Designation	Origin	Days to maturity	Latitude of origin	Reaction[a]				
				ES	SS	TS	PD	FS
3558	Po River Valley, Italy	117	45°N	9	5	9	7	7
Shin 2	Fukuoka, Japan	118	35	7	4	8	3	4
Norin 36	Fukuoka, Japan	111	35	9	4	7	9	8
Gunek 1	Fukuoka, Japan	110	35	9	5	8	7	8
Tachi-ki-kokoku-mochi	Fukuoda, Japan	123	35	7	3	9	9	6
Hukjo 97	Fukuoka, Japan	111	35	7	4	9	9	8
Fujisaka 5	Konosu, Japan	101	35	5	4	5	3	4
CI 5481	Yangtze River Valley, China	112	30	5	2	8	1	8
Tihoju	Yangtze River Valley, China	104	30	9	5	1	5	7
Yan-shon 1	Yangtze River Valley, China	108	30	9	5	7	9	8
B575A1-26-4-6	Yangtze River Valley, China	118	30	5	3	8	7	8
B573A4-20-6	Yangtze River Valley, China	118	30	3	2	7	7	7
Verceli	Pelotas, Brazil	122	30	5	5	6	9	4
ADT 19	Bihar, India	100	25	9	5	5	9	6
T36	Bihar, India	113	25	9	6	7	9	7
Vary Lava 16	Madagascar	113	25	3	3	6	5	5
DB1	Dacca, Bangladesh	119	25	7	7	8	3	5
Chenlun (Hen-li) 55	Taichung, China	110	25	1	3	6	9	8
Ming-Hoo-Tsao-Tao	Taichung, China	101	25	1	3	8	3	6
No-iku 1716	Taichung, China	117	25	9	4	8	3	9
Taichung 65	Taichung, China	131	25	9	3	—	1	4
Tainan	Tainan, China	114	23	5	3	7	3	6
RDR 2	Cuttack, India	113	20	7	5	6	9	7
PTB 26	Cuttack, India	124	20	9	5	5	5	8
IR8	Laguna, Philippines	124	15	7	9	8	9	7
A6-10-49	Sri Lanka	107	7	9	7	5	9	6
BG707	Sri Lanka	110	7	7	6	8	—	9
BG708	Sri Lanka	110	7	7	5	8	—	—
BG695	Sri Lanka	110	7	3	5	9	1	9
BO 14	Bogor, Indonesia	110	7°S	9	9	9	9	9
BO 16	Bogor, Indonesia	110	7	9	8	8	—	9
Leter	Bogor, Indonesia	130	7	7	3	9	3	7

[a]ES = early seedling stage, SS = seedling stage, TS = transplanting stage, PD = panicle development stage, FS = flowering stage. Score of 1 = good tolerance, 9 = poor tolerance or dead A dash means no data recorded.

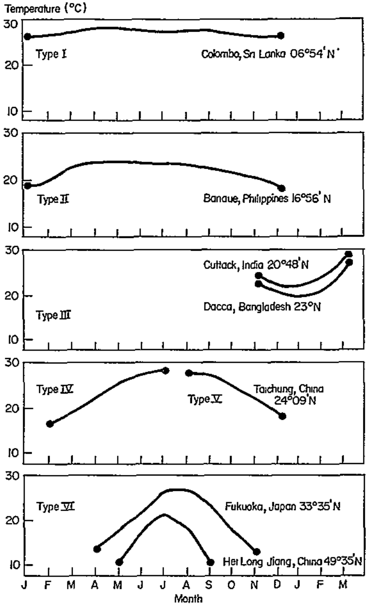
Cold tolerance and latitude. Only cold tolerance at the seedling stage (SS) was significantly correlated with the latitude of origin of the variety. Varieties from high-latitude areas generally had high tolerance for low temperature at SS.

At early seedling stage (ES), which is essentially the first 10 days of growth of the rice plant, there was no correlation between tolerance and latitude (Table 3). At that stage the nursery in some areas is usually protected from low temperature.

The varieties were generally poor in cold tolerance at the transplanting stage. Cold tolerance at panicle development stage and at anthesis showed no correlation with the latitudinal origin of the varieties. Generally, most varieties had poor cold tolerance at anthesis.

Temperature patterns. Six types of temperature patterns exist in selected rice-growing areas (Fig. 3).

- Type I — continuously high temperature (CHT). In CHT areas in the tropics, the mean temperature fluctuates little throughout the year. The average temperature is relatively high and low temperature is not a problem.
- Type II — continuously moderate temperature (CMT). There is little variation in temperature in CMT areas, but the average is less than 25° C. In those areas, maximum temperatures below 21° C can occur and cause sterility at flowering. Minimum temperature below 17° C can also occur during panicle initiation and cause sterility and reduce number of spikelets.
- Type III — high-low-high temperature (HLHT). In HLHT areas where a winter rice crop is sown, the low-temperature problem occurs during the tillering stage. The maximum temperature at sowing in November or



3. Different temperature patterns in selected rice-growing areas (World Weather Records 1974, and World Weather Handbook 1963).

December is relatively high (26°-28° C) but dips to 12°-14° C minimum temperature at active tillering stage (Jan-Feb). Subsequently, if the growth duration is relatively long, no low-temperature problem is encountered, but a very early-maturing variety may suffer from low temperature at panicle initiation.

- Type IV — low-high temperature (LHT). In subtropical LHT areas two cropping seasons are possible. The first crop sown in January-early April and harvested May-July has a low-temperature problem at sowing, but not at other stages if it is very early-maturing.
- Type V — high-low temperature (HLT). With the HLT pattern the problem is mainly low temperature at panicle development and anthesis.
- Type VI — low-high-low temperature (LHLT). In LHLT areas, low temperature is a problem at early growth stages and at reproductive and ripening stages. The shorter the growing season, the greater is the problem at late growth stages. At the tillering stage, low temperature is generally not a problem.

On the basis of the varieties' cold tolerance reaction at different growth stages, varietal cold tolerance for the six temperature patterns (Fig. 3) can be identified.

For an effective breeding program for cold tolerance, the temperature pattern of the different problem areas must be known. Areas of similar temperature patterns must be grouped so that breeding, international collaboration, and exchange of breeding materials can be more meaningful. The temperature patterns show that in many areas, it is necessary to breed for high cold tolerance only at certain specific stages.

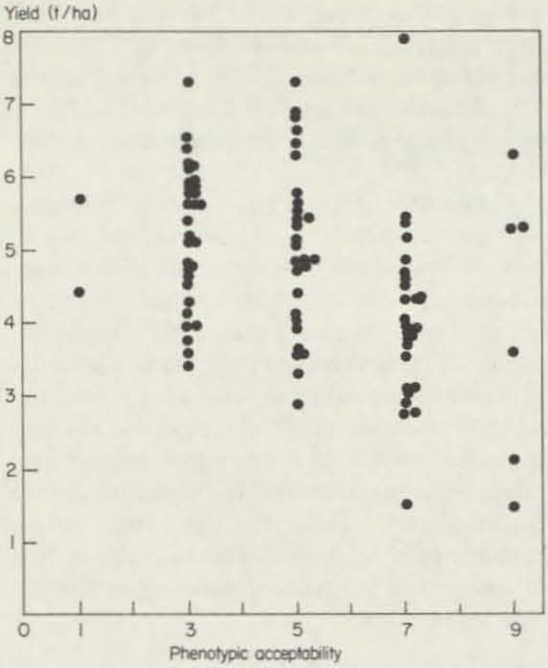
Cold-tolerant varieties from China. Eleven varieties with best cold tolerance at 4 growth stages were selected from 1,474 Chinese varieties in the IRRI germplasm bank. Early seedling stage tolerance was tested at 5° C, seedling stage at 12° C, and panicle development and flowering stages at 15° C.

All entries were sinica varieties except Hung Chao Lu Yu and Ai Yeh Lu. The agronomic characteristics among the sinica varieties selected were not greatly different. Fi-Lai-Feng had a long maturity period but was resistant to bacterial blight, Chu Cheng had the highest 1,000-grain weight. Most of the varieties did not have disease and insect resistance.

Korea-IRRI Collaborative Project. The Korea-IRRI Collaborative Project completed its third year.

Observational yield trial. One hundred entries that performed best in the cold tolerance nursery were tested for the first time in Korea under natural conditions. Many gave high yields. The best entries in terms of yield were:

China 988	6 81 t/ha
IR7167-33	6.45
IR9202-5-2-2	6.60
IR9202-6-1-1	6.51
IR9202-10-2-1-11	6 85
IR9202-10-2-1-5-1	6.30
IR15636-8-3	7.30
IR15889-32-1	7.89
Shoa-nan-tsan	6 45



4. Relationship between phenotypic acceptability and grain yield in the observational yield trial at Chuncheon, Korea. Acceptability scores are by Standard Evaluation System for Rice, 1980.

SR3044-78-3	7.30
SR4079-4-2	6.30

IR crosses were predominant among the top yielders. Most of the IR crosses included Kn-lb-361 from Indonesia. The IR9202 cross, with four promising lines, included IR2053-521-1-1/ K116//Kn-lb-361-1-8-6-9-1.

None of the top yielders had a phenotypic acceptability score of 1 because plant height and nonlodging were important criteria in scoring. Many entries had poor phenotypic acceptability but high yield (Fig. 4). Phenotypic acceptability might have been low because more weight was given to short stature in Korea where high levels of nitrogen are used.

Rice cold tolerance screening nursery. A total of 1,397 entries were screened for cold water tolerance from the vegetative stage to maturity. Each 13.5-m row entry had 17° C water at the source, and 27° C water at the outlet.

Based on excellent phenotypic acceptability at maturity, growth duration of less than 120 days, a score of 1 to 3 for leaf yellowing, a panicle exsertion score of 1 to 5, and spikelet fertility of at least 84% at the outlet, the following entries were selected:

Cheoulwon 29	SR3001-48-5-3
SR3054-55-1-2-4	SR4095-53-1-2
SR3044-1-160-2	SR5204-39-2-1
SR3044-78-3	SR5204-39-5-3

Date-of-planting experiment. The three planting dates of the IRCTN at Chuncheon provided excellent opportunities for the selection of entries with tolerance for low air temperature at the flowering stage. Most of the entries with cold tolerance at the flowering stage were from Korea. Of the entries that flowered late, the most tolerant were Anna, Silewah, and Suweon 258, which flowered between 12 and 14 September at 11.9° C average minimum temperature. No entries that flowered after 14 September had more than 50% spikelet fertility.

HIGH TEMPERATURE

Plant Physiology and Plant Breeding Departments

High-temperature tolerance of IR varieties. Spikelet fertility of IR varieties at 35° C ranged from 17% for IR46 to 74% for IR36 (Table 4). Next to IR36 in heat tolerance are IR8, IR20, IR24, and IR50.

High-temperature tolerance of some cold-tolerant varieties. The heat tolerance of eight cold-tolerant varieties was tested (Table 5). All were highly susceptible to high temperature at anthesis.

Table 4. High temperature tolerance of IR varieties. IRRI, 1980.

Variety	Fertility (%) at 35°C
IR5	19
IR8	66
IR20	67
IR22	39
IR24	62
IR26	58
IR28	50
IR29	42
IR30	27
IR32	48
IR34	39
IR36	74
IR38	37
IR40	48
IR42	62
IR43	46
IR44	36
IR45	47
IR46	17
IR48	47
IR50	67
N22 (tolerant check)	84

Table 5. High temperature tolerance of some cold-tolerant varieties at anthesis. IRRI, 1980.

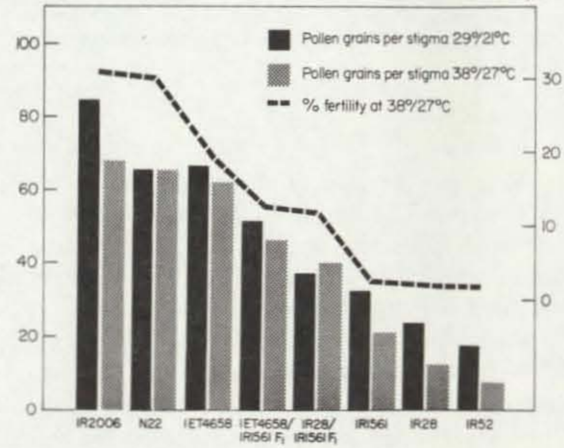
Variety	Fertility (%) at 35°C
C-21	0
Dourado Agullia	0
Leng Kwang	0
Pratao	0
Silewah	0
Somewake	18
Sorachi	27
Thangone	1
BKN6624-46-2 (susceptible check)	9
C4-63G (susceptible check)	1
N22 (tolerant check)	76

Phytotron vs field testing. Phytotron screening for heat tolerance is normally 35° C or 38° C for 8 hours from 0900 to 1700 hours. The temperature regime in the phytotron differs from that in the field in the duration of high temperature and temperature-rise pattern. Correlation of phytotron results with those obtained in the field was checked in 1980.

Data from Mishkab Rice Station, Iraq, and Imperial Valley Station, California, USA, indicate that varieties screened at 35° C in the phytotron are also tolerant of high temperature-induced sterility in the field. At the Imperial Valley Station, most lines identified as heat tolerant in the phytotron had 70-90% spikelet fertility while the US varieties Lebonnet and Starbonnet recorded only 53 and 19% spikelet fertility.

Genetics of high-temperature tolerance. A diallel cross experiment in the phytotron determined the combining ability of six lines with tolerance for high temperature-induced sterility at anthesis. The treated plants were subjected to 38° /27° C for 10 days during anthesis, and the control plants were kept under a 29° /21° C temperature regime. A heat tolerance index was calculated by dividing the fertility percentage at 38° /27° C by the fertility percentage at 29° /21° C for each genotype. General and specific combining abilities for this index were highly significant. The tolerant lines N22, IR2006-P12-12-2-2, and IET4658 (UPR96-1-1-1) had general combining abilities of 6.80, 4.08, and 3.02. The susceptible lines IR28, IR1561-228-3-3, and IR52 had general combining abilities of -3.40, -4.92, and -5.58.

The number of pollen grains shed on the stigma was measured for the six parents and two F_1 hybrids. Stigmas with more than 100 pollen grains were scored as 100. Tolerant lines shed more pollen grains on the stigma under both temperature regimes (Fig. 5). Observed pollen shedding for five of the parental genotypes growing in the field during the wet season at IRRI corresponded well with phytotron results. It appears that heat-tolerant genotypes are characterized by the ability to shed a large amount of pollen on the stigma under various environmental conditions. This trait allows them to compensate for reduced pollen growth under high temperature.



5. The number of pollen grains shed on the stigma for 6 parental genotypes and 2 F_1 hybrids is closely associated with percentage of fertility under high temperature. The data indicate that heat-tolerant lines shed a large amount of pollen on the stigma at both high temperature (38° /27° C) and the control (29° /21° C). IRRI, 1980.

Genetic evaluation and utilization (GEU) program

International Rice Testing Program

International Rice Testing Program

INTERNATIONAL NURSERIES

During 1980, 1,060 sets of 22 types of trials (nursery screening sets and collaborative research sets) were dispatched to 60 countries in the International Rice Testing network.

The results of more than 500 trials conducted in 1979-80 for the various nurseries were analyzed and reported. Further progress was made in analyzing the yield trial results on a regional basis so that scientists can quickly see which varieties are broadly adapted to their region or country.

Entries from the 1979-80 International Rice Testing Program (IRTP) trials with the highest yield performance across many sites, high phenotypic acceptability scores in various target environments, and with the best resistance to various stresses are listed in Table 1.

LINKAGES WITH NATIONAL PROGRAMS

To develop and maintain effective linkages among national programs and between IRRI and the national programs, emphasis during the past year was placed on participation in national monitoring tours. In such tours, national and IRTP scientists observe the major rice-growing areas in a given country and the national and IRTP trials intended to identify varieties for those areas. The discussions and observations during such tours encourage the selection of appropriate trials and the proper evaluation and use of the breeding and test materials.

IRRI scientists participated in national varietal improvement tours in Sri Lanka and in the Indian State of Karnataka. They also participated in two national monitoring tours in Indonesia, one focusing on the GEU activities on the main island of Java and the other one focusing on tidal swamp areas of Kalimantan. Two tours were also held in China to become acquainted with the early and late season crop.

In addition to the several national monitoring tours, two regional and two problem-oriented monitoring tours were conducted. One regional tour focused on activities in Central America and Panama. Rice scientists from all countries in the region visited Guatemala, Honduras, Nicaragua, Costa Rica, and Panama. In West Africa, a small

Table 1. The following promising entries from the 1979-80 IRTP trials had good yield performance across many sites, high phenotypic scores in target environments, or resistance to specific stresses.

Nursery	Promising entries
YIELD (yield performance across many environments)	
IRYN (Early)	IR36, IR50, IR52, B1014b-Pn-18-1-4, B2360-6-7-1-4, BR51-54-2
IRYN (Medium)	BR51-282-8, RP825-24-7-1, CR261-7039-236, IR4422-98-3-6-1, IR42, IR54, Cica 8
IRYN (Late)	CR1006, CR1009, RP1064-14-2-2, IET5656
IURYN	UPL Ri-5, IR9669 Sel., IR45, BG35-2, IR2061-522-6-9
OBSERVATIONAL (phenotypic acceptability in target environments)	
IRON (irrigated)	IR9859-45-2, IR7963-87-3-3, IR4422-480-2, IR8073-231-3-3, IR13415-9-3
IURON (upland)	C894-21, C732-14, C424-2, KN96, MRC172-9, Salumpikit, C22, Gama 318, IR3880-29, IR9575 Sel., BPI76 (NS), BG35-2, IR5929-12-3
IRLRON (rainfed lowland)	IR4215-301-2-2-6, IR4819-77-3-2, IR14632-181-1, IR14753-49-2, IR14753-66-3, IR14753-133-2, Nam Sagui
IRDWON (deep water)	BKN7022-6-4, BKN6986-147-2, BKN6986-173-5, BKN6986-108-3, BR118-3B-17, Chenab Sel. 64-117, CN539, Sitpwa, Saran Krahan
STRESS (resistance to specific stresses)	
IRCTN (cold)	JC99, Jodo, Stejaree 45, China 1039, Ahgukdo, Dadajo, Fuji 102, Shin-ei, IR579 ES38-PLP1B, IR2298 PLPB-3-19, K31-163-3, K332, Eiko
IRSATON (salinity & alkalinity)	
• Salinity	IR4595-4-1-15, IR43
• Alkalinity	IR11418-19-2-3
• Both salinity and alkalinity	Getu, CSR1, CSR2, CSR3, Pokkali
IRBN (blast)	Carreon, Tetep, IR1416-128-5-8, 5458 (Colombia), 5470 (Colombia)
IRTN (tungro)	ARC10342, DWA8, ARC13804, BKNBR1031-7-5-4, Utri Rajapan, Utri Merah
IRBPHN (brown planthopper)	IR13427-45-2, IR13427-60-1, IR17496-2-25-1
IRGMN (gall midge)	BG12-1, BKNBR1008-21, CR199-1, W1263, BG275

group of scientists visited Sierra Leone, Ivory Coast, and Nigeria to look at the national, West African Rice Development Association, and IRTP trials.

The two problem-area-related monitoring tours looked at rainfed rice in Thailand and Burma and the cold and blast problems of the hill areas of India and Nepal. After the scientists observed the vast rainfed areas of Northeast Thailand and Burma, they unanimously agreed that the breeding effort on rainfed rice must be intensified. The hill areas of India and Nepal call for strong local breeding and testing programs to identify the varieties needed for the many sites with specific environmental conditions.

PUBLICATIONS

IRTP continued to publish the various nursery reports as well as recommendations coming from monitoring tours and workshops. During 1980, the following publications were printed and dispatched to cooperators.

GENERAL REPORT

- 1979 Report of IRTP Activities

NURSERY REPORTS

1979 Final Reports
Yield
Lowland
- IRYN-E (Early)
- IRYN-M (Medium)
- IRYN-L (Late)

Upland
- IURYN

General Observational
- IRON
- IRARON (Arid Regions)

Physico-Chemical Stress
- IURON (Upland)
- IRLRON (Rainfed Lowland)
- IRDWON (Deep Water)
- IRSATON (Salinity/Alkalinity)
- IRCTN (Cold Tolerance)

Biological Stress
Diseases
- IRBN (Blast)
- IRTN (Tungro)

Insects
- IRBPHN (Brown Planthopper)
- IRGMN (Gall Midge)

FIELDBOOK

- 1980 Master Fieldbook

Genetic evaluation and utilization (GEU) program

Integrated GEU program

Plant Breeding and Statistics Departments, International Rice Testing Program, and Office of Information Services

EXCHANGE OF GERMPLASM

Plant Breeding Department

Special requests for 8,240 seed packets of improved breeding lines and varieties were filled in 1980. The International Rice Testing Program (IRTP) provided another 68,769 packets of the best GEU lines and varieties to national programs. Collaborative research with several national programs continued.

The germplasm bank provided 4,142 seed samples to 156 rice researchers in foreign countries. An increasing proportion of the seed requests was related to adverse soils, deep water, or low temperature. A similar trend was indicated in the number of requests made by GEU scientists of IRRI.

IRRI LINES NAMED IN NATIONAL PROGRAMS

Plant Breeding Department

Ten varieties from nine IRRI lines were named in national programs in 1980 (Table 1). That brought the number of named national varieties from IRRI sources to 85. Eleven varieties named directly by IRRI before 1975 bring the grand total to 96.

- IR52, released in the Philippines as a rainfed rice, matures in 115 days. It has a good level of drought tolerance.
- IR54, released in the Philippines for irrigated rice culture, has multiple resistance to major diseases and insects and matures in 120 days.
- Semeru, a short-growth-duration variety (110 days) released in Indonesia, is resistant to biotype 2 of brown planthopper present in Indonesia.
- NN6A, which is identical to Semeru, was named in Vietnam.
- NN3B, released in Vietnam, is a medium-growth-duration variety suitable for the Mekong delta.
- NN2B, released in Vietnam, is tolerant of acid sulfate soils and has multiple resistance to major diseases and insects.
- NN7A is a short-growth-duration variety (105 days) recommended for the Mekong delta of Vietnam.
- IR26, identical to its Philippine counterpart, is grown in the single-crop areas of northern Kiangsu, Hupeh, and Anhwei provinces, China. It is also the restorer parent of the F_1 hybrid varieties planted in China.

Table 1. IRRI lines named as varieties in different countries in 1980.

Variety name given	IRRI line	Country where named
IR52	IR5853-118-5	Philippines
IR54	IR5853-162-1-2-3	Philippines
Semeru	IR2307-247-2-2-3	Indonesia
NN6A	IR2307-247-2-2-3	Vietnam
NN3B	IR2797-115-3	Vietnam
NN2B	IR2823-399-5-6	Vietnam
NN7A	IR9129-192-2-3-5	Vietnam
IR26	IR1541-102-7	China
IR28	IR2061-214-3-8-2	China
32 Xuan 5	IR1561-228-3-3	China

- IR28, identical to its Philippine counterpart, is recommended for the second crop in Hunan province, China.
- 32 Xuan 5 is a multiple disease- and insect-resistant line recommended for the second crop in Hunan province, China.

BREEDING OPERATIONS

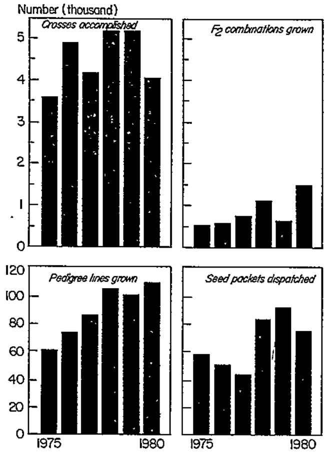
Plant Breeding Department

Crossing activity was at a level of 4,018 crosses (Fig. 1). The number of F_2 combinations grown increased sharply to 1,422, which was an all-time high. The number of pedigree lines grown increased to a record high of 109,675. Number of seed packets dispatched dropped off slightly because IRTP discontinued or reduced the size of some nurseries.

Irrigated rice. Numerous breeding lines for irrigated rice culture were tested and promising materials identified. Some of the outstanding lines are listed in Table 2. IR9752-71-3-2, IR19743-25-2-2-3-1, and IR19746-28-2-2-3 have a growth duration of less than 100 days and yield potential comparable to that of IR36. IR9129-209-2-2-2-3 has high yield potential, intermediate amylose content, and intermediate gelatinization temperature.

IR13429-109-2-2-1 and IR13429-299-1-3-1 are early-maturing lines with multiple disease and insect resistance. These two lines are resistant to three biotypes of brown planthopper in the Philippines. IR13525-43-2-3-1-3-2 and IR17494-32-1-1-3-2 are also resistant to those biotypes in the Philippines. IR15314-43-2-3-3 inherits resistance to three biotypes of brown planthopper from Babawee.

IR13423-10-2-3 and IR13423-17-1-2-1 are mul-



1. Volume of the IRRI Genetic Evaluation and Utilization program, 1975-80.

tiple resistance lines that inherit tungro resistance from Pankhari 203.

Rainfed wetland rice. For rainfed wetland rice in Asia emphasis was on an international collaborative network.

During 1980 scientists in Thailand, Burma, Bangladesh, and India were active in this network. Exchange of early generation seed was limited because of difficulties in exporting seed from many network countries. Where seed was successfully exchanged, the performance of the materials was disappointing.

In Northeast Thailand pedigree nurseries were grown at four sites. The nurseries were composed of materials selected in the previous generation from sites in the Philippines, Burma, India, and Thailand. Within a given cross the material selected in Thailand was superior in appearance. In most cases the material from other countries was unsuitable for selection. It was decided to restrict exchange of early generation seed to more specific areas, such as within Northeast Thailand, and to confine international exchange mostly to F_2 bulks distributed each year by IRRI.

Dry-seeded rice. All IRRI promising, early-maturing advanced lines were evaluated for dry-seeding as a wetland rainfed crop. The materials were seeded 6 June in 25- × 5-m plots. The trial was affected by drought in the vegetative stage but moisture was adequate prior to flowering and through maturity. A severe infestation of sheath blight at the flowering stage seriously reduced yields of some entries. No entry was significantly superior to IR36 and among those of comparable performance, none matured earlier (Table 3).

Table 2. Some promising breeding lines with multiple attributes suitable for irrigated wetland culture. IRRI, 1980.

Designation	Cross	Growth duration (days)	Amylose content (%)	Reaction[a] to Blast	Bacterial blight	Tungro	Grassy stunt	Green leafhopper	BPH[b] biotypes 1	2	3
IR8192-200-3-3-1-1	IR2070-747-6/IR2055-219// IR2061-213	120	26	6	1	3	1	3	3	3	7
IR9752-71-3-2	IR28/Kwang Chang Ai//IR36	99	25	2	1	3	1	3	3	3	7
IR9129-209-2-2-2-3	IR28/IR2053-521-1//IR36	108	22	7	1	3	1	3	3	3	7
IR13429-109-2-2-1	IR4432-53/Ptb 33//IR36	108	25	2	1	3	1	3	3	3	3
IR13429-299-2-1-3-1	IR4432-53/Ptb 33//IR36	107	26	4	1	3	1	3	3	3	3
IR13423-10-2-3	IR44/IR2588-132//IR4417-177-1	118	27	4	1	3	1	1	3	3	7
IR13423-17-1-2-1	IR44/IR2588-132//IR4417-177-1	121	27	6	1	3	1	1	3	3	6
IR13525-43-2-3-1-3-2	Ptb 33/IR30//IR36	118	27	4	1	3	1	1	1	1	3
IR15314-43-2-3-3	Babawee/IR4432-53//IR2061-628	122	26	3	1	3	1	3	3	3	3
IR17494-32-1-1-3-2	Rathu Heenati/3*IR3403-267-1	125	25	5	1	3	1	1	1	3	3
IR19743-25-2-2-3-1	IR9129-192-2///IR747B2-6/29 Lu 1//IR747B2-6	99	25	5	1	3	1	3	3	3	9
IR19746-28-2-2-3	IR9129-192///IR747B2-6/Kwang Chang-Ai//IR747B2-6	99	25	1	1	3	1	1	3	3	9

[a]Scoring based on the 1980 Standard Evaluation System for Rice. [b]Brown planthopper.

Table 3. Yield and maturity of selected IRRI breeding lines evaluated for dry seeding. IRRI, 1980 wet season

Designation	Cross	Yield (t/ha)	Maturity (DS[a])
IR2307-247-2-2	CR94-13/ IR1561-228	3.2	113
IR9093-216-3	73-1196/ IR30//IR36	3 5	110
IR9703-41-3-3	ADT 4/2*IR36	3.2	107
IR9752-1-2-1	IR28/Kwang Chang Ai//IR36	3 3	114
IR9752-222-3-2	IR28/Kwang Chang Ai//IR36	3 4	105
IR18599-68-1	IRAT 10/IR46	3.2	105
IR21018-97-1	BG 34-8/ IET 5085//IR36	3 2	115
IR36 (check)		3 2	105
LSD (.05)		0.6	

[a]Days after seeding.

Rainfed dryland rice. A substantial number of breeding lines that have moderate to high levels of drought resistance, improved yielding ability, and moderate degrees of pest resistance were evaluated at three sites: a farmer's field in Batangas province, the upland farm of IRRI, and a well-drained and low-soil-fertility site at IRRI.

A promising line with multiple attributes, IR6115-1-1 (from the cross IR1529-680-3/Moroberekan) continued to yield more than 4 t/ha (4 consecutive years) in a farmer's field in Batangas province. It has a high level of resistance to bacterial blight.

IR5931-110, from the cross MRC-172/IR1544-30-6//IR4520-76-90, is also early maturing, has good drought recovery ability, and consistently yielded nearly 4 t/ha in Batangas.

IR6023-10-1, from the cross BPI-76*9/Dawn//LAC 23, has medium-early maturity (120 days) and good drought recovery ability. It has blast resistance and tolerance for phosphorus deficiency.

A number of the breeding lines selected from dryland nurseries have been widely tested in several national programs and in IRTP nurseries. Sixteen are currently included in the Philippine Seed Board trials. IR3880-13-7, from the cross IR841-67/C22-51//Pelita I-2/IR1541-76, has shown superior performance in past years and was in seed multiplication and final testing during the 1980 wet season.

Collaborative work with other workers was expanded in drought-prone areas such as India, Brazil, and Nigeria by exchanging and evaluating advanced breeding lines. Nine single crosses were made for EMBRAPA (Brazil), 4 single crosses for IITA (Nigeria), and 125 single crosses for Indian rice breeders in drought-prone areas.

BREEDING METHODS

Plant Breeding, Plant Pathology, and Plant Physiology Departments

Although most IRRI breeding materials are handled through the conventional pedigree method of breeding, work with other breeding methods continued.

Rapid generation advance. In 1980 more than 500,000 plants involving 287 crosses were sown in rapid generation advance (RGA). The list of cooperating countries expanded to include Thailand, India, Sri Lanka, Japan, Bangladesh, Nigeria, Korea, Burma, Malaysia, and Indonesia. Research on improving RGA methods, especially the screening techniques, continued.

Crosses processed through RGA were sent to cooperators, and many crosses were planted in the field for evaluation and selection. Five RGA bulk materials were included in the 1980 International Rice Cold Tolerance Nursery and 11 in the 1980 International Rice Deepwater Observational Nursery. The Korea-IRRI Collaborative Project included 23 RGA entries.

Selection for cold tolerance at seedling stage. The possibility of screening during RGA for cold tolerance at the seedling stage of segregating F_3 materials was studied with IR20654 (K78-13/IR5908-125-1) and IR22553 (Fujisaka 5/Kn-lb-361-1-8-6-9).

Ten days after sowing, plants were subjected to 12° C water for 10 days and scored for leaf yellowing (a score of 1 was best; 9 meant almost dead or dead).

A number of F_3 plants — 4% in IR22553 and 14% in IR20654 — scored 1-3. Removal of the susceptible lines (score 7-9) eliminated 87 and 58% of the F_3 plants in the two crosses, and increased the available greenhouse space for use within 30 days after sowing. Cold water treatment at seedling stage generally delayed heading date but the delay was relatively short.

Selection for earliness. An experiment with the preceding two crosses evaluated selection for earliness during RGA. Selection of F_2 plants that flowered in 70 days or less resulted in a 31% reduction of the population for IR22553 and 12% for IR20654. Selection for earliness (< 70 days) in F_2 showed a growth duration of less than 70 days in 94% of the F_3 population of IR22553 and 84% of IR20654 F_3 population. These high values justify early selection (at F_2) for short growth duration.

Selection for earliness, however, did not select for cold tolerance at seedling stage. With selection for earliness made at F_2, a population of about 2,000 plants is the minimum for F_3 selection for cold tolerance at seedling stage.

Selection for plant height. Plants grown at low temperature are shorter than those grown at higher temperature. Selection for optimum plant height of cold-tolerant lines during RGA was studied using the given crosses. Heights of individual plants in different generations (F_2-F_4) were measured.

Although the correlations among the generations were highly significant because of the large number involved, the values were low and showed that selection for plant height should not be done during RGA.

Submergence tolerance screening. The possibility of screening for submergence tolerance during RGA was tested with nine rice varieties, including both susceptible and resistant types. The study showed that screening for submergence tolerance at seedling stage during RGA is possible. Most of the susceptible lines were eliminated and the heading date of the tolerant varieties was not greatly affected.

Mutation breeding. Ethyleneimine-derived mutants of Siyam Halus and Siyam Kuning were grown for the first time in the tidal swamps of South Kalimantan, Indonesia, the origin of their parent cultivars. Preliminary observations were promising (Fig. 2), but most of the mutants unexpectedly matured later than the Siyam Kuning check. This finding will be further investigated in 1981 using several planting dates.

Hybrid rice. Hybrid rice studies were on male sterility and fertility restoration systems, which are essential to develop hybrids, and on methods by which satisfactory seed set can be obtained on male sterile lines through natural outcrossing to produce bulk quantities of hybrid seed.

Male sterility and fertility restoration in rice.

2. Contrasting heights and leaf habits of Siyam Kuning and several of its mutant derivatives. Kalimantan, Indonesia, 1980.

Table 4. Cytosterile lines collected and maintained at IRRI, 1980.

Line	Origin	Cytoplasm source	Maintainer	Remarks
Zhen Shan 97A	China	*O. sativa f. spontanea* (WA)	Zhen Shan 97	Dwarf *indica*, highly stable for pollen sterility
V20A	China	*O. sativa* f. *spontanea* (WA)	V20	Dwarf *indica*, highly stable for pollen sterility
Er-Jiu-Nan 1A	China	*O. sativa* f. *spontanea* (WA)	Er-Jiu-Nan 1	Dwarf *indica*, highly stable for pollen sterility
V41A	China	*O. sativa* f. *spontanea* (WA)	V41	Good stigma exsertion
Yar-Ai-Zhao A	China	Gambiaca	Yar-Ai-Zhao	Semidwarf not stable for pollen sterility
Gang-yi-ya-Ai Zhao	China	Gambiaca	Gang-yi-ya-Ai Zhao	Semidwarf not stable for pollen sterility
Birco	USA	Birco	Calrose, Caloro, Colusa, ESD 7-3	Not stable for pollen sterility, poorly adaptable in the tropics
MS 517A	Korea	*O. nivara*	Wx 126-12-21	Not stable for pollen sterility
MS 519A	Korea	*O. nivara*	IR24	Appears to possess functional sterility
P 203A	IRRI	TN1	Pankhari 203	Tall, photoperiod sensitive, somewhat unstable for pollen sterility
BT MS	Japan	Chinsurah Boro II	Taichung 65	Obtained from China in F_2 of a cross of BT MS with a restorer
Wu 10A	China	Chinsurah Boro II	Wu 10	Introduced from Hunan Academy of Agricultural Sciences

Three additional cytosterile lines from China were introduced during 1980, thereby increasing the collection of cytosterile lines maintained at IRRI to 12 (Table 4). These lines are derived from six cytoplasmic sources. The cytogenetic relationship among them is not clear.

Four of the cytosterile lines — V20A, V41A, Zhen Shan 97A, and Er-Jiu-Nan 1A, all derived from *Oryza sativa* f. *spontanea* WA cytoplasm — were stable for nearly complete pollen sterility. Those lines, however, do not possess the required resistance to major diseases and insects, which is essential for their adaptation to tropical conditions. Therefore, their cytosterility was transferred into improved lines possessing the required disease and insect resistance.

By using the test cross method 14 improved breeding lines from IRRI, India, Taiwan, and Korea (Table 5), which maintained the sterility of WA male sterile lines, were identified. Some of them possess multiple disease and insect resistance. Backcrossing to the improved maintainer lines has started and 1-3 backcrosses were made. But 3-5 additional backcrosses may be required before stable male sterile lines that possess WA cytoplasm and nuclear genes of the improved maintainer lines are developed.

By test crossing with WA male sterile lines, 24 effective restorer lines originating from IRRI and India were identified (Table 6). Some of those restorer lines possess dominant genes for disease and insect resistance, which can be incorporated into the hybrid varieties. One such restorer line (IR54) was used in China for developing experi-

Table 5. Maintainers for WA cytoplasmic male sterile system identified at IRRI, 1980.

Line or variety	Origin
IR747B2-6-3	IRRI
IR9859-45-2-3	IRRI
IR10154-23-3-3	IRRI
IR10176-24-6-2	IRRI
IR10179-2-3-1	IRRI
IR19657-87-3-3	IRRI
IR19795-17-3-2	IRRI
IET4728	India
IET5324	India
IET5425	India
Suweon #105	Korea
Jikkoku Seranai 52-37	Korea
Whecheon Yukdo	Korea
C 652159/Milyang F_5 1295	Taiwan, China

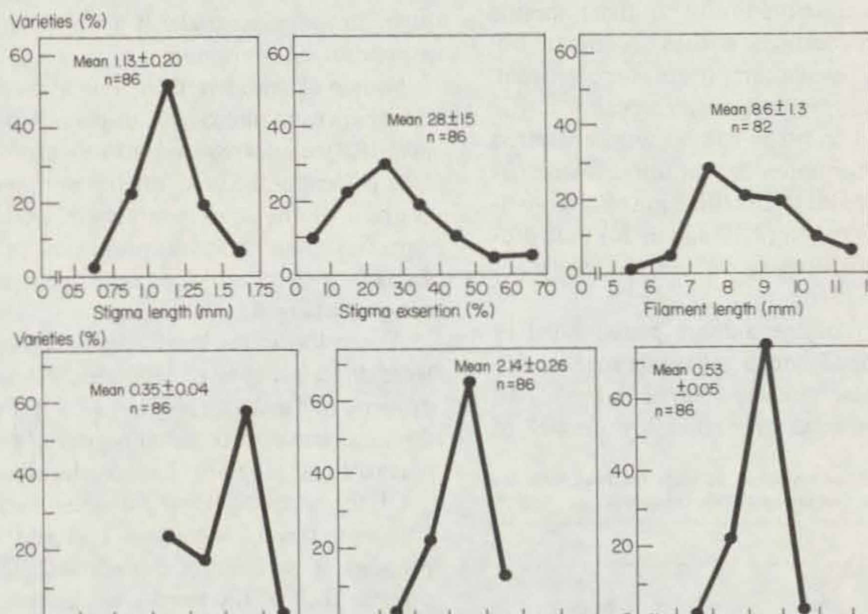
Table 6. Effective restorer lines for WA cytosterility system as identified at IRRI, 1980.

Line or variety	Origin
IR26	IRRI
IR28	IRRI
IR36	IRRI
IR42	IRRI
IR46	IRRI
IR50	IRRI
IR54	IRRI
IR2307-247-2-2-3	IRRI
IR2797-105-2-2-3	IRRI
IR9093-211-6	IRRI
IR9703-41-3-3-1	IRRI
IR9708-51-1-2	IRRI
IR9715-74-3	IRRI
IR9852-39-2	IRRI
IR13188-9	IRRI
IR13420-6-3-3-1	IRRI
IR13525-118-3-2-2	IRRI
IR13526-41-1-2	IRRI
IR15723-45-3-2	IRRI
IR17494-32-2	IRRI
IET2080	India
IET4141	India
IET5103	India
Suweon #161	Korea

mental hybrids.

During a search for new sources of cytoplasm that induces male sterility, evidence that *Oryza glaberrima* cytoplasm may also include male sterility was obtained.

Natural outcrossing on male sterile lines. Natural outcrossing of two cytosterile lines — Zhen Shan 97A and V20A — was studied during the dry season. Average seed set (mean 8-10 plants) through natural outcrossing varied from 1 to 28%, depending on the cytosterile line, direction of planting, and distance from the pollen source. Some individual plants gave as high as 35-45% seed set. Effect of distance from the pollinator was



3. Variability among selected rice varieties and breeding lines in floral traits influencing outcrossing. IRRI, 1980.

less pronounced in the plot oriented south-west, which was across the direction of wind. In that orientation the average seed set of male sterile plants 30-110 cm away from the pollen source was 22%. That seed set was attained without clipping of flag leaves and supplemental pollination as practiced in China.

Variability in floral traits exists among rice varieties (Fig. 3). Further increase in seed set on male sterile lines should be possible by selection and breeding of male sterile lines possessing well-developed and exserted stigma, and longer duration of opening of florets; and restorer lines possessing large anthers and long filaments, which would encourage cross pollination.

TISSUE CULTURE

Plant Breeding Department

A series of experiments that were started in 1979 to evaluate the application of anther culture for varietal improvement were continued. Eighty-five rice varieties were cultured and classified as high, low, and medium producers of callus and green plants (Table 7). Based on identification of varieties that performed well in a modified Linsmaer & Skoog's medium (Annual report for 1979) under specific environmental conditions, studies to compare different media and media components were initiated.

In experiments, primarily with Taipei 309, media commonly used in tissue culture were evaluated with different hormones and hormone combinations. The studies led to identification of two modified Gamborg's media (J-19 and E-24) that produced a high efficiency in callus and green plant regeneration.

Fifty percent of the anthers plated on J-19 medium developed into highly embryogenic calluses. When these were transferred to fresh J-19 medium, plant regeneration efficiency was 40% of

Table 7. Rice varieties classified as high, medium, and low producers of callus and green plants. IRRI, 1980.

High	Medium	Low
Taipei 309	IR30	IR20
Minehikari	IR40	IR38
BG90-2	Moosa Tarum	IR8
Taipei 177	Taichung 65	IR36
Nong Baek	Pelita I-1	IR28
	Mingolo	BR51-91
		Sathra 278

the anthers plated. Of the anthers plated in the E-24 medium, 22% developed multiple callus masses. When these were transferred to J-19 medium, 53% efficiency of green plant regeneration based on the number of anthers plated was observed.

Studies of agronomic characteristics among the anther culture-derived plants started. All 46 anther culture-derived plants of Taipei 309 chosen at random were shorter than the mother plant whose height is 134 cm. Of the recovered plants, 67.3% were 91-100 cm in height. Sterility was 0-73%. Among the plants, 50% were haploids, 30% autodiploids, and 20% triploids and tetraploids.

INTERNATIONAL RICE GENETIC SURVEY

Office of Information Services, Plant Breeding, International Rice Testing Program, and Statistics Departments

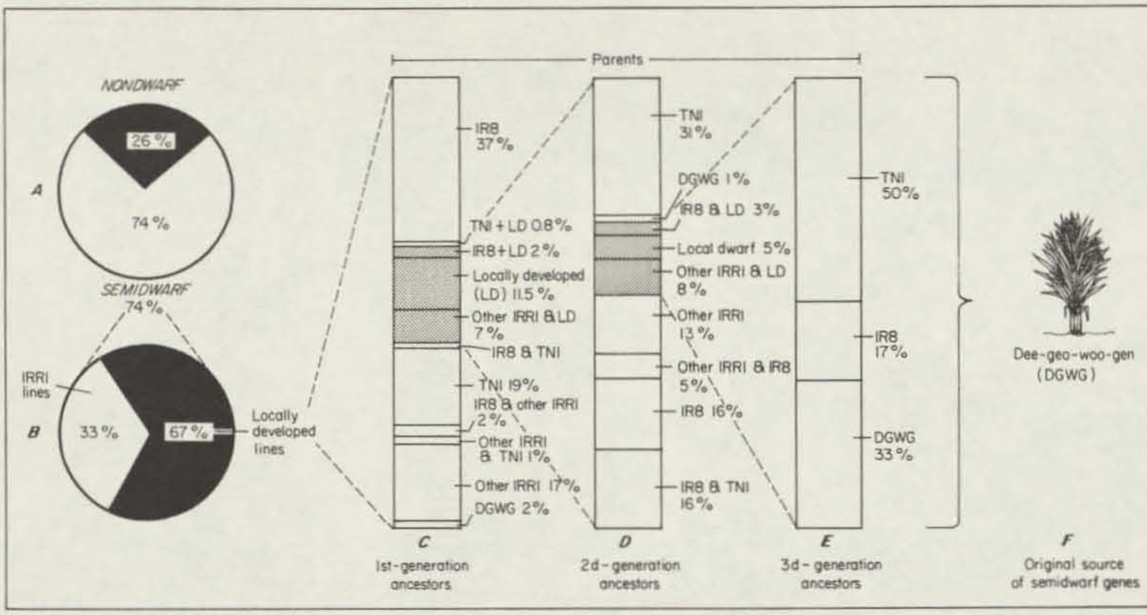
The computerization of the complete genetic ancestry of about 36,000 hybridizations made in national rice improvement programs, 500 post-IR8 varieties, and 1,100 older varieties began in 1980. The data are being incorporated into the present *History of IRRI Crosses (1-30,000)* computer program to make it an international rice genetic ancestry program.

Source of semidwarfism. The sources of semidwarfism were traced in a sample of 370 improved post-IR8 varieties released in 36 countries. Seventy-four percent of the new varieties were semidwarfs. A third of the semidwarfs were IRRI lines or varieties that national programs released to farmers; the others were developed in national programs (Fig. 4).

About 40% of the locally developed semidwarfs were direct progeny of IR8 and 22% were direct progeny of Taichung Native 1 (TN1). But 21% of the local semidwarfs were progeny of semidwarfs that national programs had developed earlier.

Of the second-generation semidwarf parents, 47% were direct progeny of TN1 and 16% were progeny of still earlier crosses with local semidwarfs. Half of the third-generation local semidwarfs were progeny of TN1 and 17% were progeny of IR8 (Fig. 4).

Cross analysis. The rice cultivars that Asian plant breeders crossed from 1965 to 1975 in India,

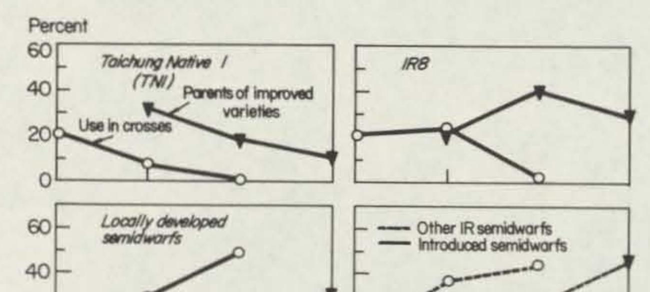


4A. Plant height groups of 370 varieties released during the post-IR8 era (1967-79). B. Ratio of 275 semidwarf varieties that were developed at IRRI or in national programs (local) and released during the post-IR8 era. C. Sources of the semidwarf genes in 183 locally developed rices released during the post-IR8 era. D. Sources of the dwarf genes in the ancestors of 38 local semidwarfs used as parents in varieties released during the post-IR8 era. E. Sources of the dwarf genes in the ancestors of 6 local semidwarfs. F. Dee-geo-woo-gen, the semidwarf gene source for almost all semidwarf varieties.

Korea, Bangladesh, Indonesia, Philippines, Sri Lanka, and Thailand were compared based on data on the genetic composition of 202 improved rice varieties developed locally and released to farmers 5 years later (1970-80) in the same countries.

TN1 was used in 22% of the crosses analyzed for 1965-67, and appeared as a parent of 40% of the new varieties released in the same countries by 1970 (Fig. 5). The subsequent decline of TN1's use as a parent was matched by a corresponding decline in its appearance as progeny among new varieties released. IR8 was seldom used as a parent by 1975, but it was a parent of 24% of the varieties released from that time until 1980.

Varieties were selected from crosses of TN1, IR8, and other semidwarfs at a greater frequency than they were used as parents. But progeny of locally developed semidwarfs appeared as varieties at a lower rate than they were used as parents.



5. Comparison of use of varieties as parents in crosses and genetic composition of improved rice varieties released from 1965 to 1980. Three hundred fifty-five randomly selected crosses involving 819 parents at 7 research centers, and 202 varieties involving 43 parents. IRRI, 1980.

Genetic evaluation and utilization (GEU) program

Computerized data management

Statistics and Plant Breeding Departments and International Rice Testing Program

GERMPLASM BANK

Statistics and Plant Breeding Departments

With the addition of 6,797 newly registered accessions of *O. sativa,* the IRRI germplasm computer data bank contained a total of 47,565 accessions by the end of 1980. Twenty-eight thousand two hundred and eighty-six accessions have complete information on the 38 basic morphoagronomic characters (Annual report for 1976), 32,101 accessions have complete information on 30 field characters, and all have varying numbers of information on the 35 GEU traits (Table 1). Seventy-five percent of the accessions in the IRRI germplasm bank are of indica type and more than 77% are from countries in South and Southeast Asia (Table 2).

A separate computer data file for the wild species of *Oryza* was created. The file contains 3,793 accessions, each with data on 85 traits.

The implementation of the computer-based seed inventory system, developed and tested in 1977, began in mid-1980 when seed stocks were transferred to standard-size aluminum cans. Information stored in the seed inventory computer file, both for seed inflow and seed outflow, consists of storage type, crop season and year of seed harvest, date processed, and amount of seed. Information on seed outflow includes the destination of the seeds. By the end of 1980, the seed inventory computer file contained 13,374 records of 4,458 acces-

Table 1. Number of accessions in the IRRI germplasm computer data bank that have information on each of the GEU traits as of 31 December 1980.

GEU trait	Accessions (no.)	GEU trait	Accessions (no.)
Bacterial leaf blight	21,405	Amylose	17,669
Blast	19,132	Gelatinization temp	14,854
Sheath blight	17,787	Drought	
Rice tungro virus	9,047	Seedling vigor	13,631
Grassy stunt virus	6,340	Rate of recovery	
Brown planthopper		After 1st stress	6,846
Biotype 1	21,685	After 2d stress	7,574
Biotype 2	4,122	Field resistance	
Biotype 3	5,908	Early vegetative	9,513
Green leafhopper	16,046	Late vegetative	12,413
Striped stem borer		Reproductive	6,230
Deadhearts	6,870	Field tolerance (3-4 bars)	1,121
Whiteheads	1,677	Field tolerance (9-10 bars)	758
Yellow stem borer		Rate of recovery from 9-10 bars	760
Deadhearts	3,869	Greenhouse screening	396
Whiteheads	2,603	Problem soil	
Rice whorl maggot	19,115	Alkalinity	879
Whitebacked planthopper	28,406	Salinity	883
Brown rice protein		Zinc	553
Dry season crop	17,587	Elongation	849
Wet season crop	13,631	Flood tolerance	4,229
		Cold tolerance	2,205

Table 2. Frequency of rice cultivar types in IRRI's germplasm bank, by region of origin and by variety group. 1980.

Region of origin	Cultivars (no.)						Percent of total
	Hybrid	Indica	Japonica	Javanica	Unknown	Total	
Africa	22	1,571	90	131	848	2,662	5.6
East Asia	18	1,479	2,100	3	781	4,381	9 2
Europe	3	40	228	11	90	372	0.8
North America	20	654	198	0	131	1,003	2.1
Oceania	1	71	15	4	8	99	0.2
South & Central America	26	519	342	13	229	1,129	2.4
South Asia	253	7,856	237	437	9,666	18,449	38.8
Southeast Asia	401	8,797	234	2,023	6,922	18,377	38.6
Southwest Asia	0	42	17	1	100	160	0.3
Others	1	220	126	4	582	933	2.0
Total	745	21,249	3,587	2,627	19,357	47,565	100 0

sions. The system is used to monitor the movement of seed stocks and to provide instant information on the current status and location of the seed stocks for each accession. Such information is necessary not only for seed distribution, which is the principal service of the germplasm bank, but also for seed rejuvenation.

BREEDING AND TESTING

Statistics and Plant Breeding Departments

With the rapid increase in the number of crosses made at IRRI and the increasing number of requests for information on the parentage of the crosses, a computer file on the parentage of IR crosses was created in 1976. In 1980, the 4,621 IR crosses made during the year were added to the file, bringing the total to 33,898 crosses.

The first volume of the compact version of the *Parentage of IRRI crosses,* including IR1-IR30,000, was produced and distributed to rice researchers. This version replaces the bulky series of 10,000 crosses each, produced in 1978.

The integration and close linkage between the history-of-IR-cross system and the testing and evaluation operations, initiated for the 1980 nurseries, made it possible for the names of the parents of each new cross to be automatically retrieved from the respective nursery files. This feature has greatly minimized the labor required, the transcribing errors, and subsequent delays in the inputting of information into the history-of-IR-cross file.

In 1980, the history-of-IR-cross file was put to another use: the retrieval of crosses whose ancestry satisfies a given set of requirements. An example of the output is a list of all IR crosses with at least four ancestors that are resistant to bacterial leaf blight (Table 3).

Efforts to expand the history-of-IR-cross system to cover rice crosses made in the various national programs continued in 1980, with emphasis given to the accumulation of information, the creation of the history-of-non-IR-cross data files, and the modification of the existing programs so as to support the non-IR crosses. Records of parent-

Table 3. List of IR crosses with at least 4 ancestors coming from the prescribed set of 15 varieties[a] known to have different genes for bacterial leaf blight. IRRI, 1980.

Ancestor combination	No. of crosses	IR cross no											
2, 12, 13, 14	1	27110											
4, 8, 13, 14	1	33644											
5, 7, 13, 14	1	33206											
5, 8, 13, 14	2	28231	33419										
5, 9, 11, 14	1	19253											
5, 11, 13, 14	1	23898											
5, 12, 13, 14	6	27306	33033	33060	33422	33423	33649						
6, 9, 11, 14	1	24617											
7, 8, 13, 14	3	23933	32824	33444									
7, 9, 11, 14	5	16958	20285	22960	24746	24758							
7, 12, 13, 14	3	19588	32827	33624									
7, 13, 14, 15	1	19311											
8, 9, 11, 14	21	20279	20281	21324	21351	22433	23904-23910		23912				
		23913	24616	24618	24743	24748	26922	26923	26930				
8, 9, 13, 14	3	23825	23856	23934									
8, 9, 14, 15	1	23848											
8, 12, 13, 14	29	25587	27315	27327	28114	28179	28204	32837	32839	32841	32847-32854		
		33047	33049	33050	33051	33062	33251	33304	33385	33499	33505	33648	33671
9, 11, 13, 14	18	16955	16956	18119	19417-19419		20266	20273	20282	21284	21415	21416	22959
		24621	24754	24759	26906	28971							
10, 12, 13, 14	1	27078											
10, 13, 14, 15	4	16777	27077	27085	27092								
11, 12, 13, 14	2	26904	28970										
4, 8, 12, 13, 14	1	33670											
5, 8, 12, 13, 14	2	28202	33421										
6, 8, 12, 13, 14	1	28119											
7, 8, 9, 11, 14	1	23911											
7, 9, 11, 13, 14	1	24755											
8, 9, 11, 13, 14	2	24324	24615										
9, 11, 12, 13, 14	2	26907	26915										

[a]1 = AUS 32, 2 = AUS 81, 3 = BASHFUL, 4 = BEAK GANGGAS, 5 = BG90-2, 6 = BJ1, 7 = DZ192, 8 = NAM SA-GUI 19, 9 = PELITA I-1, 10 = PELITA I-2, 11 = POKKALI, 12 = R. HEENATI, 13 = SIGADIS, 14 = TKM6, 15 = ZENITH

age of more than 17,000 crosses made in 16 national breeding programs are currently in the file.

INTERNATIONAL RICE TESTING PROGRAM

Statistics Department and International Rice Testing Program

Data for the International Rice Cold Tolerance Nursery (IRCTN) were computerized in 1980. That brought to 14 the number of nurseries for which data for crop years from 1976 to 1979 are stored in computer files (Table 4). The files allow for instant retrieval of desired information.

In addition to the Generalized IRTP Information Retrieval System (Phase I) completed in 1979, a specific computer program for retrieving data from any of the stress nurseries (IRBPHN, IRBN, etc.), based on a prescribed set of sites and crop years, was developed. This facilitates the examination of variability of reactions to a given stress across sites or years, or both.

A master file of IRTP entries was created. The file includes not only entries tested in at least one of the IRTP nurseries but also entries nominated by the IRTP cooperators although not yet included in a nursery. The IRTP master file consists of a 5-digit IRTP number, which uniquely identifies each rice variety or line ever nominated for inclusion in one or more IRTP nurseries, followed by the entry's name, cross and origin, and a specification of its *nomination* status. Rapid identification of entries nominated by the IRTP cooperators but not yet tested in any nursery is necessary for nursery composition.

Table 4. International Rice Testing Program nurseries that have been computerized[a] by the end of 1980.

Nursery name	I.D.	Years (no.) for which data are in computer files
International Rice Yield Nursery-Early	IRYN-E	4
International Rice Yield Nursery-Medium	IRYN-M	4
International Rice Yield Nursery-Late	IRYN-L	3
International Upland Rice Yield Nursery	IURYN	4
International Rice Observational Nursery	IRON	4
International Rice Cold Tolerance Nursery	IRCTN	2
International Upland Rice Observational Nursery	IURON	4
International Rainfed Lowland Rice Observational Nursery	IRLRON	2
International Rice Blast Nursery	IRBN	4
International Rice Tungro Nursery	IRTN	4
International Rice Sheath Blight Nursery	IRSHBN	2
International Rice Brown Planthopper Nursery	IRBPHN	4
International Rice Stem Borer Nursery	IRSBN	2
International Rice Gall Midge Nursery	IRGMN	4

[a]Both for data processing (i.e., statistical analysis and summary tables) and storage and retrieval purposes

Control and management of rice pests

Diseases

Plant Pathology Department

BLAST

Seed treatment. Seed treatment with systemic fungicides at various rates were tested (Table 1). In one test, Tricyclazole at the rates of 1, 2, and 4 g formulation/kg seeds produced slight to moderate leaf blast control. The lowest seed germination percentage obtained from 4 g Tricyclazole in the first test could not be attributed mainly to the toxic effect of the chemical as shown in the second test. All tested rates of thiophanate-methyl exhibited moderate blast control.

Seed treatment with four systemic fungicides confirmed that CGA 49104 and PP389 JF5816 are the best seed-treatment fungicides for leaf blast control (Table 2). CGA 49104 at 8 and 4 g and

Table 1. Leaf blast control with systemic fungicides as seed treatment for IR442-2-58 and seed germination when seedlings were exposed to *Pyricularia oryzae* in the blast nursery. IRRI, 1980.

Chemical	Rate (g formulation/ kg seed)	Blast lesions[a] (no /seedling)						Seed germination (%) 1 WS
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS	
		Test 1						
Tricyclazole (75% WP)	4	19.4	56.9	64 5	78.2	84.8	88 1	66 4
	2	25 2	66.1	70 3	90 0	92 6	97 3	82 8
	1	24 4	73.0	76.1	92 1	103 0	104 1	79 2
Thiophanate-methyl (70% WP)	32	28 3	67.9	70 3	81 1	88 9	90 9	80.4
	16	32.5	71.6	75 5	91.8	98 2	101 7	74 8
	8	40 7	80.0	82 9	94 8	106.7	109 1	80 0
No chemical (untreated seeds)	0	40.7	89.0	111 3	125 2	134 9	138 0	80 4
		Test 2						
Thiophanate-methyl (70% WP)	32		16.3	52 6	65 2	67 8	69.7	88.8
	16		14 2	55 8	76 8	80 0	81 8	88.8
	8		18 6	77 0	90 3	102 7	105 1	88 8
Tricyclazole (75% WP)	4		5.4	63.0	90 4	104 9	111 7	85 6
	2		10 6	83 5	111 0	122 6	127 0	84.8
	1		15 4	99 8	136 8	142 1	144 4	86 0
No chemical (untreated seeds)	0		20.1	93 0	117 2	122 9	126 6	88 4

[a]Mean of 25 seedlings used for disease readings WS = weeks after seeding

Table 2. Leaf blast control in IR442-2-58 seedlings exposed to *Pyricularia oryzae* in the blast nursery when seeds were treated with systemic fungicides IRRI, 1980

Chemical	Rate (g formulation/ kg seed)	Blast lesions[a] (no /seedling)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
		Test 1					
PP389 JF5816 (50% WP)	40	0 0	0 0	0 0	0 0	0 0	0 0
	20	0 0	0.0	0 0	0 0	0 0	0 4
CGA 49104 (50% WP)	8	0 0	0 0	0.0	0 0	0 0	0.0
	4	0.0	0 0	0.0	0 0	0 0	1 2
Benomyl (50% WP)	40	0.0	0 0	0 0	0.3	0.3	1 9
	20	0 0	0 2	0 7	1.4	2 8	8 4
Thiophanate-methyl (70% WP)	40	0 0	1 2	1 2	1 3	2 2	4 7
	20	1.4	4 4	6.9	8.5	12 6	15 8
No chemical (untreated seeds)	0	4 8	17.6	23 2	28 3	32 8	38 3
		Test 2					
CGA 49104 (50% WP)	8	0 0	0 0	0 0	0.0	0.0	0 0
	4	0 0	1.4	1 8	1 8	1 8	1 8
PP389 JF5816 (50% WP)	40	0 0	0.0	0.0	0 0	2 2	2 4
	20	0 0	0 3	2 0	2 0	5 5	7.6
Thiophanate-methyl (70% WP)	40	0 7	4.8	7.6	11.1	16.7	18.3
	20	2 7	13.9	15.9	16 0	24 9	27 3
Benomyl (50% WP)	40	9.8	15 4	16 8	19 7	25 6	29 9
	20	11.9	24 3	27.3	28 7	36 8	40 8
No chemical (untreated seeds)	0	12.6	24.4	38 8	42.7	79.7	102.5

[a]Mean of 25 seedlings used for disease readings WS = weeks after seeding

Table 3. Leaf blast control with fungicide sprays on seedlings exposed to *Pyricularia oryzae* in the blast nursery[a] IRRI, 1980

Chemical	Rate (kg or liters formulation/ ha per application)	Blast lesions[b] (no /seedling)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
CGA 49104 (50% WP)	1.0	0.0	0.0	0 0	0 1	0 1	0 1
Tricyclazole (75% WP)	0 7	1.1	1 5	1 5	1 8	2 0	2 5
Benomyl (50% WP)	1 0	0 4	0 4	1 3	3 2	5 0	6 2
PP389 JF5816 (50% WP)	1.0	6.6	13 2	14 6	17 8	18 9	20 0
Thiophanate-methyl (70% WP)	1 0	2 8	19 0	42.0	72.9	83 4	86 0
Edifenphos TCP (35% WP)	1.0	9.5	28 8	44.5	79 5	84 3	89 2
Edifenphos (50% EC)	1 0	1.8	22 6	53 7	88.8	106 4	108 7
No chemical (unsprayed seedlings)	0.0	10.8	39 4	71.9	111 9	119.3	123 2

[a]The first spray was applied 2 weeks after seeding (WS) and 2 subsequent applications were made at 1-week intervals Sprayed seedlings were immediately exposed in the blast nursery [b]Mean of 25 IR442-2-58 seedlings used for disease readings. Seedlings were grown in plastic trays

Table 4. Leaf blast control with fungicide sprays on rice seedlings[a] IRRI, 1980.

Chemical	Rate (kg or liters formulation/ ha per application)	Blast lesions[b] (no /seedling)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
CGA 49104 (50% WP)	1.0	19.1	23.6	24 2	24 6	26.3	26 6
PP389 JF5816 (50% WP)	1.0	22.2	36 1	44 1	46 4	47 2	48.0
Tricyclazole (75% WP)	0 7	18 9	37 1	47.8	48 5	49 3	50.2
Edifenphos TCP (35% WP)	1.0	21 6	33 8	42 5	44.2	49 9	51.9
Benomyl (50% WP)	1.0	31.0	47 6	54.2	60 6	63 1	65 9
Thiophanate-methyl (70% WP)	1.0	31.9	53 0	68 0	73 4	76.6	79 7
Edifenphos (50% EC)	1.0	23 7	49.9	69 5	75 5	78.2	80 8
Triphenyltin acetate (60% WP)	1 0	33 2	60 5	74 8	82 7	96 1	100 7
No chemical (unsprayed seedlings)	0.0	34.7	65.2	85 7	95 5	105 5	110 2

[a]The first spray was applied 2 weeks after seeding (WS) and 2 subsequent applications were made at 1-week intervals Plots were located in the blast nursery. [b]Mean of 3 replications of IR442-2-58 From each replication, 25 seedlings were used for disease readings

PP389 JF5816 at 40 and 20 g effectively controlled leaf blast. Benomyl and thiophanate-methyl were also effective.

Foliar sprays. Foliar spray tests of systemic and nonsystemic fungicides confirmed CGA 49104 at 1.0 kg formulation/ha as most effective for leaf blast control (Table 3, 4). Other effective chemicals were Tricyclazole at 0.7 kg, and PP389 JF5816 and benomyl, each at 1.0 kg.

Soil treatment. In soil treatment tests of systemic granular fungicides CGA 49104 (5% G) at the rates of 3 and 6 g formulation/m^2 was outstanding (Table 5). Other systemic granular fungicides that gave effective leaf blast control were Oryzemate (8% G), IBP (17% G), and Fuji-One (12% G) at 2 and 4 g.

A test of the effect of different nitrogen levels on the efficacy of CGA 49104 (5% G) for leaf blast control showed excellent control at 600 and 300 kg formulation/ha and effective control at the low rate of 50 kg/ha at nitrogen levels ranging from 120 to 480 kg N/ha (Table 6).

A replicated trial of the granular systemics in the blast nursery confirmed the outstanding performance of CGA 49104 (5% G) (Table 7). Fuji-One at 4 and 2 g, and IBP and Oryzemate, each at 6 and 3 g, showed moderately effective leaf blast control.

SHEATH BLIGHT

Seed treatment. Tests of seed treatment with systemic fungicides indicated benomyl at 40 g formulation/kg seed to be most effective for sheath blight control in seedlings (Table 8).

Foliar sprays. A foliar spray test in the greenhouse showed triphenyltin acetate (60% WP) at 1.0 kg formulation/ha per application to be effective for sheath blight control in seedlings (Table 9).

Table 5 Leaf blast control with granular systemic fungicides as soil treatment.[a] IRRI, 1980.

Chemical	Rate (g formulation/m²)	Blast lesions[b] (no./seedling)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
		Test 1					
CGA 49104 (5% G)	6	0 0	0.0	0.0	0.0	0 0	0.0
	3	0 0	0.0	0 0	0 0	0.0	0.0
Oryzemate (8% G)	6	0 4	1.2	3.1	3 4	4.7	4 7
	3	2.1	3.6	4 0	4.5	5.7	8 5
IBP (17% G)	6	0.0	2.0	3.4	5 2	6.3	13 9
	3	2.9	5.9	7.5	8 7	10 8	14.0
Fuji-One (12% G)	4	11 4	23 7	28 6	29 2	30 8	31.5
	2	10 2	24.2	29.6	33.2	34 8	36 5
No chemical (untreated soil)	0	14 1	51.0	76 1	88 6	93 3	96 1
		Test 2					
CGA 49104 (5% G)	6	0 0	0.0	0 0	0 0	0 8	2.7
	3	0.0	0.0	0.3	0 3	2.5	5 2
Oryzemate (8% G)	6	0 9	4 4	7 7	7.7	18 4	19.5
	3	0 5	8 8	14.6	15.1	41.1	47.8
Fuji-One (12% G)	4	0.6	11.3	16 8	16 8	28.1	30.3
	2	2 4	18 0	26 6	27.1	37 6	45 6
No chemical (untreated soil)	0	4.2	25.5	35 2	42.1	60.5	61.7

[a]Five rows of IR442-2-58 were seeded in treated soil in plastic trays and allowed to grow inside the greenhouse The seedlings were exposed to *Pyricularia oryzae* in the blast nursery 2 weeks after seeding (WS). [b]Mean of 25 seedlings used for disease readings.

Table 6. Effect of nitrogen fertilizer levels on the efficacy of granular systemic fungicide CGA 49104 (5% G) for leaf blast control when seedlings were exposed to *Pyricularia oryzae* in the blast nursery.[a] IRRI, 1980.

Rate (kg formulation/ha)	Nitrogen levels (kg N/ha)	Blast lesions[b] (no./seedling)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
600	120	0	0	0	0	0	0
	240	0	0	0	0	0	0
	360	0	0	0	0	0	0
	480	0	0	0	0	0	0
300	120	0	0	0	0	0	0
	240	0	0	0	0	0	0
	360	0	0	0	0	0.5	0.5
	480	0	0	0	0	6 4	6.4
50	120	0	0	0	0	0 2	0 2
	240	0	0	0	0	7 5	7.5
	360	0	0	0	0	8 9	9.5
	480	0	0	0	0	11 1	11 7
0	120	0	3.5	18 8	32 6	37.1	39 8
	240	0 2	6.7	25 9	39 1	48 0	52.3
	360	0 4	9.5	33.1	53 9	75.3	81.4
	480	1 0	13 3	47 3	67.4	85 2	90 9

[a]IR442-2-58 seedlings grown in plastic cups containing treated and untreated soils were exposed in the blast nursery 2 weeks after seeding (WS). [b]Mean of 3 replications From each replication, 25 seedlings were used for disease readings

Likewise chlorothalonil (75% WP) at 1 kg/ha and validamycin A (3% solution) at 2 liters/ha were also effective.

In a field test of benomyl at the rate of 1.0 kg formulation/ha, all plots showed effective sheath blight control on naturally infected IR36 plants grown at different levels of nitrogen fertilizer (Table 10). Sheath blight infection was higher in plots with higher nitrogen levels.

In a field trial of 19 fungicides used as foliar sprays for sheath blight control, NTN 19701 (25% WP) applied at the rate of 1.5 kg formulation/ha per application was effective, as were validamycin A at 2 liters/ha, iprodione at 2 kg/ha, and triphenyltin acetate at 0.6 kg/ha (Table 11).

Table 7. Leaf blast control with granular systemic fungicides as soil treatment in the blast nursery.[a] IRRI, 1980

Chemical	Rate (g formulatıon/m²)	Blast lesıons[b] (no /seedlıng)					
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS
CGA 49104 (5% G)	6	0 0	0 5	2.1	3.7	5 5	6.7
	3	0 0	6 3	18 2	22 6	25 7	28 6
Fujı-One (12% G)	4	30.9	66 3	83 6	95 9	101 6	105 1
	2	34 5	71 9	96.1	109.0	116.0	118.9
IBP (17% G)	6	22 7	68.0	88.7	98 5	104 5	113 5
	3	28.1	75 7	97 2	110.1	117 4	129.4
Oryzemate (8% G)	6	22.0	74 0	93.7	104 4	109 3	113.8
	3	29 9	82.4	115.1	126.1	132.6	135.4
No chemıcal (untreated soıl)	0	40 2	89 5	128.0	149.7	168 5	177.4

[a]IR442-2-58 was seeded in 10-row plots (0 5 × 1.0 m/plot) at the rate of 5 g seeds/0 5-m row immediately after applyıng the granular fungicides to the soil. [b]Mean of 3 replicatıons From each replıcation, 25 seedlıngs were used for dısease readings WS = weeks after seedıng.

Table 8. Sheath blight control with systemic fungicides as seed treatment for rice seedlings inoculated 3 weeks after seedıng. IRRI, 1980.

Chemical	Rate (g or ml formulation/ kg seeds)	Infection[a] (%)			
		4 WS	5 WS	6 WS	7 WS
Benomyl (50% WP)	40.0	0.0	1.6	7 9	7.1
	20 0	7 6	16 4	25 3	25.8
Thiophanate-methyl (70% WP)	40.0	4.4	13 6	29 3	29 7
	20.0	23 2	21 4	33.7	33 4
PP389 JF5816 (50% WP)	40 0	17.7	22 4	30.6	29.9
	20 0	45.1	41.0	37.0	34.6
RH-2161 (2% EC)	0 6	33.1	35 3	31 5	32 9
Mebenil (75% WP)	4 0	53 7	50 9	42.9	42.4
	2.0	42.3	58 1	50 5	48 8
Trıcyclazole (75% WP)	2 6	46 3	44.5	40 9	45 9
No chemıcal (untreated seeds)	0 0	54.1	61.1	56 7	53.7

[a]Mean of leaf sheath and leaf blade ınfections of 3 replıcatıons. From each replıcatıon, 25 seedlıngs were used for dısease readıngs

Table 9. Sheath blight control with fungicide sprays for seedlings artificially inoculated 1 to 2 days after the first spray application.[a] IRRI, 1980.

Chemıcal	Rate (kg or lıter formulatıon/ha per application)	Infection[b] (%)					
		4 WS	5 WS	6 WS	7 WS	8 WS	9 WS
Triphenyltın acetate (60% WP)	1.0	7 9	1 7	2 4	2 2	1 7	5 6
Chlorothalonil (75% WP)	1.0	3.5	11.8	11 5	13 0	11.5	11 8
Valıdamycin A (3% solution)	2.0	18 6	8 4	10.1	13.2	13 7	13.8
Zinc Omadıne (48% dıspersion)	2.0	42 7	67.1	65 4	64 9	65 6	62.7
No chemical (unsprayed seedlings)	0 0	41.7	50 8	47 9	52 8	50 9	50.9

[a]The fırst spray was applıed 3 weeks after seeding (WS), and 2 subsequent applıcations were made at 1-week intervals [b]Mean of leaf sheaths and leaf blades of 25 IR1317-392-1-2 seedlings used for disease readings. The seedlings were grown ın plastic trays.

BAKANAE

Yield loss in rice due to bakanae. A 1979 survey of 32 sites in Laguna province showed the percentage of rice tillers infected with bakanae disease ranged from 0.60 to 12.8%. There was a positive correlation between percentage of infection and percentage yield loss.

A 1980 pot experiment in the greenhouse determined death or recovery from bakanae, and yield loss caused by the disease at disease incidences ranging from 10 to 100%. Death of seedlings

Table 10. Sheath blight control with benomyl fungicide sprays on IR36 in the field. IRRI, 1980.

Treatment (av kg N/ha)	Sheath blight disease rating[a]		
	Sprayed plants	Unsprayed plants	Mean
18.3	3.0	5.1	4 1
32.0	3.1	5.6	4 4
32.3	2.1	5 9	4.0
48 3	2 1	6 2	4 2
50.0	3 5	6.2	4 9
65 5	3.6	6 4	5.0
67.0	3.2	6 1	4.7
75.0	4.0	6 4	5 2

[a]Mean of 4 replications, each replication with 8-m^2 plots Ten hills picked at random from each plot were used for disease reading and rated by the 1980 Standard Evaluation System for Rice.

tended to increase at 10 to 80% initial disease incidence, but decreased at 90 and 100% (Table 12). Seedling recovery increased as initial disease incidence increased.

The loss in 1,000-grain weight ranged from 2.3 to 11.8%. Actual yield loss ranged from 2.8 to 43.7%, based on the yield from healthy plants (Table 13). There was a positive correlation between percentage of disease incidence and percentage of yield loss. The correlation coefficient (*Y*) was 0.9681 for yield from plants from seeds treated with benomyl, 0.9597 for plants from seeds treated with benomyl and weekly sprays of benomyl until maturity, and 0.9606 for plants from seeds treated with benomyl and weekly sprays of Homai.

Degree of bakanae seed infection. A study compared direct seeding and 18 hours water-soaking of seeds harvested from fields naturally infected with bakanae. More seedlings exhibited abnormal elongation when seeds were soaked before seeding (Table 14). This indicates that evaluation of fungicides as presprouting treatment (18- to 24-hour soaking of naturally infected seeds) is suitable.

Artificial field inoculations with *Fusarium moniliforme*. Bakanae fungus spore suspensions were used to inoculate at flowering IR42 plants grown from naturally infected seeds. Infection of harvested seed increased from 2.6% to 18.0% (Table 15).

Two weekly sprays of benomyl 50% WP at 1.0 kg formulation/ha per application before inoculation resulted in fewer infected seeds than in the inoculated unsprayed plots (Table 16). However, a higher seed infection was obtained from inoculated plots sprayed twice after plant inoculation.

Presprouting treatment of naturally infected seeds. IR40 and IR42 seeds purchased from farmers with bakanae-infected fields were soaked

Table 11. Sheath blight control with fungicide sprays in the field.[a] IRRI, 1980.

Chemical	Rate (kg or liter formulation/ ha per application)	Sheath blight disease rating[b]	Disease control (%)
NTN 19701 (25% WP)	1.5	1.9	51 3
Validamycin A (3% solution)	2.0	2 3	41.0
Iprodione (50% WP)	2.0	2.3	41 0
Triphenyltin acetate (60% WP)	0 6	2 4	38.5
BTS 40542 (40% EC)	2 0	2 9	25.6
Hoe 00662 (47.5% WP)	0.4	3.0	23 1
Ditalimfos (50% WP)	1 0	3.0	23 1
Chevron 26745 (50% WP)	0.5	3 0	23 1
PH50-98 (20% wt/vol)	3 0	3.2	18.0
CGA 64250 (25% EC)	1 0	3 2	18.0
Chevron 20615 (50% WP)	0 5	3 3	15 4
Pyrazophos (30% EC)	3.0	3.4	12 8
Hoe 25986 (75% WP)	0 8	3 4	12 8
Chlorothalonil 500 (40.4% flowable)	4 0	3 4	12.8
Top Cop (54 4% flowable)	4.0	3.5	10 3
Benomyl (50% WP)	1 0	3.6	7 7
Hoe 00663 (62.5% dispersion)	0 3	3.7	5.1
Dowco 444 (72.1% EC)	0 8	3 8	2.6
WL-28325	1.0	3 8	2 6
No chemical (unsprayed plants)	0 0	3.9	—

[a]The first spray was applied when panicles were about 2-5 cm, and the second or last, 3 weeks later at about 80 to 90% heading. The plants were artificially inoculated with the rice-grain-hull culture of the sheath blight fungus 1 to 2 days after the first spray application. [b]Mean of 5 replications of IR442-2-58, each replication with an 11 2-m^2 plot From each plot 10 hills picked at random were scored by the 1980 Standard Evaluation System for Rice

Table 12. Recovery or death of bakanae-infected IR42 seedlings with different initial disease incidences.[a] IRRI, 1980.

Initial disease incidence (%)	Av of dead seedlings (%)	Av of seedlings that recovered (%)
10	2 8	55.0
20	5 3	60.0
30	5 6	63.4
40	6.0	68.8
50	8.2	69 0
60	8.7	70.9
70	9 2	76 5
80	10.9	78.1
90	7.1	80.6
100	5.9	88 0
None (seeds treated with benomyl)	0	
None (seeds treated with benomyl and seedlings sprayed with benomyl)	0	
None (seeds treated with benomyl and seedlings sprayed with Homai)	0	

[a]Av of 5 replications

for 24 hours in benomyl suspension and then incubated in moist jute sacks for 48 hours. The presprouted seed was sown in dapog beds and infected seedlings were counted 10 and 14 days after seeding.

The test showed that although the two varieties differed in degree of seed infection, benomyl at a concentration of 2.0 g formulation/liter suspension for seed soaking was effective in controlling bakanae in both (Table 17).

Benomyl-treated and untreated seedlings of both varieties were planted in a split-plot experimental design and 2 weekly benomyl sprays were applied. The plants grown from benomyl-treated seeds of both varieties exhibited less than 1% infected hills; those from the untreated seeds had 12 to 18% infection in IR40 and 21 to 29% infection in IR42 (Table 18). The 2 weekly benomyl sprays did not significantly reduce the number of infected hills.

In similar tests of benomyl used at three concentrations for soaking naturally infected IR42 seeds obtained from two sources, the initial and repeated (second) use of each concentration and suspension showed effective bakanae control in the dapog beds (Table 19). At 10 days after seeding the 3 concentrations exhibited slight differences in number of infected seedlings.

Three chemicals besides benomyl were tested at 2.0 and 1.0 g formulation/liter suspension as presprouting treatment: benomyl-thiram (40% WP), thiophanate-methyl-thiram (80% WP), and thiophanate-methyl (70% WP) gave effective bakanae

Table 13. Yield losses (1,000-grain weight and actual yield) in relation to bakanae disease incidence[a] IRRI, 1980.

Initial disease incidence (%)	Loss in 1,000-grain wt (%)			Loss in grain yield pot (%)		
	X̄K	X̄L	X̄M	X̄K	X̄L	X̄M
10	2 3	5.1	2.7	2.8	18.4	18 4
20	4 1	6.3	4 5	9 1	23.7	23 6
30	4 4	7.3	4.8	15.9	29 4	29 3
40	4 7	7 5	5.1	16.1	29.5	29.5
50	5.4	8.2	5 8	18 0	31.2	31.1
60	5 4	7.4	5 8	21.9	34.5	34 4
70	6 2	8 9	6 5	23 3	35.6	35 6
80	6 1	8 9	6 5	29.4	40 8	40.7
90	6 2	9 3	6 9	31 7	42 6	42 6
100	9.1	11 8	9 5	32.9	43 7	43 6

[a]Av of 5 replications X̄K = av loss based on plants from seeds treated with benomyl; X̄L = av loss based on plants with benomyl seed treatment and sprayed weekly with benomyl until maturity, X̄M = av loss based on plants with benomyl seed treatment and sprayed weekly with Homai until maturity.

Table 14. Comparison of 2 planting methods used in determining the degree of seed infection with *Fusarium moniliforme* in terms of abnormal elongation symptoms in seedlings from naturally infected IR42 seeds. IRRI, 1980.

Planting method	Infected seedlings[a] (no)			
	Rep. 1	Rep 2	Rep 3	Mean
Direct seeding of seeds in plastic trays containing soil	120	83	101	101 3
Soaking seeds in tap water for 18 hours before seeding in plastic trays with soil	174	155	219	182.7

[a]Counted 15 days after seeding, from seedlings grown from 150 g seeds/replication Rep. = replication.

Table 15. Incidence of bakanae-infected seeds after artificial field inoculations with *Fusarium moniliforme* spore suspension.[a] IRRI, 1980.

Treatment	Seeds with *Fusarium moniliforme*[b] (%)
Uninoculated	2 6
Inoculated	18 0

[a]Plants grown from benomyl-treated (presprouting treatment) and untreated naturally infected IR42 seeds were inoculated 3 times at 2- to 3-day intervals at the time the flowers opened. [b]Mean of 8 replications. From each replication, 100 seeds were used in determining the number of infected seeds using Komada's selective medium for *Fusarium* spp in the laboratory.

Table 16. Degree of infection of seed harvested from IR42 plants[a] inoculated with *Fusarium moniliforme* and sprayed with benomyl 50% WP in the field. IRRI, 1980

Treatment	Rate of benomyl (kg formulation/ ha per application)	Seeds with *Fusarium moniliforme*[b] (%)
Uninoculated + 2 sprays	1.0	2.0
Uninoculated, unsprayed	0.0	3.3
Inoculated + 2 sprays before inoculation	1.0	11.8
Inoculated, unsprayed	0.0	16.3
Inoculated + 2 sprays after inoculation	1.0	19.8

[a]Plants grown from benomyl-treated (presprouting treatment) and untreated naturally infected seeds were inoculated 3 times at 2- to 3-day intervals at the time the flowers opened. [b]Mean of 4 replications. From each replication, 100 seeds were used in determining the number of infected seeds using Komada's selective medium for *Fusarium* spp in the laboratory

Table 17. Bakanae control with benomyl 50% WP suspension as presprouting treatment.[a] IRRI, 1980.

Concn (g formulation/ liter suspension)	Infected seedlings (no.)	
	10 days after seeding[b]	14 days after seeding[c]
	Test variety. IR40	
2.0	2.0	44.1
0.0	42.9	171.6
	Test variety: IR42	
2.0	1.6	139.2
0.0	166.9	586.8

[a]12.0 kg seeds/variety were soaked for 24 hours, incubated in moist jute sacks for 48 hours until they sprouted, and finally seeded in dapog beds [b]Abnormally elongated seedlings only Mean of 10 sample portions of dapog bed, each portion measuring 0.25 × 0.75 m (0.1875 m²) [c]Abnormally elongated seedlings and those with foot rot Mean of 10 sample portions of dapog bed, each portion measuring 0.35 × 0.3 m (0.105 m²).

control in naturally infected IR40 seeds (Table 20).

A similar test with naturally infected IR42 (Table 21) confirmed the results on bakanae control with benomyl, benomyl-thiram, thiophanate-methyl-thiram, and thiophanate-methyl. TCMTB (65% WP) and thiabendazole (45 wt/vol), each at 1 g concentration, also showed effective bakanae control 10 and 14 days after seeding of treated seeds. Further tests using naturally infected IR42 seeds showed effective bakanae control at 8 and 14 days after seeding with benomyl at 2, 1, and 0.5 g formulation/liter suspension, and thiophanate-methyl-thiram and thiophanate-methyl, each at 2 and 1 g/liter (Table 22). The high concentrations of each fungicide showed better and effective bakanae control than the low ones.

The same chemical suspensions were saved and used to soak another batch of naturally infected IR42 seeds a week later. Similar results were obtained indicating that the chemical suspensions from benomyl, thiophanate-methyl-thiram, and

Table 18. Bakanae control with benomyl 50% WP suspensions as presprouting and foliar spray treatments for naturally infected IR42 seeds and plants.[a] IRRI, 1980

Concn (g formulation/ liter suspension)	Rate of benomyl sprays (kg formulation/ ha per application)	Bakanae-infected hills[b] (%)			Grain yield[c] (t/ha)
		1 MT	2 MT	3 MT	
	Test variety. IR40				
2.0	1.0	0.0	0.1	0.1	5.98
2.0	0.0	0.2	0.5	0.5	5.66
0.0	1.0	13.5	18.1	18.4	5.36
0.0	0.0	12.5	17.1	17.9	4.81
	Test variety. IR42				
2.0	1.0	0.2	0.4	0.7	5.03
2.0	0.0	0.1	0.3	0.3	4.78
0.0	1.0	27.3	29.1	29.3	4.14
0.0	0.0	21.0	25.7	26.4	3.96

[a]12.0 kg seeds/variety were soaked for 24 hours and incubated in moist jute sacks for 48 hours until they sprouted. The sprouted seeds were seeded in dapog beds and transplanted in the field 10 days after. [b]Mean of 8 replications, each replication with 625 hills/25-m² plot. MT = months after transplanting [c]Mean of 8 replications at 12% moisture content, each replication with 16-m² harvested area

Table 19 Bakanae control with benomyl 50% WP suspensions as presprouting treatment for naturally infected IR42 seeds.[a] IRRI, 1980.

Concn (g/formulation per liter suspension)	Infected seedlings[b] (no./dapog bed)	
	Initial use of benomyl suspensions[c]	Second use of the same benomyl suspensions[d]
2.0	4	7
1.0	6	3
0 5	4	7
0 0	1,197	2,950

[a]Seeds at 4 kg/concentration were soaked in benomyl suspensions and water for 24 hours The treated and untreated seeds were incubated in moist jute sacks for 48 hours When they sprouted, they were seeded in dapog beds with an area of 1.76 m² (0 8 × 2 2 m) [b]Seedlings with abnormal elongation symptoms only, 10 days after seeding [c]Naturally infected IR42 seeds bought from a farmer at Masapang, Victoria, Laguna [d]Naturally infected IR42 seeds from Agricultural Engineering Department field planting at IRRI. The same benomyl suspensions used for soaking IR42 seeds from Masapang were used to treat the IRRI seeds.

Table 20. Bakanae control with systemic fungicide suspensions as presprouting treatment[a] for naturally infected IR40 seeds. IRRI, 1980

Chemical	Concn (g formulation/ liter suspension)	Infected seedlings[b] (no /150 g seeds)
Benomyl (50% WP)	2 0	11
	1 0	8
Benomyl-thiram (40% WP)	2.0	13
	1 0	18
Thiophanate-methyl-thiram (80% WP)	2 0	20
	1.0	13
Thiophanate-methyl (70% WP)	2 0	14
	1.0	15
No chemical (untreated seeds)	0.0	57

[a]150 g seeds/treatment were soaked for 18 hours, incubated in moist jute sacks for 48 hours until they sprouted, and then seeded in plastic trays containing soil. [b]Seedlings with abnormal elongation symptoms only, counted 16 days after seeding

thiophanate-methyl can be effectively used twice to treat seeds.

CERCOSPORA LEAF SPOT

Foliar sprays. Nine fungicide samples were tested as foliar sprays to control Cercospora leaf spot. Five rows of MI 273 plants were sprayed 3 times at weekly intervals starting 3 weeks after seeding. The test plants were inoculated 1 day after the first spray application.

Table 21. Bakanae control with systemic fungicide suspensions as presprouting treatment for naturally infected IR42 seeds.[a] IRRI, 1980.

Chemical	Concn (g or ml formulation/ liter suspension)	Infected seedlings[b] (no)
Per 0.44 m² dapog bed[b]		
Benomyl (50% WP)	1.0	3.0
Thiophanate-methyl-thiram (80% WP)	1.0	3 0
Benomyl-thiram (40% WP)	1 0	7.8
Thiophanate-methyl (70% WP)	1 0	8 5
TCMTB (65% WP)	1.0	38 0
Thiabendazole (45% wt/vol)	1 0	43 0
PP389 JF5816 (50% WP)	1 0	204 5
No chemical (untreated seeds)	0 0	295.8
Per 0 22 m² dapog bed[c]		
Benomyl (50% WP)	1 0	63 5
Thiophanate-methyl-thiram (80% WP)	1.0	77 3
TCMTB (65% WP)	1.0	127.0
Benomyl-thiram (40% WP)	1.0	131.8
Thiophanate-methyl (70% WP)	1 0	148.8
Thiabendazole (45% wt/vol)	1.0	199.8
PP389 JF5816 (50% WP)	1 0	305 8
No chemical (untreated seeds)	0 0	406.3

[a]1 0 kg seeds/replication were soaked for 24 hours, incubated in moist jute sacks for 48 hours until they sprouted, and finally seeded in dapog beds [b]Seedlings with normal elongation symptoms only, 10 days after seeding. Mean of 4 replications. [c]Abnormally elongated seedlings and those with foot rot, counted 14 days after seeding. Mean of 4 replications, each replication with 0 22 m² (0.55 × 0.4 m) dapog bed

Benomyl, benomyl-thiram, thiophanate-methyl, thiabendazole, and PP296 JF7168, each applied at the rate of 1.0 k formulation/ha per application gave effective Cercospora leaf spot control 3 weeks after inoculation (Table 23). PP296 JF7168 was phytotoxic.

EFFECT OF TEMPERATURE ON SPORULATION BY *FUSARIUM MONILIFORME* IN PLANTS

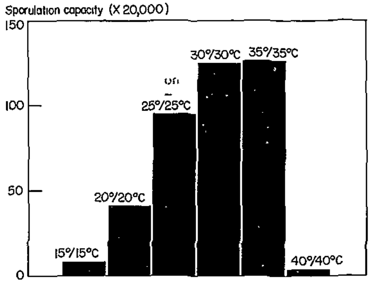
The effect of 6 constant and 13 fluctuating temperatures on sporulation by *Fusarium moniliforme* in plants was studied. Among the constant temperatures sporulation appeared to be maximum between 30°-35° C, indicating a range favorable or optimum for sporulation of the fungus (Fig. 1).

Table 22. Bakanae control with systemic fungicide suspensions as presprouting treatment for naturally infected IR42 seeds.[a] IRRI, 1980.

Chemical	Concn (g formulation/liter suspension)	Infected seedlings (no.)
	Per 0.44 m² dapog bed[b]	
Benomyl (50% WP)	2.0	0.0
	1.0	0.3
	0.5	1.0
Thiophanate-methyl-thiram (80% WP)	2.0	0.3
	1.0	0.3
Thiophanate-methyl (70% WP)	2.0	0.3
	1.0	1.8
No chemical (untreated seeds)	0.0	472.8
	Per 0.22 m² dapog bed[c]	
Benomyl (50% WP)	2.0	25.3
	1.0	35.5
	0.5	44.3
Thiophanate-methyl (70% WP)	2.0	28.8
	1.0	58.8
Thiophanate-methyl-thiram (80% WP)	2.0	34.0
	1.0	52.3
No chemical (untreated seeds)	0.0	535.0

[a]1.0 kg seeds/replication were soaked for 24 hours, incubated in moist jute sacks for 48 hours until seeds sprouted, and then seeded in dapog beds. [b]Seedlings with abnormal elongation symptoms only, 8 days after seeding. Mean of 4 replications, each replication with 1.1 × 0.4 m dapog bed. [c]Mean of 4 replications, each replication with 0.55 × 0.4 m dapog bed. Abnormally elongated seedlings and those with foot rot, counted 14 days after seeding.

The maximum number of spores was found at fluctuating day and night temperatures of 35°/25°C, followed by 35°/20°C, 40°/25°C, 40°/20°C, and 35°/30°C (Fig. 2).



1. Effect of constant temperatures on sporulation of *Gibberella fujikuroi* Saw. in rice plants. IRRI, 1980.

DETACHED-LEAF METHOD OF FUNGICIDE BIOASSAY FOR SHEATH BLIGHT

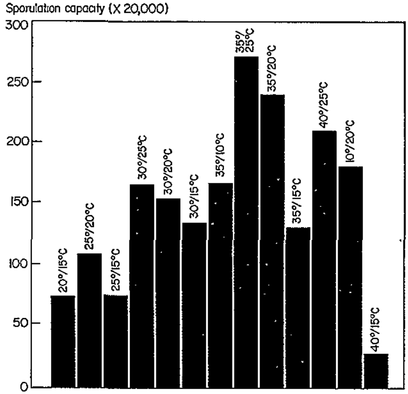
The spore germination test and the measurement of inhibition zones of mycelial growth are impractical for testing fungicide efficacy against *Rhizoctonia solani.* A laboratory technique which used detached leaves of a susceptible rice line was tested.

In a preliminary test, flag leaves of IR1487-372-1-1 were cut about 17 cm from the tip and soaked in tap water for a few minutes. The cut leaves were grouped into six: the first five groups were sprayed separately with a chemical, and the sixth served as control. The leaves were sprayed until runoff, then

Table 23. Cercospora leaf spot control with fungicide sprays on artificially inoculated MI273 plants in the greenhouse.[a] IRRI, 1980

Chemical	Rate (kg or liter formulation/ha per application)	Cercospora leaf spot disease rating[b]	Phytotoxic effect
Benomyl (50% WP)	1.0	1.0	None
Benomyl-thiram (40% WP)	1.0	1.0	None
Thiophanate-methyl (70% WP)	1.0	1.0	None
Thiabendazole (45% flowable)	1.0	1.0	None
PP296 JF7168 (12.5% wt/vol)	1.0	1.0	Phytotoxic[c]
M6953 (50% WP)	1.0	6.0	None
PP389 JF5816 (50% WP)	1.0	8.0	None
Galben (25% WP)	1.0	9.0	None
NTN 19701 (25% WP)	1.0	9.0	None
No chemical (unsprayed plants)	0.0	9.0	None

[a]Five rows of plants per plastic tray were sprayed 3 times at weekly intervals. The first spray was at 3 weeks after seeding. [b]Mean of 3 replications, each replication with 5 rows of plants per tray. Scored by the 1980 Standard Evaluation System for Rice. [c]Stunted plants with more tillers than the normal plants 3 wk after inoculation.



2. Effect of fluctuating temperatures on sporulation of *Gibberella fujikuroi* Saw. in rice plants. IRRI, 1980.

arranged at random in porcelain trays lined with moist paper towels. The test was replicated four times with two leaves in each treatment. Each leaf was inoculated in the middle with a sclerotial body of *R. solani* (R-57). After inoculation the trays were covered tightly with aluminum foil and incubated at room temperature for 4 days.

Chemicals tested with the technique were iprodione, validamycin, NTN 19701, Hoe 00662, and triphenyltin acetate. Iprodione and validamycin, which had shown satisfactory control in field tests, afforded effective control by suppressing lesion development on inoculated leaves (Table 24).

AMENDMENTS TO *ACROCYLINDRIUM ORYZAE* SPORE SUSPENSION FOR INDUCING SHEATH ROT

Spraying a spore suspension is a rapid and practical inoculation technique for most foliar fungus diseases. Experiments in 1980 sought to improve the technique for use with sheath rot.

Seedlings of IR1487-372-1-1 (susceptible breeding line) were grown (3 seedlings/pot) in the phytotron and transferred to the greenhouse after 10 weeks. The test plants were divided into two lots. One lot was treated with silicon carbide powder (600 grit carborundum) before inoculation, and

Table 24. Effect of fungicidal sprays on development of sheath blight lesions on IR1487-372-1-1; 4 days after inoculation.[a] IRRI, 1980.

Chemical	Rate[b] (ppm product)	Av percentage of leaf area infected (cm²)				
		Rep. 1	Rep 2	Rep. 3	Rep 4	Mean
Iprodione (50% WP)	500	0 88	0	0 48	3.68	1 26
Validamycin A (3% solution)	1000	0	1.12	1.0	3 77	1 47
NTN 19701 (25% WP)	500	4.23	1 34	5 92	2.23	3 43
Hoe 00662 (47.5% WP)	200	4.75	9 38	4 79	2.70	5 40
Triphenyltin acetate (60% WP)	300	5.87	5 59	4.44	9.34	6 31
No chemical (unsprayed)	—	11.47	14 15	11.87	16.97	13.57

[a]Inoculated with sclerotia Rep. = replication. [b]Based on standard recommendation.

Table 25 Sheath rot infection as influenced by various amendments on carborundum-treated and untreated plants. IRRI, 1980

Treatment	Sheath rot infection (%)			
	Carborundum-treated		Untreated	
	Infected plants	Infected tillers	Infected plants	Infected tillers
25% nutrient solution	0	0	0	0
50% nutrient solution	0	0	0	0
75% nutrient solution	0	0	0	0
25% beef extract-peptone solution	83.3	28.5	0	0
50% beef extract-peptone solution	33.3	10.3	16.6	2.2
0.125% agar	16.6	1.4	0	0
0.5% gelatin	0	0	0	0
0.1% Tween 20 [polyoxyethylene (20) sorbitan monolaurate]	8.3	0.8	0	0
Distilled water	8.3	1.0	0	0
Uninoculated	0	0	0	0

the other was left untreated. The powder was mixed with water (1 g/100 ml) and sprayed on the plants from the boot to the flag leaf. Each lot was further subdivided into 10 groups of 4 pots each to accommodate subplot treatments — 25, 50, and 75% nutrient solution, 25 and 50% beef extract-peptone solution, 0.125% agar, 0.5% gelatin, 0.1% Tween 20 [polyoxyethylene (20) sorbitan monolaurate], distilled water, and uninoculated.

Spores of *Acrocylindrium oryzae* from 1-week-old cultures were dislodged and suspended in the various solutions as inoculant. Inoculated plants remained in the greenhouse until sheath rot symptoms developed.

A spore suspension in 25% beef extract-peptone solution was the best effective subplot treatment: 83.3% of the carborundum-treated plants and 28.5 of the tillers/plant exhibited sheath rot symptoms (Table 25). Sheath rot appeared 2 weeks after inoculation, and became more severe with time. Wounding of the plants with carborundum before inoculation greatly increased disease development.

ECOLOGY OF *THANATEPHORUS CUCUMERIS* AND CULTURAL CONTROL OF SHEATH BLIGHT

Weed hosts. The basidial stage of the rice sheath blight pathogen *Thanatephorus cucumeris* was observed frequently on rice in rainfed wetland and dryland fields at IRRI. It was also noted on *Paspalum distichum* in a rainfed wetland field, but was not seen in irrigated wetland rice.

Many weed species have been reported as hosts of *T. cucumeris* (Table 26). In addition, three species of *Cyperus* — *C. compactus*, *C. ferax*, and *C. kyllingia* — in a fallow field after rainfed wetland rice were found infected with *T. cucumeris*. This could be the first observation of these weeds naturally infected by the rice sheath blight pathogen (Table 27).

Effect of land preparation and herbicides on sheath blight. When a fallow and a preemergence herbicide for grassy weeds were applied, the number of sclerotia of *T. cucumeris* was less than in plots not treated with herbicides (Table 28). Recovery of the fungus from rice debris 1 week after harvest was also less. The sheath blight incidence was lower in fields where land preparation was 4 weeks before transplanting than in fields prepared 2 weeks before transplanting (Table 29). The mean incidence and severity of sheath blight infection that was not closely related to application of herbicides for grassy weeds was perhaps due to infection of *Monochoria vaginalis*, which was also a host of the pathogen.

Saprophytic colonization and infectivity. Competitive saprophytic colonization of rice straws in soil infected with the sheath blight pathogen was influenced by submergence, whether the soil was from a wetland or dryland rice field (Fig. 3). The rate of colonization in dryland soil was considerably higher than in wetland soil when the inoculum level was below 50%. Infectivity of the rice straw being colonized by the pathogen was lower in wetland, suggesting that the inoculum potential of the pathogen was affected by submergence.

Table 26. Weed species identified and reported to be hosts of *Thanatephorus cucumeris,* the rice sheath blight pathogen in Asia, 1980.

Weed species	Family	IRRI	Taiwan	Bangladesh	India
Alternanthera sessilis	Amaranthaceae	+	+	+	–
Andropogon asper	Poaceae	–	–	–	+
Chloris sp.	Poaceae	+	–	–	–
Cleome rutidosperma	Capparidaceae	+	–	–	–
Cynodon dactylon	Poaceae	+	+	+	+
Cyperus compactus	Cyperaceae	+	–	–	–
C. difformis	Cyperaceae	–	+	–	–
C. ferax	Cyperaceae	+	–	–	–
C. kyllingia	Cyperaceae	+	–	–	–
C. pilosus	Cyperaceae	–	+	–	–
Cyperus sp.	Cyperaceae	–	–	–	+
Digitaria sp.	Poaceae	+	–	–	–
Echinochloa colona	Poaceae	+	–	–	–
F. crus-galli var. *austro-japonensis*	Poaceae	–	+	–	–
E. crus-galli var. *candata*	Poaceae	–	–	–	+
E. crus-galli ssp. *hispidula*	Poaceae	+	–	–	–
E. glabrescens	Poaceae	+	–	–	–
E. stagnina	Poaceae	+	–	–	–
Eclipta prostrata	Asteraceae	–	+	–	–
Eichhornia crassipes	Pontederiaceae	–	–	+	–
Eleusine indica	Poaceae	–	–	+	–
Eriochloa procera	Poaceae	–	–	–	+
Fimbristylis littoralis	Cyperaceae	–	+	–	–
Hydrocotyle formosana	Apiaceae	–	+	–	–
Hymenache pseudo-interrupta	Poaceae	–	–	+	–
Imperata cylindrica	Poaceae	+	–	+	–
Leersia hexandra	Poaceae	–	–	+	–
Leptochloa chinensis	Poaceae	+	+	–	–
Lindernia procumbens	Scrophulariaceae	–	+	–	–
Lobelia chinensis	Campanulaceae	–	+	–	–
Ludwigia peploides spp. *stipulacea*	Onagraceae	–	+	–	–
Marsilea minuta	Marsileaceae	–	+	–	–
Monochoria vaginalis	Pontederiaceae	+	+	–	–
Panicum repens	Poaceae	–	+	–	+
Paspalidium flavidum	Poaceae	+	–	–	–
Paspalum conjugatum	Poaceae	–	+	–	–
P. distichum	Poaceae	+	–	–	–
Rotala indica	Lythraceae	–	+	–	–
Rottboellia exaltata	Poaceae	+	–	–	–
Scirpus juncoides	Cyperaceae	–	+	–	–
Setaria sp.	Poaceae	–	–	+	–

Microbes and survival of the sheath blight pathogen. Microbial decomposition of rice straw affects the survival of the sheath blight pathogen. A *Trichoderma* sp. isolated from a dryland rice field was found to decompose rice straw.

Table 27. Weed species found as host of *Thanatephorus cucumeris* in rainfed wetland rice fields. IRRI, 1980.

Weed species	Natural infection
Cyperus compactus Retz.	+
C. ferax Rich.	+
C. kyllingia	+[a]
Echinochloa stagnina	+
Imperata cylindrica	+[a]
Alternanthera sessilis	+

[a]In the field ditches.

Rice straw infested with *Trichoderma* alone became dark in color 2 weeks after incubation, an indication of decomposition (Fig. 4). With *T. cucumeris* alone as inoculant, only 40% of the straw pieces became dark-colored after 16 weeks of incubation. A mixture of the two organisms caused 100% decomposition of straw 16 weeks after incubation.

The microbial decomposition of rice straw greatly affected the survival of the sheath blight pathogen (Fig. 4). When *Trichoderma* and *T.*

Table 28. Recovery of *Thanatephorus cucumeris* from plant residues (<5 mm in size) in wetland irrigated fields where fallow and preemergence herbicides were applied before planting of IR36. IRRI, 1980.

Treatment	Recovery (%)		Sclerotia[a] (no.)	
	At harvest	1 wk after harvest	Total	Viable
No herbicide	6.4	11.7	24	11
With herbicide				
Fallow (none) Preemergence (X-150)	5.4	9.7	19	9
Fallow (glyphosate) Preemergence (none)	3.5	7.4	5	0
Fallow (glyphosate) Preemergence (X-150)	4.4	5.8	2	2

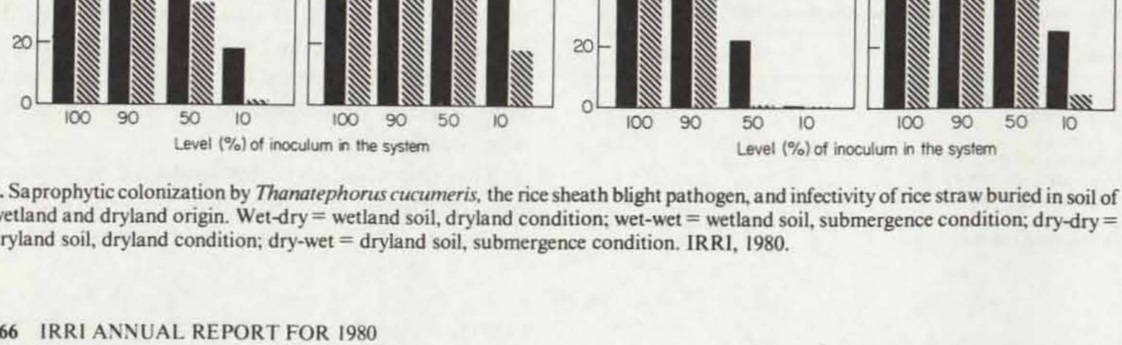
[a]Per liter of surface soil.

Table 29. Effect of herbicides and land preparation on incidence and severity of rice sheath blight disease in wetland irrigated rice (IR36). IRRI, 1980 wet season.

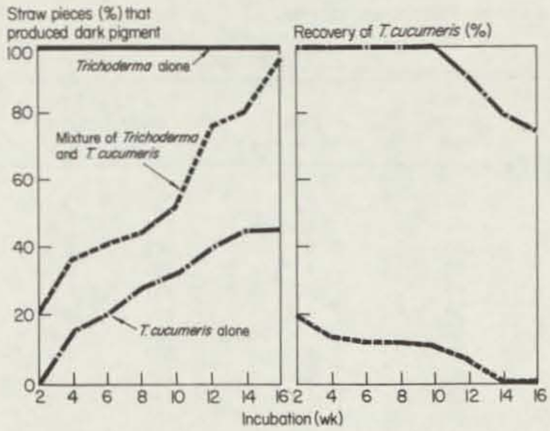
Treatment[a]	Land preparation (wk before transplanting)	Sheath blight[b]		Sclerotia[b] (no.)	Yield (t/ha)	*Monochoria* infection[c]	
		Incidence (%)	Severity index (0-100)			No.	Sheath blight incidence (%)
No herbicide	2	41	23	85	[d]	79	12
	3	40	18	152	3.1	44	9
	4	31	11	24	3.6	79	7
Fallow (glyphosate)	2	39	24	61	2.9	127	25
Preemergence (none)	3	35	18	56	2.8	77	16
	4	31	13	34	3.1	31	18
Fallow (none)	2	48	18	58	3.7	52	6
Preemergence (X-150)	3	38	17	113	3.8	114	5
	4	27	14	16	3.9	53	6
Fallow (glyphosate)	2	48	21	82	3.6	105	6
Preemergence (X-150)	3	35	19	54	3.6	194	9
	4	24	15	31	4.0	136	6

[a]Herbicides for graminaceous weeds. [b]Mean of 25 hills/plot. [c]Infection after transplanting. [d]Damaged by rats.

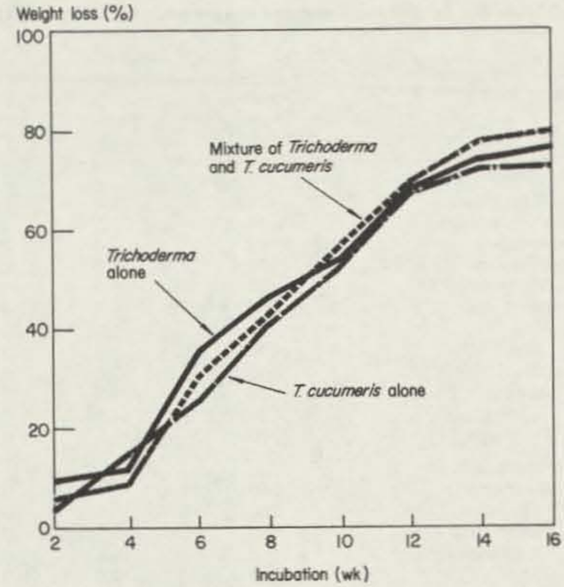
cucumeris were mixed together with the rice straw, recovery of the sheath blight pathogen was reduced to 20% at 2 weeks after incubation. Rice straw weight loss due to colonization by the two organisms, either singly or in combination, was not significantly different (Fig. 5). The *Trichoderma* sp. appeared to be highly competitive, and with a cellulolysis adequacy index higher than that of *T.*



3. Saprophytic colonization by *Thanatephorus cucumeris,* the rice sheath blight pathogen, and infectivity of rice straw buried in soil of wetland and dryland origin. Wet-dry = wetland soil, dryland condition; wet-wet = wetland soil, submergence condition; dry-dry = dryland soil, dryland condition; dry-wet = dryland soil, submergence condition. IRRI, 1980.



4. Effect of *Trichoderma* sp. isolated from dryland rice field on rice straw decomposition and on saprophytic survival of the sheath blight pathogen *Thanatephorus cucumeris*. IRRI, 1980.



5. The weight (wet) loss of rice straw being colonized by *Trichoderma* sp. and the rice sheath blight pathogen *Thanatephorus cucumeris* at different durations of incubation as compared to rice straw that was not infested by any of the two organisms. IRRI, 1980.

cucumeris and other rice fungal pathogens (Table 30).

Survival of *T. cucumeris* was better in a dryland than in a wetland soil where sclerotia were often colonized by saprophytic bacteria in paddy water. Bacteria isolated from sclerotia collected in a paddy wetland field inhibited the mycelium growth *in vitro* (Table 31).

FIELD EPIDEMIOLOGY OF RICE TUNGRO

Studies on the epidemiology of rice tungro disease in 37 farmers' fields in Luzon continued. From November 1979 to October 1980, the incidence of tungro disease on different varieties at various growth stages was observed. A total of 558 collections of tungro vectors (*Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis)* was made to determine the population density of the vectors. The infectivity of 5,349 vectors collected from the fields was determined by seedling infection.

The results revealed that tungro incidence, number of tungro vectors per collection, and percentage of infective insects varied among months, provinces, types of field, and rice cultivars (Table 32). The highest tungro incidence was found in November 1979, the lowest in February 1980. The number of tungro vectors was highest in November

Table 30. Cellulolysis adequacy index (CAI) of *Thanatephorus cucumeris* and other rice disease pathogens, and of *Trichoderma* sp., a soil saprophytic fungus, on filter paper. IRRI, 1980.

Organism	% loss of filter wt[a]	Rate of linear growth (mm/day)	CAI
Rhynchosporium oryzae	10.33	19.6	0.53
T. cucumeris from			
Dryland rice	25.81	47.8	0.54
Wetland rice	27.54	51.0	0.54
Monochoria	34.33	42.3	0.81
Sclerotium rolfsii from rice	23.33	20.4	1.14
Fusarium moniliforme	16.00	11.0	1.45
Trichoderma sp. from dryland rice field	31.00	10.3	3.01

[a]Based on control, 7 weeks after incubation.

Table 31. Inhibition of *Thanatephorus cucumeris* mycelium growth by bacteria isolated from its sclerotia in irrigated rice fields. IRRI, 1980.

Bacterial isolate	Inhibition area[a] (mm in diam)
In-b-4	32.5 ± 0
In-b-5	25.8 ± 1.4
In-b-3	18.5 ± 3.5
In-b-9	14.2 ± 0.8
In-b-7	11.3 ± 1.1

[a]Mean of 3 replications.

Table 32. Tungro incidence and tungro vectors in 37 study fields in Luzon, Philippines, 1979-80.

	Tungro			Tungro vectors[a]			
	Observations (no.)	Fields (%)	Incidence (%)	Collections (no.)	Av per 10 sweeps (no.)	Tested (no.)	Infective (%)
Month							
November	74	25.4	5.75	44	7.7	704	2.41
December	74	12.3	3.53	43	1.4	370	0.81
January	93	5.4	0.36	60	0.5	163	0.00
February	74	0.0	0.00	40	1.2	120	0.00
March	74	5.2	0.09	45	3.7	247	1.21
April	92	10.7	0.81	50	6.8	563	0.00
May	74	9.5	0.72	48	3.1	429	0.23
June	74	8.7	0.87	58	7.0	812	0.25
July	93	3.6	0.01	55	6.8	904	0.00
August	74	1.8	0.01	39	2.8	335	0.00
September	88	14.1	0.03	51	5.0	484	0.00
October	78	17.6	0.15	25	3.7	218	0.00
Province							
Bulacan	260	8.6	0.46	169	6.7	2169	0.09
Laguna	208	13.6	0.72	114	2.6	840	0.36
Nueva Ecija	130	5.1	0.02	83	7.3	1133	0.09
Pampanga	156	14.5	5.76	103	1.1	420	4.52
Tarlac	208	7.0	0.01	89	2.5	787	0.13
Type of field							
Seedbed	50	0.0	0.00	49	10.0	860	0.00
Paddy	443	7.4	0.18	202	2.8	1227	0.16
Stubble	213	16.4	2.92	213	6.1	3221	0.75
Idle	256	0.0	0.00	94	0.1	41	0.00
Rice cultivar							
C1	3	100.0	15.00	3	2.7	32	18.75
C21	9	100.0	52.22	9	8.2	180	7.22
IR34	11	0.0	0.00	6	2.2	51	0.00
IR36	487	5.7	0.13	315	3.5	3118	0.13
IR42	57	17.5	0.02	39	7.2	589	0.51
IR44	106	8.5	0.03	72	10.5	1092	0.00
IR46	3	0.0	0.00	1	0.0	0	0.00
IR247	8	0.0	0.00	5	2.6	52	0.00
IR2307	11	0.0	0.00	7	12.0	110	0.00
Muslim var.	11	81.8	10.94	7	2.9	84	0.00

[a]The vectors are *Nephotettix virescens*, *N. nigropictus*, and *Recilia dorsalis*.

and lowest in January. The infective insects were found in November, December, March, May, and June, but the highest percentage was in November.

The tungro incidence was higher in study fields in Pampanga than in other provinces. Stubble fields had higher tungro incidence and higher percentage of infective insects. However, the number of tungro vectors in seedbeds was higher than that in fields at other growth stages of the plants.

Rice varieties C21 and C1 had higher tungro incidence than other rice cultivars in the study fields.

The results again indicated that the incidence of tungro disease in the wet season crop was affected by the vectors' population and percentage of infective insects (as indication of virus sources) in April to June (Table 33). The period from April to June was before and after seedbed and field preparation, seedbeds with rice seedlings, and fields with newly transplanted rice plants. Consequently, the data collected in early stages of the rice crop could be used as criteria for forecasting the incidence of tungro disease.

RICE TUNGRO VIRUS COLLABORATION

A RTV (rice tungro virus) Collaboration Project, launched in 1978 with the main objective of determining the possible causes of variation in varietal reaction to tungro disease, continued in 1980. The project had collaborators at:

- AICRIP (All India Coordinated Rice Improvement Project), Rajendranagar, India;
- BRRI (Bangladesh Rice Research Institute),

Table 33. Tungro vectors in study fields from April to June and incidence of rice tungro disease from June to October in Luzon. IRRI, 1973-80.

Year	Tungro vectors[a] (Apr-Jun)				Tungro (Jun-Oct)		
	Collections (no.)	Av/10 sweeps (no.)	Tested (no.)	Infective (%)	Observations (no.)	Fields (%)	Incidence (%)
1973	68	5.8	1028	0.00	151	1[b]	0.60
1974	166	11.0	2425	1.77	244	45[c]	2.38[c]
1975	181	9.8	3319	0.69	234	72	3.32
1976	145	3.9	2244	0.18	267	25	0.33
1977	172	3.0	1578	0.00	235	17	0.03
1978	170	2.3	1844	0.00	241	0	0.00
1979	162	3.3	1782	0.34	234	18	2.01[d]
1980	156	5.8	1804	0.17	203	11	0.06

[a]The vectors are *Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis.* [b]Rice fields with only a few tungro-infected plants were excluded. [c]The Philippine Government launched a green leafhopper control program in the area in July and August. [d]95% was due to the occurrence of the disease on varieties C1 and C21 in 3 study fields.

Joydebpur, Bangladesh;

- CRRI (Central Rice Research Institute), Cuttack, India;
- LPPM (Lembaga Penelitian Pertanian Maros), Sulawesi, Indonesia; and
- RPB (Rice Pathology Branch, Division of Plant Pathology and Microbiology, Department of Agriculture), Bangkhen, Thailand.

The data on tungro transmission and seedling infection for 10 varieties contributed by the collaborators were used to evaluate the susceptibility of the varieties to tungro and also to differentiate strains of RTV.

Varietal reaction to tungro vector. The life span of tungro-viruliferous *N. virescens* was not identical in a sample, among rice varieties, among sites, between the tests made in 2 years, and between sexes. However, when the average life span of the tungro vector was used as a criterion, the reaction of rice varieties could be arbitrarily grouped into *resistant, intermediate,* and *susceptible* as shown in Table 34. The grouping revealed that a rice variety resistant at a site might not always be resistant at other sites. For instance, Ptb 18 was resistant at all sites except at AICRIP, where it was intermediate. Only TN1 showed a similar reaction at all sites.

Difference in biotypes of tungro vector. A colony of the tungro vector can build up its "adaptability" to Pankhari 203 when the insects are reared continuously on Pankhari 203 in the greenhouse (Annual report 1969). Green leafhoppers collected in fields at IRRI, Pila, and La Trinidad survived much longer on IR8 than insects reared in the greenhouse (Annual report for 1970). Therefore, differentiating biotypes merely on the basis of the life span of the tungro vector on a rice variety may

Table 34. Reactions of 10 rice varieties to tungro-viruliferous *Nephotettix virescens* and to tungro virus at 6 sites[a], on the basis of an arbitrary classification system, 1980.

Variety	Reaction[b] to vector (letter on left) and to virus (right)					
	AICRIP	BRRI	CRRI	IRRI	LPPM	RPB
Ambemohar 159	IS	S–	SS	SS	SI	II
Gam Pai 30-12-15	RI	I–	RI	RI	II	II
Habiganj DW8	SS	I–	SR	SR	SR	SI
IR26	SS	S–	SS	SS	SS	RI
IR34	II	I–	RI	RI	RI	SS
Kataribhog	IS	I–	SR	SI	SI	SS
Latisail	IS	S–	SS	SS	SS	RI
Pankhari 203	II	—	SI	IR	IR	RI
Ptb 18	IS	R–	RR	RI	RR	RI
TN1	SS	S–	SS	SS	SS	SS

[a]AICRIP = All India Coordinated Rice Improvement Project, Rajendranagar, India; BRRI = Bangladesh Rice Research Institute, Joydebpur, Bangladesh; CRRI = Central Rice Research Institute, Cuttack, India; LPPM = Lembaga Penelitian Pertanian Maros, Sulawesi, Indonesia; RPB = Rice Pathology Branch, Division of Plant Pathology and Microbiology, Department of Agriculture, Bangkhen, Thailand. [b]R, I, S, and a (–) indicate resistant, intermediate, susceptible, and data not available.

Table 35. Possible combinations[a] of rice varieties to be used for differentiating biotypes of *Nephotettix virescens* at 6 sites.[b]

Variety	Ambemohar	Gam Pai	Habiganj	IR26	IR34	Kataribhog
	aBcCilmrR	aBcCilmrR	aBcCilmrR	aBcCilmrR	aBcCilmrR	aBcCilmrR
Gam Pai	lILLLLLSs					
IR26		SsSSSSSLL				
IR34	ILLLLLLsS			LLLLLLLSS		
Kataribhog		SlSSSSSSS				
Latisail		SsSSSSSLL			sSSSSSSLL	
Pankhari	s-lILLLl-	S-SSSssL-	l-ssLLLL-	l-slLLL	s-SSSsSL-	
Ptb 18	lLLLLLLLL		lLLLLLLLL		=lLlssLLL	
TN1	sllssssSS		sssSllsss			sSsslllIL

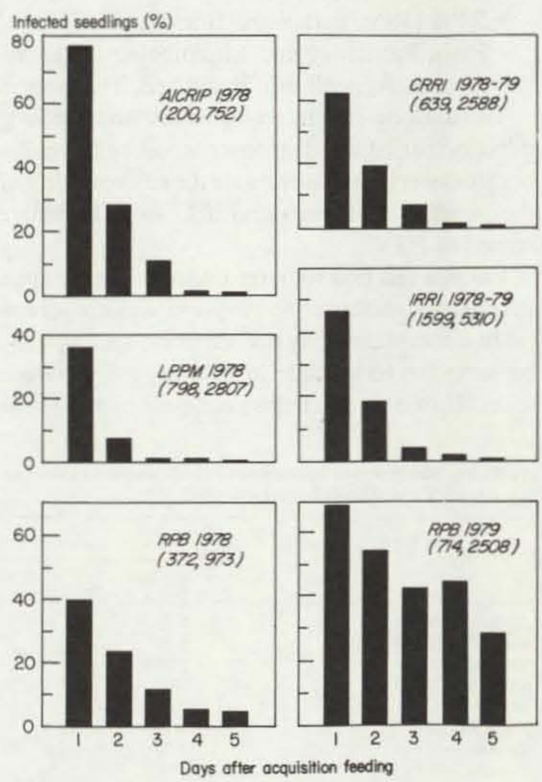
[a]L and l = longer life span; S and s = shorter life span. Capitals mean significantly different at the 1% level when the life span of the insect on the varieties listed on the top are compared with those on the varieties listed on the side. The equal sign (=) means the same life span; a dash (–) means data not available. Underlines indicate differences between sites. [b]a = AICRIP, India; B = BRRI, Bangladesh; c, C = CRRI, India; i, I = IRRI; m = LPPM, Indonesia; r, R = RPB, Thailand. Small letters refer to 1978 data, capital letters to 1979 data.

not be reliable. However, the difference in life span of the tungro vector between two varieties tested under the same condition can serve as criterion for differentiating biotypes among colonies at one or more sites. For instance, the average life span of the tungro vector on IR34 was significantly longer at the 1% level than on IR26 at the Thailand site while the reverse was true at the five other sites (Table 35). The tungro vector apparently has different biotypes. The biotype of the tungro vector at RPB differed from the biotypes at the other sites.

In some cases, more than one set of two varieties are essential for the differentiation. For instance, IR34 and Ptb 18 as well as IR26 and Pankhari 203 would be needed to differentiate the insect biotype at LPPM from the biotypes at IRRI and other sites.

Varietal reaction to tungro virus. Based on percentage of infective insects, average retention period, percentage of infected seedlings, number of infected seedlings per insect, and number of infected seedlings per infective insect, the 10 rice varieties were arbitrarily grouped into resistant, intermediate, and susceptible as shown in Table 34. The grouping revealed that Gam Pai 30-12-15 was intermediate and TN1 was susceptible at all five sites. The reactions of the eight other varieties differed among the five sites. Ambemohar 159, IR26, IR34, and Latisail were either susceptible or intermediate. Habiganj DW8, Kataribhog, and Ptb 18 were susceptible, intermediate, or resistant. Pankhari 203 was either intermediate or resistant in the five sites.

Tungro transmission. The tungro virus-vector interaction has been categorized as transitory. The average retention period of tungro virus by *N. virescens* is generally less than 2 days unless the temperature is low and only a low percentage of the insects retain infectivity for 5 days. This was confirmed by the fact that less than 1% of the



6. Seedlings infected by tungro-viruliferous *Nephotettix virescens* at different sites showing the retention of insects' infectivity after acquisition feeding when tested by daily serial transmission for 5 days. Numbers in parentheses indicate number of insects tested (left) and number of seedlings inoculated (right). 1980.

Table 36. Reactions of 6 varieties to *Nephotettix virescens* and to rice tungro virus at 5 sites, 1980.

Variety	Reaction[a] to vector (letter on left) and to rice tungro virus (right)				
	AICRIP	CRRI	IRRI	LPPM	RPB
Habiganj DW8	SS	SR	SR	SR	—
IR26	SS	SS	SS	SS	RI
IR34	II	RI	RI	RI	SS
Kataribhog	IS	SR	—	—	SS
Latisail	IS	SS	SS	SS	RI
Ptb 18	IS	RR	—	RR	—

[a]R, I, and S indicate resistant, intermediate, and susceptible. Underlines indicate remarkably different from the others. A dash (—) means no data available.

insects tested retained their infectivity 5 days at AICRIP, CRRI, IRRI, and LPPM (Fig. 6). But at RPB, 4.3% and 27.6% of the insects remained infective for 5 days in 1978 and 1979. The retention periods of the virus by the tungro vector at RPB were unusually long, particularly in the test conducted in 1979. The reason remains obscure but it indicated a difference in tungro transmission between RPB and the four other sites.

Possible tungro strains. The reactions of IR26 and Latisail were intermediate at RPB but susceptible at the other sites. Similarly, IR34 was susceptible at RPB but intermediate at other sites (Table 36). It suggests that the tungro strain at RPB differed from the strains at other sites. The differences in varietal reaction to RTV appeared to be correlated with the degree of resistance to tungro vector of the varieties at those sites and those varieties may not properly differentiate the RTV strain at RPB from the strains at other sites. Ptb 18, which showed different reactions to RTV, might be a proper differential for differentiating the RTV strains at AICRIP from those at CRRI and LPPM.

Habiganj DW8 was susceptible to the tungro vector at AICRIP, CRRI, IRRI, LPPM, and RPB and was resistant to the tungro virus at CRRI, IRRI, and LPPM, but not at AICRIP. Consequently, Habiganj DW8 could be used for differentiating the RTV strain at AICRIP from those at CRRI, IRRI, and LPPM, particularly from those at CRRI where it did not become infected in 1978 and 1979 tests. Kataribhog showed susceptible reaction to the tungro vector at CRRI and RPB, but was resistant to tungro virus at CRRI but not at RPB. Therefore, this variety could be used to differentiate RTV strains at CRRI and RPB.

LIGHT-TRAPPING OF RICE VIRUS VECTORS

The weekly collection of rice virus vectors at IRRI by light from 1700 until 2 hours after sunset continued. The infectivity of a portion of the trapped vectors was determined by daily serial transmission tests. Although the number of virus vectors trapped varied from time to time, the vectors were trapped by light in each month throughout the year (Table 37). Among the species of tungro vectors, the ratio was 31:21:45 for *N. virescens*:*N. nigropictus*:*R.*

Table 37. Average number of rice virus vectors collected by light trap[a] at IRRI and percentage of infective insects of various viruses. 1979-80.

Month	Insects (no./trap)		Infective insects (%)		
	Tungro vectors[b]	Brown planthopper	Tungro	Grassy stunt	Ragged stunt
Nov 1979	149	147	0.29	0	11.19
Dec	37	81	0	0	15.38
Jan 1980	125	56	0.31	0	6.29
Feb	28	9	0	0	9.68
Mar	341	341	0.84	0.65	13.64
Apr	390	3686	1.05	0.33	9.75
May	459	822	1.16	0	18.45
Jun	233	122	0.76	0.90	13.12
Jul	399	223	1.18	0	7.34
Aug	1982	2450	0.75	0	5.14
Sep	4288	2615	0.18	0.31	2.19
Oct	1005	621	0.72	0	8.86

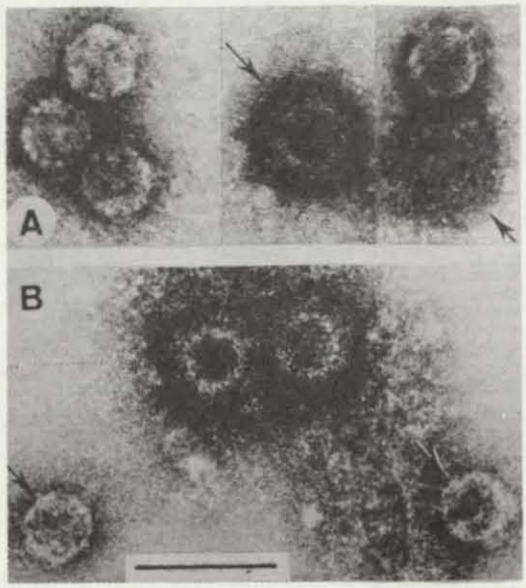
[a]From 1700 until 2 hours after sunset every Tuesday. [b]*Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis.* The ratio among the 3 species for the whole period was 34:21:45.

dorsalis. However, the infective insects were 1.50% of *N. virescens*, 0.06% of *N. nigropictus*, and 0.17% of *R. dorsalis*. The overall incidence of tungro disease at IRRI was low.

In each month, 2-18% of the trapped brown planthoppers were ragged stunt infective. The overall incidence of ragged stunt disease was rated as moderate. Incidence of grassy stunt disease was rated at trace; the percentage of grassy stunt infective insects was also low.

IDENTITY OF RICE RAGGED STUNT

Rice ragged stunt disease is known to occur in China, India, Indonesia, Japan, Malaysia, Philippines, Sri Lanka, and Thailand. Specimens were collected in some countries and sent to the Laboratorio di Fitovirologia Applicata del Consiglio Nazionale delle Ricerche, Italy, for identity studies. The laboratory prepared antiserum against rice ragged stunt virus from the Philippines and developed an *immunoelectron microscopy decoration test* for determining specificity of the reaction between antiserum and virus. The reacting subviral particles had dark haloes of antibody and negative stain, whereas nonreacting particles were paler, with sharp borders under an electron microscope (Fig. 7). The specimens collected in China, India, Indonesia, and Thailand had symptoms similar to those of ragged stunt disease in the Philippines and also similar morphology of virus particles. Furthermore, they showed positive serological reaction with the antiserum against rice ragged stunt virus in the Philippines. Consequently, the disease in those countries are similar, if not identical.



7. Immunoelectron microscopy decoration test applied to artificial mixtures of subviral particles of rice ragged stunt virus (RRSV, arrow) and maize rough dwarf virus (MRDV) decorated with RRSV antiserum (A) and MRDV antiserum (B). Reacting particles have dark haloes of antibody and negative stain; nonreacting particles are paler, with sharp borders. Bar = 100 nm.

CAUSAL AGENT OF RICE GRASSY STUNT

The causal agent of rice grassy stunt disease was assumed to be a virus 70 nm in diameter (Annual report 1965), but without support of bioassay studies; and by a microplasma-like organism (Annual report 1968).

Diseased plants were sent to Hokkaido University for study in 1980. Diseased rice leaves, and abdomens and salivary glands of viruliferous brown planthoppers were fixed and embedded in epoxy resin, cut by an ultramicrotome and double stained in 2% uranyl acetate and lead citrate. The electron micrographs of the cells of diseased rice leaves revealed small isometric particles about 20 nm in diameter, scattering or accumulating within cytoplasm of phloem cells. Particles of the same shape and size were also found in cells of fat body and trachea of the viruliferous insects.

When the partially purified virus preparation was injected into abdomens of healthy nymphs of the brown planthopper, the insects became infective. Thus, the bioassay studies confirmed the infectivity of the virus particles.

On the other hand, symptoms of the diseased plants were not suppressed by treatments of chloramphenicol sodium succinate, oxytetracycline hydrochloride, potassium penicillin G, sulfisomidin, and tetracycline hydrochloride. Hence, the causal agent of the disease was not likely to be mycoplasma-like organism, Chlamydia, or Rickettsia.

Control and management of rice pests

Insects

Entomology Department

TAXONOMY OF SPIDERS

Work to clarify the role of spiders in rice insect pest regulation continued. A survey in 17 Philippine areas from 1977 to 1980 revealed 51 species comprising 34 genera under 16 families. Forty-two species, belonging to 33 genera under 16 families, were new in Philippine records, and 17 species, 15 genera, and 1 family were new to the Asian checklist.

The three main rice environments and the spider species dominant there were:

- dryland — *Tetragnatha mandibulata, T. javana, Oxyopes javanus,* and the araneids;
- rainfed wetland — *T. javana, Lycosa pseudoannulata, Callitrichia formosana, Araneus inustus,* and *Argiope catenulata;* and
- irrigated wetland — *C. formosana* and *L. pseudoannulata.*

INSECT REARING

Greenhouse rearing of the zigzag leafhopper is extremely difficult during the rainy season because of the high incidence of the fungus *Metarhizium anisopliae.* Fungicides were tested for control of the fungus without adverse effect on the leafhopper. Dithane M-45, benomyl, fungitox, and BAS 3050 F had no effect on the leafhoppers or the hatchability of the eggs and all except BAS 3050 F were highly effective in controlling the fungus.

INSECTICIDE EVALUATION

Insectary studies. Coded and commercial insecticides were evaluated in the insectary against the brown planthopper (BPH), whitebacked planthopper (WBPH), and green leafhopper (GLH).

Contact toxicity. Insecticides were used with a Potter's spray tower to determine their activity as a contact poison. Compounds with activity against BPH and GLH are given in Table 1; those active against the BPH, GLH, and WBPH are in Table 2. New compounds causing high mortality (⩾80%) were M 9918, dioxacarb, RH 0308, RH 0994 (Table 1), and UC 54229 and RP 32861 (Table 2). UC 54229 was effective against the three hopper species and the yellow stem borer in field trials.

NNI 750, an insect growth regulator, killed

Table 1. Contact toxicity of insecticides applied at 0.075%[a] with a Potter's spray tower against the brown planthopper and green leafhopper IRRI insectary, 1980.

Treatment	Mortality[b] (%)							
	Brown planthopper				Green leafhopper			
	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT
Test 1								
M 9918 20 OE	90 a	94 a	99 a	100 a	80 a	86 b	100 a	100 a
Carbofuran 12 F	69 b	70 bc	84 cd	95 a	79 a	83 b	98 a	98 a
Dioxacarb	58 b	79 b	89 bc	94 a	11 c	99 a	100 a	100 a
M 10604 20 OE	41 c	65 c	74 de	74 b	76 ab	79 b	100 a	100 a
UC 27867 50 WP	25 d	45 d	59 e	76 b	9 cd	89 b	100 a	100 a
RH 0308 4 EC	6 e	16 e	94 ab	95 a	5 cde	11 c	100 a	100 a
RH 0994 4 EC	5 ef	20 e	97 ab	97 a	4 def	6 c	88 b	100 a
Methidathion 40% EC	4 ef	19 e	23 f	54 c	61 b	85 b	100 a	100 a
Methiocarb 50 WP	1 ef	9 e	21 f	39 c	1 ef	14 c	53 c	55 b
Control	0 f	0 f	1 g	5 d	0 f	0 d	5 d	8 c
Test 2								
Carbofuran 12 F	85 a	90 a	96 a	96 a	99 a	100 a	100 a	100 a
A-41286 48 EC	5 b	14 b	29 b	44 b	0 b	0 b	23 c	60 b
U-56295 85 WP	1 b	4 c	8 cde	14 cdef	0 b	0 b	0 d	15 def
Agrotin 300	1 b	1 c	4 de	21 cd	0 b	0 b	3 d	25 cd
Trichlorfon 95 SP	1 b	1 c	10 cd	29 bc	0 b	0 b	3 d	21 cde
Dioxathion 96 EC	0 b	1 c	15 c	38 b	0 b	0 b	63 b	70 b
U-57770 85 WP	0 b	0 c	4 de	10 ef	0 b	1 b	5 d	26 cd
UBI-WA89-1265 50 WP	0 b	0 c	1 e	6 f	0 b	0 b	3 d	28 c
SAN 285 AD 76 WP	0 b	1 c	4 de	21 cd	0 b	0 b	3 d	13 def
SAN 2401 74 WP	0 b	1 c	6 cde	19 cde	0 b	0 b	0 d	8 f
Control	0 b	4 c	8 cde	11 def	0 b	3 b	4 d	11 ef

[a]0.75 kg a.i. in 1,000 liters water/ha. Area is based on surface area of the petri dish in which the insects were sprayed. [b]Separation of means in a column and for each test by Duncan's multiple range test at the 5% level. HT = hours after treatment

nymphs at the molting stage. It was effective against BPH, GLH (Table 3), and WBPH (Table 4) at rates of 0.25 kg a.i./ha.

Foliar sprays. NNI 750 was evaluated as a foliar spray. As in the contact toxicity study, low rates of 0.25 kg a.i./ha provided 100% control of WBPH, BPH, and GLH (Table 4, 5).

Commercial and coded compounds effective against BPH, GLH, and WBPH are given in Tables 6 and 7. RH 0994, M 9918, methiocarb, RH 0308, UC 27867, and M 10604 were effective against both BPH and GLH (Table 6), and UC 54229 and UCSF-1 were effective against BPH, GLH, and WBPH (Table 7).

Table 2. Contact toxicity of insecticides applied at 0.075%[a] with a Potter's spray tower against the brown planthopper, green leafhopper, and whitebacked planthopper. IRRI insectary, 1980.

Treatment	Mortality[b] (%)											
	Brown planthopper				Green leafhopper				Whitebacked planthopper			
	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT
UC 54229 100 Tech.	100 a	100 a	100 a	100 a	97 a	97 ab	99 ab	99 a	100 a	100 a	100 a	100 a
Permethrin 10 EC	94 ab	100 a	100 a	100 a	83 b	100 a	100 a	100 a	94 a	100 a	100 a	100 a
Carbofuran 12 F	84 bc	84 b	87 b	100 a	97 a	100 a	100 a	100 a	95 a	95 a	99 ab	100 a
RP 32861 20 EC	74 c	76 b	85 b	91 b	46 c	90 b	96 ab	96 a	64 b	95 a	96 ab	99 ab
UC SF-1 40% F	29 d	51 c	64 cd	69 cd	9 d	53 c	93 b	94 a	3 c	19 c	25 d	33 c
EXP 5494 25 EC	16 de	24 d	39 ef	80 bc	5 d	10 d	10 d	18 c	4 c	69 b	91 bc	91 b
Perthane 45 EC	14 e	23 d	78 bc	87 b	4 d	4 de	10 cd	39 b	1 c	1 d	4 e	43 c
UC/MP 19779 48 EC	5 ef	9 de	33 f	58 d	0 d	8 de	29 c	43 b	1 c	1 d	6 e	15 d
Pirimiphos methyl + carbophenothion 20 EC	1 f	10 de	54 de	78 bcd	1 d	1 de	19 cd	53 b	3 c	21 c	84 c	95 ab
Control	0 f	5 e	11 g	26 e	0 d	0 e	0 e	1 d	0 c	0 d	0 e	4 d

[a]0.75 kg a.i./ha in 1,000 liters water/ha. Area is based on surface area of the petri dish in which the insects were sprayed. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. HT = hours after treatment.

Table 3. Contact toxicity of different rates of the insect growth regulator NNI 750 25 WP when applied on nymphs of the brown planthopper and the green leafhopper with a Potter's spray tower. IRRI insectary, 1980.

Treatment and rate (kg a.i./ha)	Mortality[a] (%)					
	Brown planthopper			Green leafhopper		
	1 DAT	3 DAT	6 DAT	1 DAT	3 DAT	6 DAT
Carbofuran 12 F						
0 75	96 a	100 a	100 a	94 a	99 a	99 a
NNI 750						
1.00	14 b	63 c	95 a	11 b	75 b	96 a
0.75	20 b	63 c	96 a	8 bc	73 b	90 bc
0 50	16 b	85 b	99 a	10 bc	83 b	95 ab
0.38	9 b	71 c	98 a	8 bc	83 b	96 ab
0 25	10 b	88 b	96 a	3 c	76 b	86 c
Control	3 c	5 d	9 b	4 bc	8 c	10 d

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment

Table 4. Effect of 3 rates of NNI 750 on whitebacked planthopper nymphs when applied to insects with a Potter's spray tower or applied on plants as foliar spray.[a] IRRI insectary, 1980.

Treatment and rate (kg a.i./ha)	Potter's spray tower			Foliar spray		
	1 DAT	3 DAT	6 DAT	2 DC	4 DC	6 DC
	Mortality[b] (%)					
Carbofuran 12 F						
0.75	100 a	100 a	100 a	66 a	88 a	100 a
NNI 750						
0.25	25 b	76 b	99 a	39 b	64 b	96 a
0.50	18 bc	71 bc	100 a	38 b	48 c	99 a
1 00	11 c	58 c	96 a	30 b	45 c	100 a
Control	1 d	1 d	10 b	1 c	4 d	5 b
	Exuviae in control (%)					
	26	80	95	11	39	98

[a]DAT = days after treatment, DC = days after caging. [b]Separation of means in a column by Duncan's multiple range test at the 5% level

Table 5. Effect of different rates of NNI 750 25% WP applied as foliar spray on mortality of brown planthopper and green leafhopper nymphs. IRRI insectary, 1980.

Treatment and rate (kg a.i /ha)	Mortality[a] (%)					
	Brown planthopper			Green leafhopper		
	2 DC	4 DC	6 DC	2 DC	4 DC	6 DC
Carbofuran 12 F						
0.75	40 a	41 b	100 a	68 a	68 a	100 a
NNI 750 25 WP						
1.00	56 a	71 a	100 a	11 o	53 ab	98 a
0.75	43 a	46 b	100 a	6 bc	49 b	100 a
0.50	41 a	50 b	100 a	11 b	54 ab	100 a
0 38	50 a	54 b	100 a	6 bc	50 ab	99 a
0.25	44 a	50 b	100 a	8 bc	39 b	100 a
Control	3 b	3 c	11 b	1 c	4 c	8 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level DC = days after caging on plants.

A microencapsulated formulation (slow-release) of methyl parathion (Penncap M) provided longer residual activity than the EC formulation (Table 8).

Previous field studies indicated that Perthane is equally effective at spray volumes ranging from 200 to 1,000 liters/ha. In a 1980 insectary study, Perthane gave equal control at volumes of 250, 500, and 1,000 liters/ha, but the residual activity of carbofuran and UC 54229 was greater at the higher volumes (Table 9).

Root-zone application. To identify insecticides that can be applied into the root zone with a row marker-injector and mechanical transplanter, tests of insecticides continued. Although not as effective as carbofuran for BPH control, UC 54229 and UCSF-1 were promising (Table 10).

Three rates of carbofuran were applied in the root zone and insect mortality and feeding activity compared at 5-day intervals (Table 11). Although there was substantial feeding at all rates, plants with the 0.75 and 0.50 kg a.i./ha showed less feeding than the control for as long as 40 days after treatment.

Field studies. Insecticides were field tested against yellow stem borer, caseworm, and BPH.

Yellow stem borer. Insecticides were tested as foliar spray and as granules applied to paddy water at the Maligaya Rice Research and Training Center, Philippines. As foliar spray (Table 12) many insecticides commonly recommended for stem borer control in Asia gave poor control. The combination chlorpyrifos + BPMC was most effective in preventing deadhearts. None of the insecticides was effective in preventing whiteheads.

Of the granular formulations, carbofuran was most effective in preventing deadhearts (Table 13). Again, no insecticide prevented whiteheads.

Caseworm. Few insecticide trials have been conducted against the caseworm because of the pest's uneven distribution in the field. Insects were reared in the greenhouse and field plots were hand infested with 4 second-instar larvae/hill. Each plot was enclosed with a plastic sheet to prevent inter-plot movement of larvae and sprayed 1 day after larval infestation. All insecticides decreased leaf damage by the caseworm (Table 14).

When plants and paddy water were removed from the field and insects separately exposed to them in the greenhouse, most of the insecticides provided >80% control (Table 15). These studies indicate that when caseworms move with irrigation water to low-lying fields, plants in those fields will

Table 6. Knockdown and residual effects of compounds applied as 0 075% (0.75 kg a.i./ha in 1,000 liters water) foliar spray against the brown planthopper and green leafhopper. IRRI insectary, 1980.

Treatment	Mortality[a] (%)									
	Brown planthopper					Green leafhopper				
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
Carbofuran 12 F	100 a	96 a	83 a	44 b	31 b	100 a	100 a	96 a	45 b	84 bc
RH 0994 4 EC	99 a	74 b	65 ab	39 b	31 b	100 a	100 a	70 c	44 b	15 e
M 9918 20 OE	99 a	100 a	75 a	78 a	69 a	100 a	100 a	90 ab	100 a	93 ab
Methiocarb 50 WP	99 a	78 b	64 ab	25 bc	15 bc	100 a	100 a	93 ab	63 b	30 d
RH 0308 4 EC	98 a	71 bc	51 b	40 b	14 bc	100 a	99 ab	79 bc	59 b	65 c
UC 27867 50 WP	96 a	73 b	14 c	9 c	15 bc	100 a	100 a	46 d	15 c	6 ef
M 10604 20 OE	91 ab	81 b	48 b	45 b	16 bc	100 a	100 a	89 ab	56 b	96 a
Methidathion 40% EC	93 ab	61 bc	21 c	11 c	4 c	100 a	99 ab	44 d	19 c	6 ef
Dioxacarb 50% WP	84 b	48 c	25 c	10 c	18 bc	100 a	89 ab	35 d	19 c	4 ef
Control	8 c	5 d	10 c	13 c	11 bc	9 b	3 c	4 e	14 c	0 f

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 7. Evaluation of insecticides applied as foliar spray at 0.75 kg a.i./ha against adults of the brown planthopper, green leafhopper, and whitebacked planthopper. IRRI insectary, 1980.

Treatment	Mortality[a] (%)														
	Brown planthopper					Green leafhopper					Whitebacked planthopper				
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
Carbofuran 12 F	100 a	58 a	29 b	10 abcd	5 bc	100 a	95 a	49 ab	29 bc	11 c	100 a	76 a	10 bc	6 b	1 c
Permethrin 10 EC	99 ab	39 ab	61 a	26 a	9 bc	100 a	91 a	62 a	87 a	78 a	100 a	91 a	65 a	38 a	14 a
UC 54229 100 Tech.	91 bc	21 bc	26 b	14 abc	11 bc	97 a	66 b	9 de	4 de	2 c	100 a	5 d	8 bc	8 b	8 abc
UCSF-1 40 F	88 c	41 ab	35 b	8 bcd	11 bc	96 a	90 a	24 cd	12 cd	2 c	96 a	20 bc	4 bc	4 b	18 ab
Pirimiphos methyl + carbophenothion 20 EC	85 c	16 cd	35 b	2 cd	19 ab	92 a	50 c	2 e	6 de	4 c	99 a	38 b	4 bc	4 b	6 abc
UC/MP 197779 48 EC	46 d	25 bc	29 b	9 bcd	22 abc	91 a	74 b	36 bc	39 b	35 b	34 b	6 cd	12 b	10 b	1 c
EXP 5494 25 EC	31 de	21 bc	32 b	5 bcd	38 a	24 b	6 de	2 e	0 e	9 c	96 a	6 cd	11 b	9 b	4 bc
NNI 750 25 WP	20 e	16 cd	29 b	19 ab	14 bc	9 cd	1 e	1 e	2 de	4 c	8 c	1 d	9 bc	14 b	14 a
RP 32861 20 EC	19 e	6 d	32 b	11 abcd	14 bc	12 bc	22 d	15 d	2 de	4 c	2 c	1 d	5 bc	8 b	1 c
Control	15 e	9 cd	2 c	1 d	5 c	1 d	1 e	2 e	2 de	1 c	2 c	1 d	1 c	4 b	4 abc

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment, when insects were placed on treated plants. Mortality was recorded 48 hours after insects were placed on treated plants.

be protected if an insecticide has been sprayed a few days before.

Ovicidal activity. Insecticides were evaluated for their ability to kill BPH and caseworm eggs.

Brown planthopper. Twelve insecticides were tested in the insectary for ovicidal activity against the BPH. Carbaryl, azinphos ethyl, and four coded compounds were highly active (Table 16).

Caseworm. Insecticides were tested as foliar spray and granules in the field and insectary. In the field trial, 1-day-old eggs on cut leaves were placed on the water surface and the plots sprayed with insecticides. Azinphos ethyl was the most effective ovicide, causing 90% mortality (Table 17). Nine insecticides were applied to 1- or 3-day-old eggs in petri dishes with water and kept in a headhouse room. Triazophos, malathion, and BPMC were effective against both egg ages (Table 17).

Eggs of 3 ages (1, 2, and 3 days) were exposed for 24 hours to 3 granular insecticides in water in the headhouse. Carbofuran and diazinon provided the most effective control of eggs at all ages (Table 18).

Slow-release formulations. The search continued for formulations that extend the residual activity of insecticides. Two lignin-based formulations were compared with carbofuran. The formulations did not significantly differ when tested against the BPH. For GLH, CLFC15 and CLFC45 were similar to carbofuran 3 G at 0.5 and 0.25 kg a.i./ha, but increased mortality at 0.12 kg a.i./ha.

Insect growth regulator. NNI 750, which was effective at low rates in insectary tests, was tested for field control of BPH. Foliar sprays were applied 30 and 40 days after transplanting (DT). At 30 DT, NNI 750 at 0.125 kg a.i./ha was more effective than BPMC at 0.75 kg a.i./ha at 5 days after treatment (DAT). At 40 DT, the 0.5 kg a.i. NNI 750/ha was more effective than 0.75 kg a.i./ha rate of BPMC at 5 DAT. The 0.75 kg a.i./ha rate of NNI 750 still caused 45% mortality at 10 DT, but BPMC at the same rate caused only 10% mortality (Table 19).

Resistance to insecticides. Insect cultures collected at four sites in the Philippines were compared with the IRRI greenhouse culture to determine whether the Philippine cultures had developed resistance to acephate, methyl parathion, MIPC, or monocrotophos (Table 20). The Palayan culture had resistance to acephate and methyl parathion (1.32- and 2.02-fold), and the Santa Maria culture

Table 8. Comparative study of the residual activity of foliar sprays of 2 formulations of methyl parathion (Penncap M and methyl parathion EC) against the brown planthopper and green leafhopper. IRRI insectary, 1980.

Treatment[a]	Mortality[b] (%)											
	Brown planthopper						Green leafhopper					
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	25 DAT	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	25 DAT
Carbofuran 12 F	100 a	86 a	95 a	90 a	26 a	33 a	100 a	100 a	100 a	100 a	69 a	63 a
Penncap M 25 EC	100 a	76 a	60 b	31 b	13 a	21 ab	100 a	93 a	98 a	91 a	40 b	36 b
Methyl parathion 50 EC	84 b	31 b	11 c	16 bc	11 a	15 ab	100 a	71 b	20 b	28 b	6 c	11 c
Control	10 c	10 b	3 c	6 c	10 a	10 b	9 b	11 c	8 b	10 b	9 c	9 c

[a]Insecticides were applied at the rate of 0.75 kg a.i./ha [b]Separation of means in a column by Duncan's multiple range test at the 5% level DAT = days after treatment, when insects were placed on treated plants. Mortality readings were taken 48 hours after insects were placed on treated plants.

Table 9. Mortality of the brown planthopper as affected by volume of sprays applied at 0 75 kg a i /ha. IRRI insectary, 1980.

Insecticide and volume (liters/ha	Mortality[a] (%)				
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
Carbofuran 12 F					
1000	100 a	98 a	91 a	65 a	23 a
500	100 a	99 a	93 a	70 a	28 a
250	95 a	43 b	23 b	13 b	5 b
Perthane 45 EC					
1000	100 a	98 a	46 a	24 ab	6 a
500	98 a	86 a	45 a	34 a	9 a
250	100 a	94 a	46 a	11 b	5 a
Monocrotophos 30 EC					
1000	94 ab	39 a	18 a	15 a	6 a
500	96 a	35 a	16 a	9 a	3 a
250	85 b	34 a	10 a	6 a	3 a

Insecticide and volume (liters/ha)	Mortality[a] (%)				
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
UC 54229 100 Tech.					
1000	99 a	100 a	92 a	59 a	28 a
500	100 a	99 a	84 a	45 ab	10 a
250	98 a	84 b	63 b	26 b	10 a
Control					
1000	8 a	11 a	9 a	9 a	4 a
500	13 a	10 a	10 a	6 a	1 a
250	14 a	11 a	11 a	4 a	5 a

Separation of means in a column under each insecticide by Duncan's multiple range test at the 5% level DAT = days after insecticide treatment, when insects were placed on plants Mortality readings were taken 48 hours after insects were placed on plants.

Table 10. Evaluation of insecticides applied at 1.0 kg a.i./ha in the root zone for brown planthopper and green leafhopper control. IRRI insectary, 1980

Treatment	Mortality[a] (%)									
	Brown planthopper					Green leafhopper				
	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT	1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
Carbofuran 12 F	100 a	100 a	86 a	83 a	13 a	100 a	100 a	94 a	83 a	86 a
UC 54229 100% Tech	76 b	48 b	8 b	43 b	1 a	99 a	88 a	71 b	68 a	71 a
UC SF-1 40 F	60 b	66 b	10 b	21 bc	3 a	99 a	95 a	53 b	75 a	64 a
Pirimiphos methyl + carbophenothion 20 EC	10 c	10 c	1 b	26 bc	1 a	4 b	5 b	8 c	14 b	0 b
EXP 5494 25 EC	10 c	9 c	4 b	1 d	1 a	3 b	6 b	8 c	1 c	3 b
Control	10 c	6 c	4 b	9 cd	5 a	1 b	4 b	1 c	10 bc	1 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level DAT = days after treatment, when insects were placed on treated plants. Mortality readings were taken 48 hours after insects were placed on plants.

Table 11. Residual activity of 3 carbofuran rates applied in the root zone for control of the green leafhopper and their effect on insect feeding as indicated by area of honeydew spot on filter paper.[a] IRRI insectary, 1980.

Days after treatment	Insect mortality (%)				Honeydew spot (mm^2)			
	0.75 kg a.i /ha	0 50 kg a.ı./ha	0 25 kg a.ı /ha	Control	0.75 kg a ı./ha	0.50 kg a.ı./ha	0 25 kg a.i./ha	Control
1	90 a	33 b	38 b	0 c	106 b	172 b	262 b	625 a
5	100 a	98 a	63 b	0 c	60 b	91 b	205 b	540 a
10	100 a	100 a	100 a	0 b	44 b	46 b	52 b	623 a
15	100 a	100 a	78 b	0 c	34 b	37 b	136 b	626 a
20	95 a	98 a	70 b	0 c	46 b	60 b	117 b	637 a
25	90 a	50 b	20 b	0 c	115 c	349 c	736 b	978 a
30	80 a	48 b	13 c	0 c	173 b	256 b	593 a	669 a
35	68 a	40 b	10 c	3 c	177 b	338 b	652 a	641 a
40	65 a	25 b	3 c	3 c	210 b	394 b	733 a	641 a
45	30 a	5 ab	0 b	0 b	438 b	874 a	1079 a	904 a

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

Table 12. Evaluation of commercial insecticides applied on IR29 as foliar spray for yellow stem borer control. Maligaya Rice Research and Training Center, Philippines, 1980

Treatment[a]	Deadhearts[b] (%)		Whiteheads[b] (%)	Treatment[a]	Deadhearts[b] (%)		Whiteheads[b] (%)
	20 DT	40 DT	115 DT		20 DT	40 DT	115 DT
Endosulfan 35 EC	9.1 abc	14 9 bcd	2 6 b	Carbophenothion 40 EC	9 9 abc	17 0 abcd	4.4 ab
Phosphamidon 50 EC	10.7 abc	7.7 e	3.3 ab	Dimethoate 40 EC	12.2 abc	16.7 abcd	5 2 ab
Diazinon 20 EC	10.5 abc	15.8 abcd	2.6 b	Metalkamate 23 EC	11 3 abc	15.3 abcd	6 7 a
Monocrotophos 16.8 EC	7.3 bc	12 8 cd	3 2 ab	Azinphos ethyl 40 EC	11.1 abc	11 1 de	2 5 b
Chlorpyrifos + BPMC 31.5 EC	6.9 c	2.8 f	4 8 ab	Fenthion 50 EC	9.8 abc	12 6 cd	3.6 ab
				Phosmet 50 WP	10.9 abc	19 7 ab	4.9 ab
Methomyl 19.8 EC	13.4 abc	17 0 abcd	3 0 ab	*B. thuringiensis*	10.2 abc	18 1 abc	5 6 ab
BPMC 50 EC	14.4 a	14.6 bcd	5.2 ab	Control	13.1 ab	22 6 a	3.9 ab
Fenitrothion 30 EC	11.1 abc	12.1 cde	4.6 ab				

[a]All insecticides were applied at 0 75 kg a i /ha except *B. thuringiensis*, which was applied at 0.4 kg formulation (600 IU/mg) per ha. Insecticides were applied at 10, 25, 45, 60, and 75 DT. [b]Av of 4 replications Separation of means in a column by Duncan's multiple range test at the 5% level DT = days after transplanting

Table 13. Evaluation of granular formulations of commercial insecticides for yellow stem borer control on variety IR29. Maligaya Rice Research and Training Center, Philippines, 1980.

Treatment[a]	Rate (kg a.i./ha)	Deadhearts[b] (%)		Whiteheads[b] (%)
		20 DT	40 DT	115 DT
Carbofuran 3 G (SI)	1.0	1.4 bc	0.2 e	3.7 a
Carbofuran 3 G	1.0	1.0 bc	0 7 e	3 0 a
Gamma BHC + carbaryl 6 + 6 G	1.0	3.5 ab	11 6 b	4 6 a
Diazinon 5 G	1.0	0 6 c	5.4 cd	4.2 a
Gamma BHC + MIPC 6 + 4 G	1.0	1.9 bc	7 2 bc	5.0 a
Carbofuran 3 G	1.5	0.3 c	0.1 e	3.2 a
Gamma BHC + carbaryl 8 + 8 G	1.5	5 6 a	5.9 cd	3.4 a
Diazinon 5 G	1.5	0.9 c	3.5 d	4.4 a
Gamma BHC + MIPC 6 + 4 G	1.5	4.7 a	5.6 cd	3.0 a
Control	—	6.1 a	18.0 a	3.8 a

[a]All treatments were applied to paddy water, except one treatment of carbofuran, which was soil incorporated (SI) before transplanting Insecticides were applied at 10, 25, 45, 60, and 75 days after transplanting (DT). [b]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 14. Effect of foliar insecticides on plant damage from rice caseworm larvae IRRI, 1980.

Treatment[a]	Tillers (%) with cut leaves[b]	
	0 DS	10 DS
Azinphos ethyl 40 EC	7 a	2 a
Triazophos 40 EC	8 a	2 a
Malathion 57 EC	8 a	2 a
MIPC 50 WP	9 a	3 a
Chlorpyrifos 40 EC	9 a	3 a
Carbaryl 85 WP	8 a	3 a
Endosulfan 35 EC	8 a	3 a
BPMC 50 WP	9 a	3 a
Phosphamidon 50 EC	8 a	2 a
Diazinon 20 EC	11 a	3 a
MTMC 50 WP	7 a	7 b
Control	8 a	17 c

[a]Insecticides were applied at 0.75 kg a.i./ha 15 days after transplanting [b]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. DS = days after spraying.

Table 15. Effect on caseworm larval mortality of foliar insecticides applied to rice plants, paddy water, or both. IRRI, 1980.

Insecticide[a]	Larval mortality[b] (%) 48 h after treatment		
	Plants and paddy water sprayed	Plants sprayed[c]	Paddy water sprayed[d]
MIPC 50 WP	100 a	100 a	100 a
Diazinon 20 EC	100 a	97 ab	100 a
Azinphos ethyl 40 EC	100 a	90 ab	100 a
Chlorpyrifos 40 EC	100 a	97 ab	95 ab
BPMC 50 WP	100 a	92 ab	95 ab
Malathion 57 EC	100 a	92 ab	85 ab
Carbaryl 85 WP	100 a	95 ab	75 bc
Endosulfan 35 EC	100 a	68 c	85 ab
Phosphamidon 50 EC	95 a	82 bc	80 bc
MTMC 50 WP	85 a	63 c	55 c
Mean	98	88	88

[a]Applied at 0.75 kg a.i./ha, 15 days after transplanting [b]Corrected using Abbott's formula. Ten second-instar larvae/replication (one cage). Separation of means in a column by Duncan's multiple range test at the 5% level [c]Av of 4 replications [d]Av of 2 replications.

had a 1.36-fold resistance to acephate. It was evident that resistance to insecticides tested was not a problem for farmers in the areas sampled.

Insecticide-induced BPH resurgence. Insecticides were field-tested to identify those that induce BPH resurgence. Rates of resurgence-inducing insecticides were compared to determine their effect on level of resurgence. The effect of the level of varietal resistance to the BPH on the level of resurgence was also determined.

Table 16. Ovicidal activity of insecticides applied as foliar spray at 0.75 kg a.i./ha on plants containing 1-day-old eggs of brown planthopper. IRRI insectary, 1980.

Treatment	Hatched eggs[a] (%)
UC 54229 100 Tech.	0 a
FMC 35001 20 EC	1 a
UC SF-1 40 F	3 a
UC 27867 50 WP	3 a
Carbaryl 85 WP	3 a
Azinphos ethyl 40 EC	4 a
Propoxur 20 EC	78 b
Decamethrin 2.5 EC	78 b
NNI 750 25 WP	80 b
Diazinon 20 EC	94 c
BHC 26 WP	97 c
Chlorpyrifos 40 EC	96 c
Control	98 c

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level

Table 17. Ovicidal activity of insecticides applied as foliar spray against the rice caseworm.[a] IRRI, 1980.

Insecticide[b]	Mortality[c] (%) of eggs exposed for 24 h at indicated age		
	1 day		3 days, at
	Field[d]	Headhouse[e]	headhouse[e]
Azinphos ethyl 40 EC	90 a	—	—
Diazinon 20 EC	78 ab	95 a	20 cd
Triazophos 40 EC	68 abc	94 a	99 a
Malathion 57 EC	44 abc	84 a	99 a
BPMC 50 WP	33 bc	96 a	91 ab
Phosphamidon 50 EC	31 bc	19 b	12 d
Carbaryl 85 WP	28 bc	—	—
Endosulfan 35 EC	29 bc	—	—
MTMC 50 WP	21 c	41 b	99 a
MIPC 50 WP	12 c	91 a	76 b
Carbophenothion 40 EC	—	98 a	41 c
Ethion 40 EC	—	96 a	71 b

[a]100 eggs/replication [b]400 ppm [c]Separation of means in a column by Duncan's multiple range test at the 5% level. A dash indicates no test. Mortality readings adjusted with Abbott's formula. [d]Applied at 0.75 kg a.i./ha on water surface. Av of 2 replications. [e]Av of 3 replications

Table 18. Ovicidal activity of insecticides applied as granules in paddy water against the rice caseworm. IRRI, 1980.

Insecticide[a]	Mortality[b] (%) of eggs exposed for 24 h at indicated age		
	1 day	2 days	3 days
Carbofuran 3 G	100 a	100 a	97 a
Diazinon 6 G	96 a	99 a	82 b
γ-BHC 6 G	52 b	31 b	85 b

[a]Applied at 0.75 kg a.i./ha (375 ppm). [b]Av of 3 replications (100 eggs/replication). Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 19. Mortality of 3d-instar nymphs of the brown planthopper on IR22 plants treated with NNI 750 and BPMC. IRRI, 1980 wet season.

Treatment and rate (kg a.i./ha)	Mortality[a] (%)	
	Spray at 30 DT	Spray at 40 DT
	5 days after treatment	
NNI 750		
0.125	93 a	21 b
0.250	85 a	34 b
0 500	93 a	55 a
0 750	95 a	68 a
BPMC		
0 750	1 b	30 b
Control	0 b	8 c
	10 days after treatment	
NNI 750		
0.125	20 a	9 c
0 250	18 a	20 bc
0.500	18 a	28 b
0.750	18 a	45 a
BPMC		
0.750	0 b	10 c
Control	0 b	0 d

[a]Separation of means in a column under the same days after treatment by Duncan's multiple range test at the 5% level. DT = days after transplanting.

Identification of resurgence-inducing insecticides. Insecticides used for rice insect control in Asia were tested for BPH resurgence activity. Important BPH predators were also monitored. Nine insecticides significantly reduced BPH numbers, but propoxur and ethylan (Perthane) gave the most consistent and effective control. Sixteen insecticides caused resurgence (Table 21). Destruction of predators by the insecticides did not appear to be a major cause for resurgence. Although decamethrin, a resurgence-inducing insecticide significantly decreased the spider and *C. lividipennis* populations, quinalphos, which is another resurgence-inducing insecticide, did not adversely affect the predator species (Table 22). Chlorpyrifos + BPMC, which did not cause resurgence, significantly reduced the spider and *C. lividipennis* population to below that of the control.

Insecticide rates and resurgence. Three field tests determined the effect of insecticide rates on BPH resurgence. Observations were also made on the number of predators in the various treatments.

The first test had foliar sprays of 2 rates each of decamethrin, diazinon, and FMC 35001 at 34, 49, and 64 DT. The high rate of decamethrin and low rate of FMC 35001 caused the highest levels of resurgence, but there was no significant difference between the BPH populations in the two diazinon rates (Table 23). There was no distinct rate effect on populations of *C. lividipennis*. Populations were equally depressed by all treatments at 37 DT, but populations at the high rate of FMC 35001 were lower than that at the low rate at 52, 63, and 67 DT. The high rate of decamethrin had lower spider and *M. atrolineata* populations than the low rate. The high rate of FMC 35001 had the lowest *M. atrolineata* population after applications at 37 and 52 DT.

In the second test, three rates of carbofuran granules and FMC 35001 sprays caused similar levels of resurgence, and all rates of Perthane sprays provided equal BPH control (Table 24). *C. lividipennis* populations were equally depressed by all rates of the three insecticides. Spider and *M. atrolineata* numbers were low and equal in all

Table 20. Level of resistance of field-collected green leafhopper cultures to insecticides, based on LC_{50} values.[a] IRRI insectary, 1980.

Source of Philippine culture	Level of resistance[b]			
	Acephate	Methyl parathion[c]	MIPC	Monocrotophos
Palayan, Isabela	1.32*	2 02*	0.86	0 84
Santa Maria, Pangasinan	1.36*	1.11	0.28	0.62
Rosales, Pangasinan	0.95	1.12	0 28	0 53
Pura, Tarlac	1.00	1.24	0 52	0 55

[a]LC_{50} = lethal concentration in kg a.i./ha applied in a Potter's spray tower to kill 50% of the insect population. [b]Level of resistance =

$$\frac{LC_{50} \text{ of field-collected culture}}{LC_{50} \text{ of greenhouse culture}}$$

A resistance ratio >1.00 indicates that level of resistance in the field culture is greater than that in the greenhouse culture The asterisk indicates field-collected cultures with a significantly higher LC_{50} than the greenhouse culture at the 5% level [c]Penncap M formulation.

Table 21. Effect of insecticides on the brown planthopper (BPH) in 5 tests at IRRI, 1979-80.

Treatment[a]	Brown planthopper[b] (av no./hill)							Hopper-burn (%)
	First treatment		Second treatment		Third treatment		Last sampling	
	Before	After	Before	After	Before	After		
				Test 1				
†Azinphos ethyl 40 EC	1 4 ab	2.6 a	2.9 ab	4.9 a	21.5 ab	77.2 a	209.2 a	0 a
†Quinalphos 25 EC	1 9 ab	1.7 ab	5 2 ab	3.7 bc	21.0 ab	64.5 a	241.5 a	0 a
Chlorfenvinphos 20 EC	2 0 ab	1.7 ab	4 2 ab	5.5 abc	13.1 ab	39.1 a	99.9 ab	0 a
††Carbofuran 12 F	1 8 ab	0.3 c	3 7 ab	1.6 d	6.9 b	5.1 b	29.4 c	0 a
Diazinon 20 EC	1.1 ab	1.1 abc	4.2 ab	4.8 abc	28.4 ab	41.7 a	88.9 ab	0 a
†Phenthoate 50 EC	1.5 ab	1.2 ab	6.2 a	8.8 a	30.4 a	51.2 a	273.7 a	0 a
Fenthion 50 EC	2.3 a	1.1 abc	4.4 ab	4.4 abc	15.6 ab	38.1 a	138.8 ab	0 a
†FMC 35001 20 EC	1.0 ab	0.3 c	2.3 b	4.6 cd	14.9 ab	5.6 b	133.7 bc	0 a
†Methomyl 19.8 EC	1 1 ab	2.4 a	5.8 ab	9.9 ab	26.0 ab	87.8 a	418.9 a	0 a
††Ethylan 45 EC	0.4 b	0.4 bc	2.9 ab	1.5 d	7.9 b	2.2 b	12.4 d	0 a
Control	0.8 ab	3.3 a	4.4 ab	5.5 abc	15.8 ab	95.1 a	45.3 bc	0 a
				Test 2				
Cartap 4 G	6.9 a	6.6 bc	179.3 ab	65.7 b	18.5 b	19.6 c	113.2 b	0 a
†Diazinon 5 G	9.1 a	15.3 a	309.4 a	256.1 a	54.0 ab	358.6 a	2544.8 a	100 b
†Isazophos 3 G	6.2 a	4.6 c	308.5 a	255.8 a	58.0 ab	861.6 a	2814.0 a	100 b
Carbaryl + BHC 4/4 G	8.5 a	13.1 ab	74.8 b	66.4 b	28 4 ab	9.4 c	45.2 b	5 a
†Carbofuran 3 G	10.4 a	8.0 ab	262.2 a	141.9 a	54.2 a	77.2 b	2695.4 a	80 b
Control	9.0 a	11.4 ab	215.7 a	40.0 b	36.2 ab	14.8 bc	76.6 b	0 a
				Test 3				
†Tetrachlorvinphos 75 WP	19.1 a	75.4 ab	43.6 ab	45.1 a	722 5 a	1244.9 a	361.4 b	12 d
††BHC 20 EC	23.8 a	6.3 c	8.4 c	14.0 b	130.8 bc	30.4 ef	40.7 c	0 f
†Methyl parathion 50 EC	30.0 a	93.9 a	43.3 ab	33.3 a	419 9 ab	1110.7 ab	814.8 ab	65 b
†Monocrotophos 16.8 EC	27.8 a	43.6 ab	25.9 b	18.5 ab	399 3 ab	442.6 bcd	55.8 c	2 ef
†Pyridaphenthion 75 WP	32.2 a	51 4 ab	35.9 ab	31.5 ab	955.2 a	1012.3 ab	363.5 b	29 c
†Cyanofenphos 40 EC	21.3 a	79.5 ab	59.3 a	39.7 a	967 8 a	1244.3 ab	1787.5 a	91 a
Carbaryl 80 EC	16.6 a	31.3 b	21.2 b	12.3 ab	225.0 bc	353.6 bc	61.3 c	0 f
††Ethylan 45 EC	20.4 a	0.9 d	4.0 d	1.6 c	30.6 d	11.0 f	25.1 c	0 f
Control	20.3 a	82.0 ab	8.0 cd	12.3 ab	76.0 cd	69.7 de	25.0 c	0 f
				Test 4				
††BPMC 50 EC	109.4 a	7.1 a	382 8 a	466.2 bc	500.0 cd	269.4 abc	267.2 cd	12 cde
MIPC 50 WP	69.0 ab	16.3 a	355.4 a	1241.5 abc	748.6 abc	310.6 abc	529.1 abcd	25 cd
††Carbophenothion 48 EC	55.9 ab	11.0 a	507.0 a	612.9 bc	623.3 bcd	235.7 abc	445.2 abc	30 c
††MTMC 30 EC	39 6 ab	7 4 a	450.9 a	396.1 c	286.0 d	117.2 c	107.0 d	2 e
Phosphamidon 50 EC	17.7 b	8.7 a	231.2 a	856.5 abc	701.1 abc	439.0 ab	536.9 abc	14 cde
††Endosulfan 35 EC	29.4 ab	12.8 a	343.4 a	517.4 bc	640.5 bcd	267.3 bc	283.2 bcd	1 e
†Triazophos 40 EC	64.7 ab	12.8 a	487.0 a	1752.7 ab	1578.6 a	844.9 a	1203.5 a	78 b
†Decamethrin 31 EC	34.1 ab	8.1 a	342.4 a	1452.2 ab	1304.0 ab	868.8 a	1162 9 a	100 a
Control	32.0 ab	17.1 a	326.6 a	2502.2 a	445.9 cd	428.9 abc	217 4 bcd	10 cde

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Table 21. Effect of insecticides on the brown planthopper (BPH) in 5 tests at IRRI, 1979-80.

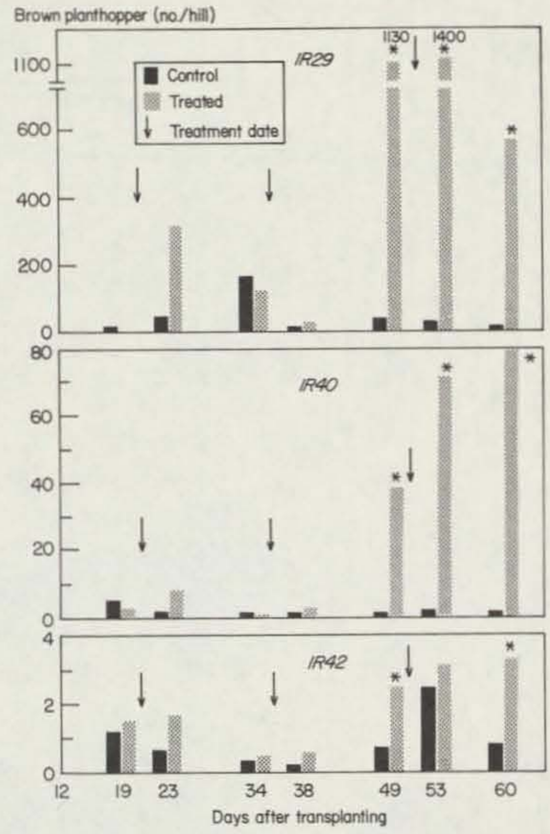
Treatment[a]	Brown planthopper[b] (av no./hill)							Hopper-burn (%)
	First treatment		Second treatment		Third treatment		Last sampling	
	Before	After	Before	After	Before	After		
				Test 5				
Acephate 75 WP	81.2 a	50.6 a	471.6 ab	1860.9 abc	1023.5 b	799.0 ab	199.2 bc	0 e
Azinphos ethyl + MTMC 32 EC	51.0 a	38.2 a	803.3 a	920.5 de	391.1 bcd	814.7 ab	178.7 bc	5 cd
BPMC + chlorpyrifos 32 EC	30.4 a	37.9 a	443.3 ab	1393.0 bcd	98.9 e	504.7 ab	106.9 c	3 de
Dimethoate 38 EC	51.5 a	53.5 a	1427.6 a	2579.3 ab	2293.3 a	1094.3 ab	409.4 ab	91 b
††Propoxur 20 EC	24.0 a	39.7 a	243.8 b	577.7 e	31.7 c	42.6 c	11.3 d	0 e
††Chlorpyrifos 40 EC	44.4 a	37.1 a	840.8 a	1146.1 cd	200.7 d	359.5 b	93.2 c	9 cd
†Penncap-M 25 EC	28.8 a	62.0 a	1031.8 a	3155.4 a	2747.9 a	1139.1 a	499.0 a	91 b
†Fenvalerate 38 EC	64.5 a	28.4 a	658.7 ab	1143.8 bcd	992.1 bc	1024.6 a	613.5 a	99 a
Control	65.7 a	53.0 a	993.8 ab	1891.9 abcd	1301.5 ab	1250.3 a	216.9 bc	13 c

[a]A single dagger (†) indicates the insecticide caused a significantly larger BPH population than in untreated check plots after the first insecticide application. The 2 daggers (††) indicate the insecticide significantly reduced BPH population below that in the untreated check in samples taken 2 days after 1 or more applications. [b]In a column and for each test, separation of means by Duncan's multiple range test at the 5% level.

treatments.

In the third test, three rates of isazophos granules in paddy water and methomyl sprays were compared. Both compounds caused resurgence. The lower rates of isazophos caused the highest levels of resurgence, but there was no difference in resurgence among the rates of methomyl (Table 25). Populations of *C. lividipennis,* spiders, and *M. atrolineata* were low and no difference in effect of rates on the population was observed.

Level of BPH resistance and resurgence. Three rice varieties (IR29, IR40, and IR42) respectively susceptible, moderately resistant, and resistant to BPH in the Philippines were treated in the field with decamethrin, which is known to cause resurgence. BPH populations increased to a significantly higher level in the treated plots than in untreated checks, but the degree of resurgence varied among varieties. The maximum population



1. Brown planthopper populations in decamethrin-treated and untreated field plots of a susceptible (IR29), a moderately resistant (IR40), and a resistant (IR42) rice variety. Asterisks indicate populations significantly higher than those on the untreated control at the 5% level. IRRI, 1980.

Table 22. Comparison of predator numbers and the av no. of prey/predator in insecticide-treated and untreated plots.[a] Los Baños, Laguna, Philippines, 1980.

Treatment	Spiders				*Microvelia atrolineata*				*Cyrtorhinus lividipennis*			
	Av no./hill[b]		Av no. of BPH/ spider		Av no./hill[b]		Av no. of BPH/ *Microvelia*		Av no./hill[b]		Av no. of BPH/ *Cyrtorhinus*	
	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample
					Test 1							
Azinphos ethyl 40 EC	0.9 ab	2.0 c	33 a	114 a	0.9 bcd	6.2 a	33 a	63 a	0.1 ab	0.6 ab	431 a	963 a
Quinalphos 25 EC	1.0 ab	2.2 bc	23 ab	105 ab	3.1 ab	23.7 a	16 b	20 ab	<0.1 ab	1.2 ab	844 a	428 ab
Chlorfenvinphos 20 EC	1.0 ab	2.9 abc	15 ab	36 cd	3.6 a	8.6 a	5 b	22 ab	0.1 ab	0.3 ab	256 a	150 b
Carbofuran 12 F	0.7 b	2.7 c	4 b	14 d	1.8 abcd	12.0 a	2 b	6 b	<0.1 ab	0.1 ab	53 a	100 b
Diazinon 20 EC	1.1 ab	2.3 bc	16 ab	48 cd	3.3 ab	24.7 a	8 b	14 b	<0.1 b	2.5 ab	509 a	206 b
Phenthoate 50 EC	1.1 ab	4.8 a	21 ab	56 bcd	2.0 abc	30.2 a	11 b	26 ab	0.1 ab	4.7 a	500 a	98 b
Fenthion 50 EC	1.0 ab	2.5 abc	15 ab	58 bcd	3.3 ab	24.3 a	9 b	34 ab	<0.1 ab	1.4 ab	439 a	58 b
FMC 35001 20 EC	0.7 b	3.7 abc	5 b	27 cd	0.5 d	13.0 a	8 b	9 b	<0.1 ab	0.1 b	163 a	1572 a
Methomyl 19.8 EC	0.9 ab	4.4 ab	36 a	80 abc	4.2 ab	18.1 a	13 b	36 ab	0.1 ab	1.9 ab	399 a	173 b
Ethylan 45 EC	0.8 ab	2.5 bc	2 b	9 d	0.7 cd	17.6 a	2 b	7 b	<0.1 b	0.3 ab	19 a	41 b
Control	1.2 a	2.5 abc	27 a	17 d	4.2 a	6.9 a	12 b	27 ab	0.1 a	1.5 ab	457 a	149 b
					Test 2							
Cartap 4 G	1.9 ab	1.8 ab	15 c	28 b	0.1 c	0.3 c	232 ab	197 bc	2.1 a	7.2 a	13 b	7 b
Diazinon 5 G	2.3 a	3.1 ab	65 b	527 a	1.9 a	2.2 abc	98 b	682 ab	2.3 a	14.0 a	80 b	96 b
Isazophos 3 G	1.6 b	2.4 ab	137 a	630 a	0.9 ab	2.5 ab	474 a	701 a	0.1 b	9.9 a	1611 a	173 b
Carbaryl + BHC 4/4 G	1.9 ab	1.3 b	14 c	24 b	0.6 b	0.3 c	111 b	61 c	2.5 a	3.4 b	14 b	15 b
Carbofuran 3 G	2.0 ab	3.4 a	31 bc	472 a	1.8 a	4.0 a	40 b	358 abc	0.3 b	2.2 b	428 b	692 a
Control	1.5 b	1.8 ab	13 c	21 b	0.3 bc	0.4 bc	68 b	82 c	3.3 a	4.8 b	11 b	8 b
					Test 3							
Tetrachlorvinphos 75 WP	1.5 a	2.8 a	293 ab	140 b	0.8 cd	1.2 a	592 a	318 bc	1.0 bc	0.5 ab	729 ab	762 b
BHC 20 EC	0.3 d	0.8 b	87 ab	55 b	0.5 d	1.9 a	44 b	76 c	1.5 b	1.3 a	12 b	47 b
Methyl parathion 50 EC	1.3 ab	3.4 a	310 ab	300 b	2.6 ab	0.9 a	201 b	1113 a	0.3 cd	0.8 ab	2120 ab	1158 b
Monocrotophos 16.8 EC	0.5 cd	0.6 b	535 a	92 b	3.8 a	1.9 a	36 b	134 c	0.1 d	0.1 c	1982 ab	362 b
Pyridaphention 75 WP	1.1 ab	2.3 a	346 ab	156 b	3.8 a	10.8 a	135 b	174 c	0.2 d	0.5 bc	1646 ab	2121 b
Cyanofenphos 40 EC	1.0 ab	2.2 a	452 ab	1040 a	3.9 a	2.7 a	141 b	914 ab	0.2 d	0.3 bc	3660 a	5877 a
Carbaryl 80 WP	0.9 abc	1.6 ab	195 ab	51 b	2.2 abc	3.0 a	128 b	41 c	0.2 d	0.2 bc	1010 ab	259 b
Ethylan 45 EC	0.7 bc	0.8 b	7 b	35 b	0.6 d	1.2 a	11 b	44 c	0.4 cd	0.3 bc	32 b	90 b
Control	1.4 ab	1.7 ab	45 ab	16 b	0.9 bcd	2.1 a	71 b	24 c	5.2 a	1.2 ab	11 b	30 b
					Test 4[c]							
BPMC 50 EC	0.7 ab	0.6 ab	365 b	337 b	3.0 ab	0.1 a	101 b	1695 c	0.5 bc	1.5 a	770 bc	165 a
MIPC 50 WP	0.7 ab	0.6 ab	779 b	799 b	2.2 abc	<0.1 a	292 b	9825 a	0.5 bc	1.6 a	1130 bc	290 a
Carbophenothion 48 EC	0.6 ab	0.5 ab	511 b	1120 b	1.5 abcd	<0.1 a	311 b	7650 b	0.3 bc	2.0 a	940 bc	316 a
MTMC 30 EC	0.6 ab	0.5 ab	457 b	194 b	0.9 cd	<0.1 a	358 b	—	0.2 bc	0.4 a	904 bc	257 a
Phosphamidon 50 EC	0.7 ab	1.1 a	642 b	592 b	5.1 a	<0.1 a	128 b	—	0.2 bc	1.6 a	8862 ab	353 a
Endosulfan 35 EC	0.4 abc	0.5 ab	633 b	440 b	0.8 bcd	<0.1 a	324 b	1322 d	0.5 bc	1.4 a	770 bc	356 a
Triazophos 40 EC	0.5 ab	0.4 ab	1904 b	3711 b	0.5 d	<0.1 a	3356 a	—	0.1 c	3.1 a	13052 a	727 a
Decamethrin 31 EC	0.3 c	0.2 b	5632 a	10443 a	1.0 bcd	<0.1 a	1734 ab	—	0.8 b	2.2 a	2094 bc	571 a
Control	0.8 a	0.8 a	1131 b	286 b	1.4 bcd	<0.1 a	1070 ab	—	4.4 a	2.3 a	273 c	100 a

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Table 22. Comparison of predator numbers and the av no. of prey/predator in insecticide-treated and untreated plots.[a] Los Baños, Laguna, Philippines, 1980.

Treatment	Spiders				*Microvelia atrolineata*				*Cyrtorhinus lividipennis*			
	Av no./hill[b]		Av no. of BPH/ spider		Av no./hill[b]		Av no. of BPH/ *Microvelia*		Av no./hill[b]		Av no. of BPH/ *Cyrtorhinus*	
	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample	After treat-ments	Last sample
					Test 5							
Acephate 75 WP	1.4 abc	1.4 ab	654 ab	94 bcd	12.6 a	3.5 a	92 ab	145 a	1.9 ab	1.3 bc	681 a	161 b
Azinphos ethyl + MTMC 32 EC	1.0 d	1.4 ab	590 abc	79 bcd	3.2 c	0.7 a	253 ab	260 a	0.6 b	2.2 b	2165 a	97 b
BPMC + chlorpyrifos 32 EC	1.1 bcd	1.5 ab	613 abc	40 cd	7.3 abc	2.3 a	106 ab	64 a	0.6 b	0.5 cde	2026 a	345 b
Dimethoate 38 EC	1.5 ab	1.6 ab	921 a	209 b	10.1 abc	4.5 a	397 a	286 a	0.8 b	1.2 bcd	1855 a	601 b
Propoxur 20 EC	1.2 bcd	1.1 ab	182 c	7 d	10.3 ab	4.7 a	23 b	4 a	1.0 b	0.1 e	1990 a	66 b
Chlorpyrifos 40 EC	1.4 ab	1.0 b	358 bc	95 bcd	6.8 abc	6.0 a	86 ab	19 a	0.6 b	0.3 de	2680 a	512 b
Penncap-M 25 EC	1.4 ab	2.3 a	1049 a	168 bc	24.1 a	8.3 a	178 ab	469 a	0.9 b	0.4 cde	3710 a	1607 a
Fenvalerate 38 EC	1.0 cd	1.3 ab	798 ab	349 a	4.1 bc	3.9 a	216 ab	458 a	3.4 a	19.2 a	250 a	37 b
Control	1.7 a	2.3 a	612 abc	74 bcd	7.8 abc	2.0 a	205 ab	129 a	5.3 a	9.7 a	261 a	24 b

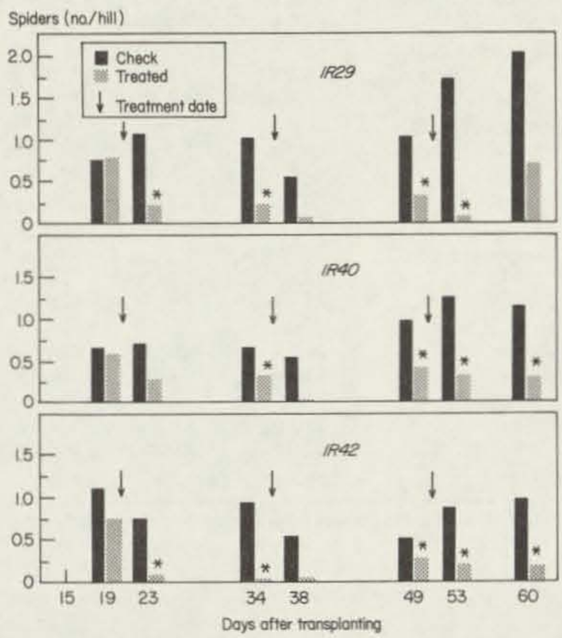
[a]Separation of means in a column by Duncan's multiple range test at the 5% level. BPH = brown planthopper. [b]Av no./hill after treatments = $\frac{\text{no. after treatment } 1 + 2 + 3}{\text{total no. of hills sampled}}$ [c]Dash indicates no *M. atrolineata* were collected.

increases in the treated plots compared to the checks were 74x for IR29, 40x for IR40, and 5x for IR42 (Fig.1). Decamethrin was toxic to predators (Fig. 2-4) and this reduction of natural enemies may have contributed to BPH resurgence. However, the differences between BPH populations in treated and untreated plots within varieties were larger than differences in predator numbers, suggesting that other factors were also involved.

Resurgence-inducing insecticides and plant chemistry. Because resurgence may be a host-plant-mediated phenomenon, the effects of resurgence-inducing insecticides on the nutritional adequacy of the rice plant for BPH was studied.

Potted seedlings of BPH-susceptible TN1 and BPH-resistant IR36 rices were sprayed with 0.04% methyl parathion, 0.002% decamethrin, or 0.04% Perthane at 10, 20, and 30 DT. Plants in the control were sprayed with water only. Forty days after the last spraying, leaf and leaf sheath tissue were sampled and analyzed for changes in levels of carbohydrates and nitrogen, chemicals that constitute the major dietary source for BPH.

TN1 plants treated with decamethrin, a resurgence-



2. Spider populations in decamethrin-treated and untreated field plots of a susceptible (IR29), a moderately resistant (IR40), and a resistant (IR42) rice variety. Asterisks indicate populations significantly lower than those on the untreated control at the 5% level. IRRI, 1980.

Table 23. Effect of insecticide and rate of application on number of brown planthopper and its predators on IR29.[a] IRRI, 1980 dry season.

Treatment and rate (kg a.i./ha)	1st application 34 DT		2d application 49 DT		3d application 64 DT		Last sample 83 DT
	Before 33 DT	After 37 DT	Before 48 DT	After 52 DT	Before 63 DT	After 67 DT	
			Brown planthoppers (no./hill)				
Decamethrin 20 EC							
0.04	125.8 ab	314.5 a	1,634.5 a	1,071.0 ab	15,079.0 a	14,326.2 a	2,151.5 a
0.002	85.2 ab	315.8 a	2,891.8 a	782.5 ab	4,034.0 b	4,037.0 ab	731.5 b
Diazinon 20 EC							
1.0	74.5 ab	372.2 a	2,026.5 a	761.0 ab	4,084.2 b	4,792.2 ab	230.0 b
0.2	103.0 ab	912.8 a	1,141.2 a	959.0 ab	3,010.5 b	1,014.8 bc	114.2 bc
FMC 35001 20 EC							
1.0	164.8 a	40.0 b	339.2 a	40.2 c	2,147.5 b	510.5 c	194.2 bc
0.2	105.0 ab	82.2 b	1,449.5 a	1,654.0 a	3,727.5 b	618.8 bc	285.0 b
Control	52.8 b	368.5 a	913.8 a	170.2 bc	329.8 c	69.8 d	27.5 c
			Cyrtorhinus lividipennis (no./hill)				
Decamethrin 20 EC							
0.04	32.2 a	1.0 b	22.8 a	5.2 c	104.0 a	35.2 b	848.2 a
0.002	30.5 a	1.5 b	53.2 a	9.8 c	150.2 a	84.2 a	333.5 b
Diazinon 20 EC							
1.0	23.8 a	2.2 b	32.8 a	12.5 c	232.2 a	13.5 b	192.5 ab
0.2	25.8 a	2.8 b	44.8 a	27.0 ab	351.0 a	84.5 a	84.5 bc
FMC 35001 20 EC							
1.0	33.5 a	1.0 b	29.2 a	1.2 d	41.2 b	10.5 b	213.8 ab
0.2	26.2 a	2.5 b	55.0 a	14.0 bc	198.5 a	77.5 a	91.5 bc
Control	19.0 a	28.0 a	82.5 a	62.5 a	131.8 a	16.2 b	9.0 c
			Spiders (no./hill)				
Decamethrin 20 EC							
0.04	10.5 a	0.5 c	2.2 c	1.5 b	5.0 b	9.0 a	8.0 b
0.002	5.8 a	2.0 abc	4.8 c	4.8 ab	10.0 a	57.2 a	16.0 a
Diazinon 20 EC							
1.0	8.8 a	3.5 abc	9.2 ab	5.2 ab	5.8 ab	11.8 a	19.5 a
0.2	8.2 a	4.2 ab	6.2 ab	10.2 a	15.8 a	20.5 a	13.0 ab
FMC 35001 20 EC							
1.0	9.5 a	1.0 bc	6.8 ab	2.5 ab	6.2 ab	10.2 a	18.5 a
0.2	8.8 a	3.2 abc	12.8 a	9.0 a	16.8 a	13.5 a	12.0 ab
Control	9.0 a	6.7 a	11.0 a	6.2 a	15.2 a	17.2 a	18.5 a
			Microvelia atrolineata (no./hill)				
Decamethrin 20 EC							
0.04	92.5 a	4.7 bc	14.2 b	10.2 c	21.2 b	17.5 b	76.2 a
0.002	39.0 a	12.8 bc	78.2 b	562.5 ab	74.2 a	58.2 ab	57.2 a
Diazinon 20 EC							
1.0	30.2 a	7.8 abc	183.2 a	344.5 a	88.2 a	80.2 ab	72.5 a
0.2	55.5 a	16.2 abc	231.5 a	260.2 ab	58.2 ab	57.5 ab	59.8 a
FMC 35001 20 EC							
1.0	33.2 a	5.0 c	107.2 a	45.0 bc	44.2 ab	22.5 ab	58.8 a
0.2	37.0 a	129.0 ab	218.8 a	621.5 a	80.8 a	55.0 ab	45.2 a
Control	19.8 a	171.2 a	104.5 a	654.0 a	90.5 a	85.2 a	42.5 a

[a]Separation of means in a column and under the pest and each predator by Duncan's multiple range test at the 5% level. DT = days after transplanting.

Table 24. Effect of insecticide and rate of application on number of brown planthopper and its predators on IR29.[a] IRRI, 1980 wet season.

Treatment and rate (kg a.i./ha)	1st application 35 DT		2d application 50 DT		3d application 65 DT		Last sample 78 DT
	Before 34 DT	After 37 DT	Before 49 DT	After 52 DT	Before 64 DT	After 67 DT	
			Brown planthoppers (no./hill)				
Carbofuran 3 G							
1.0	36 a	9 bc	201 a	135 ab	37 abc	55 bc	453 a
0.5	23 a	7 bc	132 ab	81 ab	18 bc	46 bc	268 a
0.25	34 a	28 a	132 a	211 a	57 a	146 ab	154 a
FMC 35001 20 EC							
1.0	79 a	15 ab	132 a	61 b	1 e	122 c	779 a
0.5	102 a	16 ab	125 a	166 ab	3 de	378 a	927 a
0.25	100 a	23 a	156 a	189 a	3 de	379 a	839 a
Perthane 45 EC							
1.0	46 a	1 e	4 c	1 c	33 c	0 e	1 c
0.5	93 a	4 cd	5 c	1 c	35 ab	2 de	37 b
0.25	102 a	4 d	8 c	2 c	52 a	1 de	11 b
Control	37 a	21 ab	21 bc	46 b	6 cd	4 d	14 b
			Cyrtorhinus lividipennis (no./hill)				
Carbofuran 3 G							
1.0	6 ab	0 c	3 ab	0 cd	5 a	0 c	1 de
0.5	6 ab	1 bc	2 b	0 bcd	2 ab	0 c	1 de
0.25	6 ab	1 bc	3 ab	1 bc	3 a	0 a	7 ab
FMC 35001 20 EC							
1.0	3 b	0 bc	3 ab	0 cd	0 c	0 bc	4 cd
0.5	8 a	0 bc	3 ab	1 bc	0 c	0 abc	6 bc
0.25	11 a	1 b	4 ab	1 b	1 c	0 a	20 a
Perthane 45 EC							
1.0	6 ab	1 b	4 a	0 d	2 ab	0 c	0 e
0.5	11 a	5 a	3 ab	1 bcd	2 ab	0 bc	1 de
0.25	11 a	4 a	3 ab	1 bcd	2 a	0 bc	1 de
Control	5 ab	6 a	4 ab	5 a	1 bc	0 ab	2 cd
			Spiders (no./hill)				
Carbofuran 3 G							
1.0	1 a	0 b	1 a	1 b	1 a	1 ab	2 a
0.5	1 a	1 ab	1 a	1 b	1 a	1 ab	3 a
0.25	1 a	1 ab	1 a	1 ab	1 a	2 ab	5 a
FMC 35001 20 EC							
1.0	1 a	0 b	1 a	1 b	2 a	1 b	2 a
0.5	1 a	0 b	1 a	1 b	2 a	2 a	3 a
0.25	1 a	1 ab	1 a	1 b	1 a	2 ab	3 a
Perthane 45 EC							
1.0	1 a	1 ab	1 a	1 ab	1 a	1 ab	2 a
0.5	1 a	1 ab	1 a	1 b	1 a	1 ab	2 a
0.25	1 a	1 a	1 a	1 ab	1 a	1 ab	2 a
Control	1 a	1 a	1 a	2 a	2 a	2 a	4 a
			Microvelia atrolineata (no./hill)				
Carbofuran 3 G							
1.0	6 ab	9 abc	9 abc	2 abc	1 a	2 ab	20 ab
0.5	6 a	4 bcd	2 c	1 bc	1 ab	2 a	32 ab
0.25	4 ab	11 a	2 bc	4 a	1 ab	3 a	28 ab
FMC 35001 20 EC							
1.0	2 b	1 d	13 ab	2 abc	0 b	0 b	19 ab
0.5	5 ab	2 abcd	5 abc	2 abc	0 ab	1 ab	23 ab
0.25	6 ab	8 ab	14 a	3 ab	0 ab	1 ab	53 a
Perthane 45 EC							
1.0	2 ab	1 cd	5 abc	0 d	0 ab	1 ab	1 d
0.5	7 ab	4 abcd	14 a	1 cd	1 a	1 ab	2 d
0.25	5 ab	2 abcd	5 abc	2 bc	1 ab	1 ab	4 c
Control	3 ab	4 abcd	3 bc	4 ab	1 ab	1 ab	9 bc

[a]Separation of means in a column and under the pest and each predator by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. DT = days after transplanting.

Table 25. Effect of insecticide and rate of application on number of brown planthopper and its predators on IR29.[a] IRRI, 1980 wet season.

Treatment and rate (kg a.i./ha)	1st application 25 DT		2d application 40 DT		3d application 60 DT		Last sample 70 DT
	Before 24 DT	After 28 DT	Before 39 DT	After 43 DT	Before 59 DT	After 63 DT	
			Brown planthoppers (no./hill)				
Isazophos 3 G							
1.5	5 a	2 a	63 a	7 b	1098 a	519 b	332 bc
0.5	7 a	1 a	70 a	19 a	1515 a	1024 a	701 ab
0.25	5 a	2 a	83 a	12 ab	697 a	1030 a	857 a
Methomyl 20 EC							
1.5	5 a	2 a	50 a	13 ab	1143 a	890 a	1187 a
0.5	5 a	3 a	69 a	20 a	957 a	1056 a	532 ab
0.25	6 a	2 a	71 a	12 ab	1119 a	1006 a	1195 ab
Control	4 a	2 a	25 a	11 ab	165 b	399 ab	133 c
			Cyrtorhinus lividipennis[b] *(no./hill)*				
Isazophos 3 G							
1.5	3 a	0 b	3 a	0 b	7 ab	1 bcd	9 b
0.5	3 a	0 ab	4 a	0 b	11 a	13 a	17 ab
0.25	3 a	1 ab	5 a	1 b	8 a	2 b	21 a
Methomyl 20 EC							
1.5	4 a	0 b	4 a	0 b	5 ab	0 d	12 ab
0.5	2 a	1 b	4 a	0 b	5 ab	0 cd	14 ab
0.25	3 a	0 b	5 a	0 b	6 ab	2 bc	23 a
Control	2 a	1 a	4 a	3 a	4 b	12 a	10 ab
			Spiders[b] *(no./hill)*				
Isazophos 3 G							
1.5	1 a	0 a	1 a	0 c	4 c	2 d	5 b
0.5	1 a	0 a	1 a	1 b	6 abc	4 c	7 ab
0.25	1 a	1 a	2 a	1 bc	5 bc	3 cd	11 a
Methomyl 20 EC							
1.5	1 a	0 a	1 a	1 bc	6 abc	4 bc	7 ab
0.5	1 a	0 a	2 a	1 ab	8 a	9 a	6 ab
0.25	1 a	0 a	1 a	2 a	7 ab	8 ab	12 a
Control	1 a	1 a	3 a	1 ab	6 abc	10 a	14 a
			Microvelia atrolineata (no./hill)				
Isazophos 3 G							
1.5	2 a	0 a	4 ab	0 a	1 a	0 a	0 a
0.5	2 a	1 a	10 a	1 a	0 a	0 a	0 a
0.25	1 a	0 a	6 ab	1 a	0 a	2 a	2 a
Methomyl 20 EC							
1.5	1 a	1 a	4 ab	1 a	0 a	0 a	0 a
0.5	1 a	1 a	6 ab	1 a	1 a	1 a	0 a
0.25	1 a	1 a	4 ab	1 a	0 a	0 a	1 a
Control	1 a	1 a	3 b	3 a	0 a	1 a	0 a

[a]Separation of means in a column and under the pest and each predator by Duncan's multiple range test at the 5% level. DT = days after transplanting. [b]Identical numbers may be followed by different letters because of rounding.

inducing insecticide, had the highest level of free amino nitrogen in the leaf sheath tissue. Next highest was the level in leaf sheath tissue of plants treated with methyl parathion or water. Leaf sheath tissue of plants sprayed with Perthane, an insecticide that does not cause resurgence, had significantly less free amino nitrogen than that in the corresponding tissue of decamethrin-treated plants. The carbohydrate-nitrogen ratio (C:N) of the soluble constituents was lowest in the decamethrin-treated TN1 plants, followed by that in the methyl parathion-treated, water-treated, and Perthane-treated plants. Increased feeding rate of BPH on plants treated with resurgence-causing insecticides may be attributed to this optimization of C:N.

Changes in levels of starch, sugars, and total nitrogen in leaf and leaf sheath tissues of insecticide-treated and control plants were indistinguishable.

Table 26. Effect of the addition of a spreader-binder (Triton CS-7)[a] to foliar sprays of MIPC on insect control in IR29. IRRI, 1980 wet season.

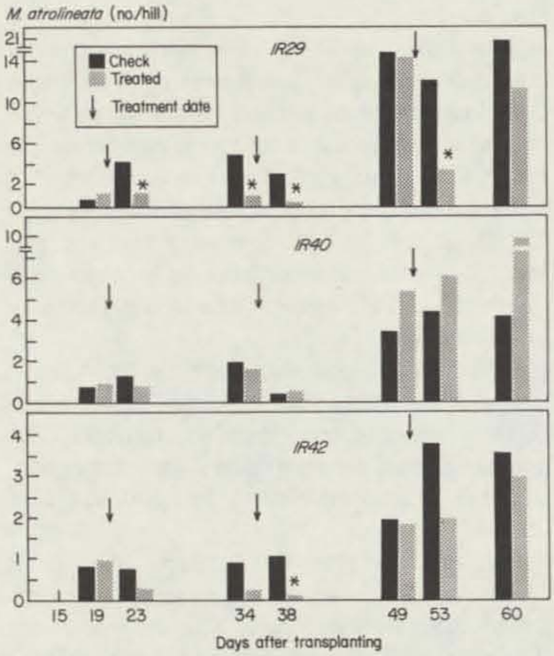
Treatment and rate (kg a.i./ha)	Insect control[b]					
				Nilaparvata lugens control (%)		
	Whorl maggot ratings[c] 35 DT	Dead-hearts (%) 60 DT	Ragged stunt virus (%) 60 DT	2d application 50 DT	3d application 65 DT	Hopper burned plants (%)
0.75 MIPC	6 b	3.7 a	49 a	43	20	90 a
0.75 MIPC + Triton CS-7	6 b	4.0 a	46 a	45	51	49 b
0.50 MIPC	6 b	4.2 a	45 a	46	0	20 c
0.50 MIPC + Triton CS-7	6 b	2.9 a	41 a	68	35	33 bc
Control	8 a	3.1 a	47 a	—	—	38 bc

[a]Applied at 1 liter/ha in a spray solution of 300 liters/ha. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. DT = days after transplanting. [c]Based on the 1980 Standard Evaluation System for Rice.

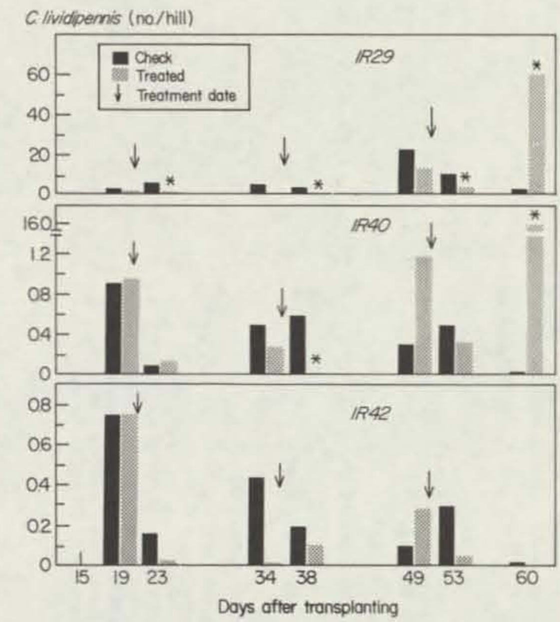
IR36 plants treated with decamethrin had only a marginal increase in the level of free amino nitrogen and a correspondingly low C:N. Changes in IR36 plants, however, were not as dramatic as in TN1 plants.

Insecticide application methods. Insecticide application methods were tested for increased residual activity of insecticides. A spreader-binder was added to the spray solution to increase deposit on the plants and two root-zone applicators developed by IRRI engineers were tested.

Spreader-binder in foliar sprays. Triton CS-7 added to a spray solution of MIPC at two rates did not distinctly increase the level of insect control in a wet season experiment (Table 26). Hopperburn was higher in the 0.75 kg a.i. MIPC/ha rate than in



3. *Microvelia atrolineata* populations in decamethrin-treated and untreated field plots of a susceptible (IR29), a moderately resistant (IR40), and a resistant (IR42) rice variety. Asterisks indicate populations significantly lower than those on the untreated control at the 5% level. IRRI, 1980.

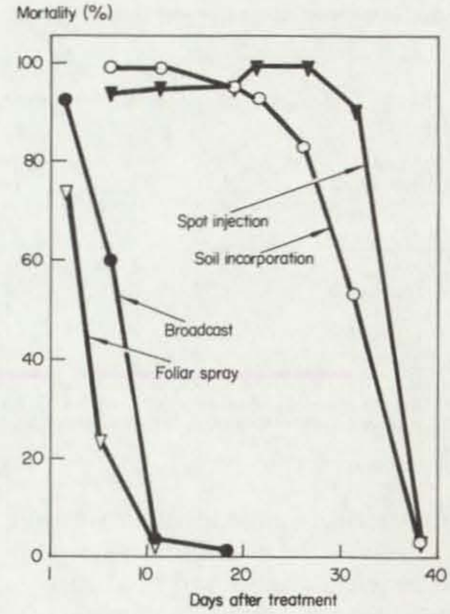


4. *Cyrtorhinus lividipennis* populations in decamethrin-treated and untreated field plots of a susceptible (IR29), a moderately resistant (IR40), and a resistant (IR42) rice variety. Asterisks indicate populations significantly different from those on the untreated control at the 5% level. IRRI, 1980.

Table 27. Effect of method of carbofuran application on insect control on IR22.[a] Victoria, Laguna, Philippines, 1980 dry season.

Treatment[b]	Whorl maggot rating[c]	BPH (no./20 hills)		GLH (no./20 sweeps)			Tungro virus (%)		Deadheart damage (%)		Whitehead damage (%)	Grain yield (t/ha)
	31 DT	32 DT	66 DT	25 DT	40 DT	45 DT	73 DT	91 DT	31 DT	60 DT		
Foliar spray[d]	4.0 b	39.0 a	9.3 b	3.7 ab	77.7 ab	53.0 ab	12.3 abc	40.7 ab	0.77 a	1.30 ab	1.15 ab	2.88 c
Broadcast 20 DT	1.8 a	18.3 a	6.7 b	4.0 ab	33.3 bc	25.0 cd	15.7 ab	44.3 ab	0.07 b	3.94 a	0.76 b	3.05 c
Soil incorporation before transplanting	0.7 a	22.3 a	1.7 a	5.3 a	65.0 abc	25.3 bc	1.3 cd	12.7 bc	0.03 b	3.12 ab	0.88 b	3.94 b
Spot injection before transplanting	0.2 a	15.7 a	5.0 ab	3.3 ab	56.3 abc	36.7 abc	0.3 d	2.7 c	0.00 b	0.95 b	0.51 b	4.75 a
Spot injection 20 DT[e]	1.7 a	6.7 a	3.7 ab	4.3 ab	36.0 bc	12.7 d	4.7 bcd	17.0 bc	0.05 b	2.36 ab	2.22 a	3.94 b
Broadcast 20 DT and incorporated	1.7 a	7.7 a	8.7 b	2.0 b	29.7 c	31.0 abc	1.3 d	9.0 c	0.14 b	1.54 ab	1.52 ab	4.25 ab
Control	4.9 b	35.3 a	3.3 ab	3.7 ab	92.7 a	58.0 a	28.0 a	71.3 a	1.18 a	1.90 ab	0.78 b	1.94 d

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DT = days after transplanting, BPH = brown planthopper, GLH = green leafhopper. [b]All treatments received 0.5 kg a.i. carbofuran/ha applied once, except the foliar spray treatment which was applied 5 times — 5 days after transplanting and at 14-day intervals — at 0.1 kg a.i./ha per application. [c]Based on the 1980 Standard Evaluation System for Rice. [d]300 liters/ha. [e]125 liters solution/ha applied with a row marker-injector.



5. Mortality of the green leafhopper 48 hours after caging on IR22 plants treated with 0.5 kg a.i. carbofuran/ha by different methods of application. Victoria, Laguna, Philippines, 1980 dry season.

the control.

Root-zone application. A row marker-applicator and mechanical transplanter were compared with commonly practiced methods of insecticide application. Spot injection of 0.5 kg a.i. carbofuran/ha before transplanting provided excellent control of whorl maggot, tungro virus, and stem borer (Table 27). Good control of tungro virus with the spot injector and the soil incorporation treatment was due to good GLH control as indicated by mortality of caged insects (Fig. 5).

In another test, granules and a flowable formulation were applied to seedlings 1 day before transplanting with the mechanical transplanter. The granular formulation provided slightly better control of GLH than the flowable formulation (Table 28, 29).

Because of the effectiveness of spot injection of carbofuran, minimum effective rates were determined in comparison with soil incorporation. Although yields were low because of a typhoon, 0.2 kg a.i./ha significantly increased yield (Table 30). Mortality readings on caged GLH indicated effective control up to 28 DT for rates of 0.5 to 0.3. The low rate of 0.2 kg a.i./ha caused 70% mortality at

Table 28. Comparison of methods of applying carbofuran for rice insect control on IR22.[a] IRRI, 1980 wet season.

Treatment[b]	Whorl maggot damage[c] 30 DT	*Rivula* nr *atimeta* larvae (no./10 hills) 23 DT	Green leafhoppers (no./10 sweeps) 20 DT	28 DT	36 DT	41 DT	54 DT	Brown planthoppers (no./20 hills) 29 DT	35 DT	42 DT	49 DT	56 DT	63 DT	70 DT	Stem borer deadhearts (%) 58 DT	Tungro virus (%) 85 DT	Stem borer whiteheads at harvest (%)	Grain yield (t/ha)
Row marker spot injector	0 d	16 ab	0 a	4 a	7 a	21 ab	13 bc	12 a	73 a	937 a	377 a	130 a	13 a	98 a	0 a	2 b	1 a	2.8 a
Mechanical transplanter-F[d]	3 b	28 ab	1 a	4 a	12 a	45 ab	24 ab	9 ab	79 a	685 ab	485 a	136 a	14 a	86 a	1 a	1 b	0 a	2.2 a
Mechanical transplanter-G[e]	0 d	13 bc	2 a	6 a	12 a	17 b	7 c	9 ab	60 a	811 ab	237 a	149 a	13 a	106 a	1 a	1 b	1 a	2.9 a
Soil incorporation	1 d	24 ab	1 a	6 a	12 a	34 ab	28 ab	4 b	63 a	793 ab	405 a	184 a	22 a	175 a	0 a	3 b	1 a	2.4 a
Paddy water broadcast	1 d	14 ab	0 a	5 a	13 a	30 ab	18 abc	6 b	56 a	492 ab	325 a	139 a	16 a	235 a	0 a	15 ab	1 a	2.2 a
Foliar spray	2 c	3 c	1 a	2 a	17 a	34 ab	22 ab	8 ab	88 a	1073 a	511 a	173 a	20 a	174 a	3 a	4 b	0 a	2.1 a
Control	6 a	29 a	0 a	6 a	18 a	51 a	47 a	6 b	54 a	396 b	109 b	86 a	21 a	229 a	1 a	46 a	0 a	0.4 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]All treatments received one application of carbofuran at 0.5 kg a.i./ha before transplanting, except paddy water broadcast and foliar spray treatments, which received 2 applications of 0.5 kg a.i./ha at 6 and 16 days after transplanting (DT). [c]Based on the 1980 Standard Evaluation System for Rice. [d]Flowable formulation applied to the seedbed 1 day before transplanting. [e]Granular formulation applied to the seedbed 1 day before transplanting.

21 DT (Table 31).

Seedbed application of insecticide to control tungro virus. GLH transmits tungro virus in the seedbed. Carbofuran was applied to the seedbed by 5 methods, and the seedbed was infested with viruliferous hoppers 11 days after seeding. All treatments significantly decreased tungro infection (Table 32).

Preplanting and postplanting field application of insecticide. Preplanting and postplanting treatments with 0.75 kg a.i. carbofuran/ha were compared for control of BPH, GLH, and tungro virus (Table 33). Most effective were spot injection as a preplanting treatment and capsule in the root zone applied postplanting.

Timing of sprays for BPH control. Studies continued to determine the best timing of insecticide application for BPH control (Table 34). Yield was highest in plots sprayed once when hoppers were in the second generation or when hopper populations reached 20-30/hill.

PLANT EXTRACTS FOR INSECT CONTROL

Neem cake blended with urea for BPH management. Urea mixed with 10% neem cake (wt/wt), 20% neem cake (wt/wt), and 133 ml neem oil/kg urea (vol/wt) was applied to BPH-susceptible IR1917-3-17 at rates of 60 kg N/ha at seedling stage, 30 kg N/ha at maximum tillering, and 30 kg N/ha at panicle initiation. Control plots received urea only.

BPH nymphs and adults and their predators were counted weekly on 20 hills/plot in each treatment, and daily insect counts were made for 5 successive days after each fertilizer application. The incidence of grassy stunt, ragged stunt, tungro, and other plant pests was also recorded.

Trials in both crop seasons showed that 20% neem cake gave significantly higher yields than urea only (Table 35). The incidence of virus diseases was generally lower in the neem cake-treated plots. Other pests and predators were not affected by neem cake at the concentrations tested.

Greenhouse trials indicated that the BPH population increase on potted TN1 plants with neem cake-blended urea basally applied was not as high as that on plants treated with urea only.

Effects of neem oil on leaf folder. Neem oil is an

Table 29. Effect of method of carbofuran application on mortality of green leafhopper (GLH) on IR22. IRRI, 1980 wet season.

Treatment[a]	GLH mortality[b] (%) at indicated days after transplanting					
	6	14	21	28	36	49
Row marker-injector	100 a	100 a	87 ab	93 a	29 ab	13 ab
Mechanical transplanter- F[c]	100 a	93 ab	70 b	34 bc	4 b	0 b
Mechanical transplanter- G[d]	96 a	57 bc	93 ab	66 bc	29 ab	0 b
Soil incorporation	97 a	77 abc	80 ab	68 ab	33 a	27 a
Paddy water broadcast	100 a	77 abc	100 a	42 bc	13 ab	0 a
Foliar spray	100 a	53 c	87 ab	27 c	4 b	0 b

[a]Mortality readings were taken 48 hours after insects were caged on plants. All treatments received one application of carbofuran at 0.5 kg a.i./ha before transplanting, except paddy water broadcast and foliar spray treatment, which received 2 applications of 0.5 kg a.i./ha 6 and 16 days after transplanting. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. Observed mortality percentages were adjusted with Abbott's formula. [c]Flowable formulation applied to the seedbed 1 day before transplanting. [d]Granular formulation applied to the seedbed 1 day before transplanting.

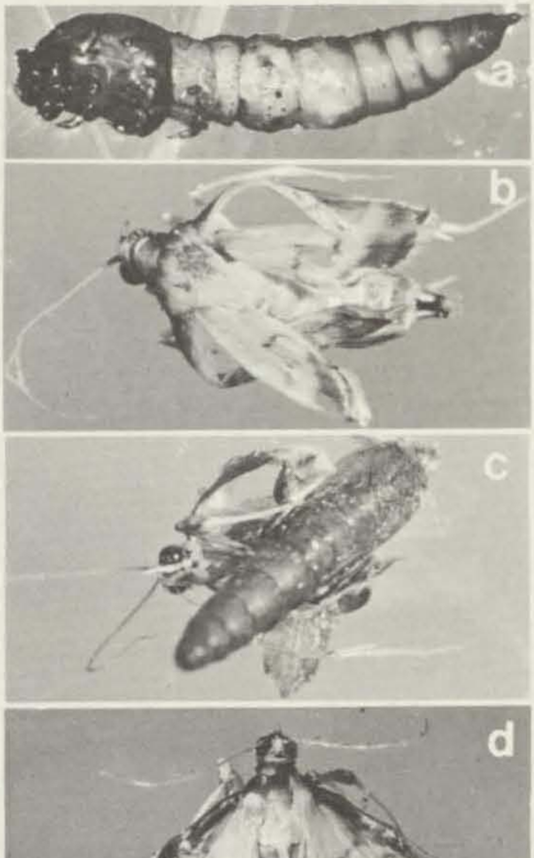
effective repellent, feeding deterrent, and oviposition and embryo inhibitor (1979 annual report). Neem oil effects on leaf folder (LF) development were studied in 1980.

Ten 5th-instar larvae were placed in a filter-paper-lined petri dish containing 10 leaf cuts (each 7.5 cm long) from TN1 plants that had been sprayed with 12, 25, or 50% emulsified neem oil. In the control, larvae were confined on leaf cuts from plants sprayed with 1.66% detergent solution. Larvae were examined daily and the leaf cuts were replaced when necessary. Developmental abnormalities and mortality of insects were recorded daily.

In another test, batches of 10 freshly collected, 5th-instar larvae were topically treated with a neem oil-acetone solution at a dosage of 5, 20, or 50 μg neem oil/larva. In the control, larvae were similarly treated with acetone only. The larvae were then confined on moist-filter-paper-lined petri dishes containing 10 leaf cuts of TN1 plants.

Larvae confined on leaf cuts treated with ≥12% neem oil showed pronounced aberrations of behavior and form and increased mortality during metamorphosis (Table 36, Fig. 6). Some larvae ceased feeding, became shrunken and dark, and died. Others failed to fold the leaves before pupation; a few developed into larval-pupal monstrosities. Moths emerging from apparently normal-looking pupae often had poorly developed or twisted wings and occasionally failed to emerge from the pupal case. In the control, mortality during metamorphosis was low and a significantly high percentage of normal, healthy moths emerged.

Topical application of low doses of neem oil



6. Selected examples of developmental abnormalities of the leaf roller when 5th-instar larvae were confined on leaf cuts from rice plants sprayed with 12, 25, or 50% neem oil in 3 passes of the ultralow-volume applicator. The control plants were sprayed with 1.66% detergent-water solution. a) Larval-pupal monstrosity with larval cuticle patches, head capsule, and thoracic legs; posterior half of body has pupal characteristics. b) Moth with narrow and twisted forewings. c) Moth unable to emerge from pupal case. d) Control: normal moth with fully developed and expanded wings. IRRI, 1980.

Table 30. Comparison of rates of carbofuran spot-injected in the root zone of IR22 rice plants for control of rice pests.[a] Victoria, Laguna, Philippines, 1980 wet season.

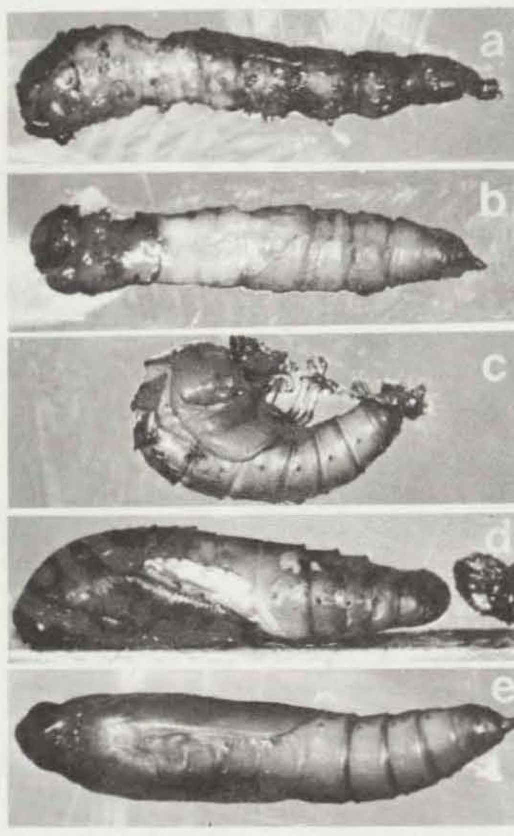
Treatment[b] (kg a.i./ha)	Whorl maggot damage[c] 20 DT	Whorl maggot damage[c] 30 DT	*Rivula* nr *atimeta* larvae (no./10 hills) 23 DT	Green leafhoppers (no./10 sweeps) 20 DT	28 DT	36 DT	41 DT	48 DT	Brown planthoppers (no./20 hills) 29 DT	35 DT	41 DT	49 DT	56 DT	63 DT	70 DT	Stem borer deadhearts (%) 58 DT	Tungro virus (%) 86 DT	Grain yield (t/ha)
Carbofuran																		
0.5	0 c	0 c	18 abc	2 a	7 ab	13 b	31 a	16 c	3 a	34 a	228 a	91 a	27 a	7 b	128 a	0 a	2 c	2.8 a
0.4	0 c	0 c	17 bc	3 a	3 b	13 b	39 a	20 bc	3 a	19 a	778 a	118 a	28 a	12 ab	100 a	1 a	1 c	2.9 a
0.3	0 c	1 b	14 bc	2 a	8 ab	16 ab	36 a	32 abc	4 a	30 a	365 a	74 a	33 a	17 ab	142 a	1 a	20 bc	2.5 ab
0.2	0 c	2 b	28 ab	1 a	10 ab	21 ab	61 a	42 abc	8 a	39 a	367 a	202 a	58 a	25 a	162 a	1 a	10 bc	2.5 ab
0.1	2 b	5 a	38 a	1 a	13 a	32 a	63 a	60 a	4 a	26 a	412 a	106 a	34 a	19 ab	266 a	1 a	47 ab	1.7 cd
0.5 (SI)	1 c	1 b	20 abc	2 a	8 a	24 ab	47 a	44 abc	5 a	32 a	457 a	123 a	40 a	14 ab	138 a	0 a	40 ab	2.1 bc
Control	4 a	5 a	13 c	1 a	9 a	31 ab	77 a	54 ab	3 a	33 a	154 a	88 a	38 a	17 ab	223 a	0 a	74 a	1.4 d

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DT = days after transplanting. [b]125 liters/ha of the insecticide solution (flowable formulation in water) was spot injected in the root zone with a row marker-injector before transplanting. Each hill received 0.5 ml of the solution. The standard treated check was soil incorporation (SI), one day before transplanting, of a granular formulation (3 G). [c]Based on the 1980 Standard Evaluation System for Rice.

(20-50 μg/larva) on 5th-instar larvae also caused significantly high developmental abnormalities and mortality (Table 37, Fig. 7). In the control, development proceeded normally.

Indigenous plant extract for pest control. In 1979, the extract of an indigenous plant was found effective against numerous insect pests of rice and other crops (1979 annual report). In 1980, the extract was tested for systemic activity and other biological effects against insects and diseases.

Brown planthopper. The extract significantly reduced growth and development of first-instar nymphs caged on 15-day-old potted TN1 rice seedlings grown in soil or water treated with the extract



7. Selected examples of developmental abnormalities of rice leaf folder when 5th-instar larvae were topically treated with neem oil-acetone solutions, 0.2 μl of which delivered dosages of 5, 20, or 50 μg/larva. Control larvae were treated with acetone. a) Dark and shrunken larva with distinct head capsule, thoracic legs, and vestigeal prolegs. b) Larval-pupal monstrosity with larval cuticle patches, head capsule, and thoracic legs; posterior half of body has pupal characteristics. c) Pupa with larval thoracic legs and cuticle patches on tergites. d) Pupa with larval cuticle patches on left and right (not visible) sides. e) Control — normal pupa. IRRI, 1980.

Table 31. Effect of rate of carbofuran applied in the root zone with a row marker-injector on mortality of green leafhopper (GLH) on IR22. Victoria, Laguna, Philippines, 1980 wet season.

Carbofuran rate[a] (kg a.i./ha)	GLH mortality[b] (%) at indicated days after transplanting					
	7	14	21	28	36	49
0.5	80 a	77 ab	100 a	80 a	27 ab	7 a
0.4	100 a	100 a	100 a	83 a	45 a	3 a
0.3	79 a	67 b	93 a	87 a	21 ab	10 a
0.2	100 a	93 ab	90 a	53 ab	27 ab	10 a
0.1	93 a	83 ab	70 a	37 b	3 b	0 a
0.5 (SI)[c]	100 a	90 ab	87 a	87 a	49 a	23 a

[a]A row marker-injector was used to spot-inject different rates of carbofuran flowable formulation. A total volume of 125 liters/ha was injected in the root zone. Each hill received 0.5 ml of the solution. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. Values shown were adjusted with Abbott's formula to compensate for mortalities in the control. Mortality readings were taken 48 hours after insects were caged on plants. [c]Carbofuran 3 G was soil-incorporated with a power tiller one day before transplanting.

(Table 38). With increase in the concentration of the extract, a corresponding decrease in nymphal growth was recorded. The feeding deterrent activity of the extract was reflected in the reduced amount of honeydew excreted by brachypterous females caged on TN1 plants sprayed with the extract (Table 39). The ovipositional response of gravid females was also strongly deterred on the extract-sprayed rice plants. However, the hatchability of the eggs laid inside the plant tissues was not affected (Table 40).

Rice blast. The growth rate of *Pyricularia oryzae* (isolate T27) on nutrient agar plates containing the indigenous plant extract was determined (Fig. 8). Fungal growth at 10 ppm concentration of the extract was similar to that in the control, intermediate at 100 ppm, and nil at 1,000 ppm. The spore count at 9 days after inoculation was highest in the control and in agar plates treated with 10 ppm of the extract but significantly less at 100 ppm; at 1,000 ppm, there was total inhibition of sporulation and death of the fungus.

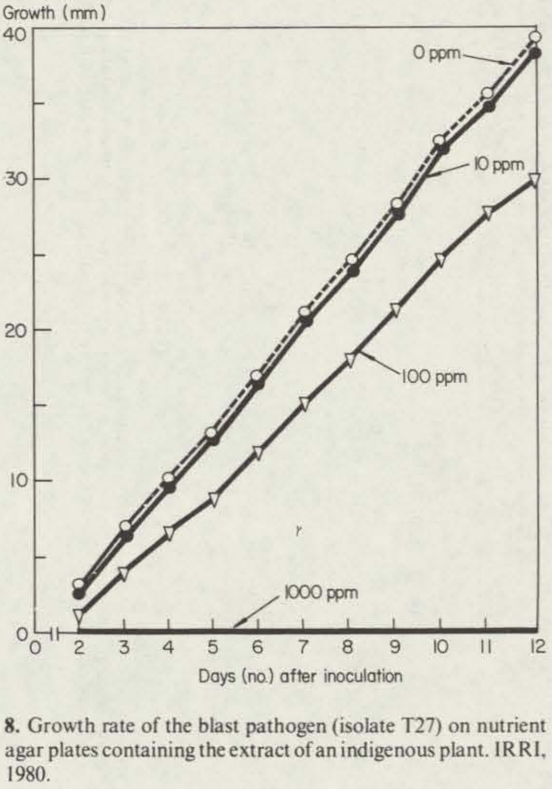
Nonrice insects. Topical application of extremely low doses of the extract on mango blossom leafhopper caused significantly high mortality and all insects died at the dose of ⩾10 μg/insect.

Topical application of low doses of the extract caused significantly high mortality of cotton aphid. Mortality remained high even when the aphids

Table 32. Effect of method of carbofuran application in the seedbed on percentage of rice tungro virus-infected plants in the field. IRRI, 1980.

Treatment[a]	Infected hills[b] (%) 30 DT
Soil incorporation before sowing	25.30 b
Broadcast at sowing	32.79 b
Seed soak before sowing	38.20 b
Foliar spray at 10 and 17 DS	39.08 b
Broadcast at 10 DS	42.55 b
Control	84.28 a

[a]All applications were made once at 0.75 kg a.i./ha, except for foliar spray which was sprayed twice — 10 and 17 days after sowing (DS). [b]Viruliferous green leafhopper adults were released on the seedbed at 11 DS. DT = days after transplanting. Separation of means by Duncan's multiple range test at the 5% level.



8. Growth rate of the blast pathogen (isolate T27) on nutrient agar plates containing the extract of an indigenous plant. IRRI, 1980.

Table 33. Effect of method of carbofuran application on control of brown planthopper (BPH) and green leafhopper (GLH) on IR22.[a] IRRI, 1980 wet season.

Treatment[b]	BPH mortality[c] (%)							GLH mortality[c] (%)							Tungro virus (%)	Yield (t/ha)
	2	7	12	17	22	27	32	2	7	12	17	22	27	32		
Preplanting[d]																
Spot injection	95 a	100 a	98 a	96 a	93 a	71 a	29 b	99 a	100 a	98 a	99 a	98 a	80 a	56 a	52 cd	2.9 a
Soil incorporation	87 ab	88 b	50 b	20 b	19 b	3 b	1 c	99 a	95 b	84 b	80 b	63 b	15 b	2 b	67 bcd	1.2 b
Seedling soak	84 bc	84 b	48 b	21 b	19 b	6 b	2 c	99 a	98 ab	74 b	68 b	58 bc	12 bc	4 b	74 d	1.1 b
Postplanting[e]																
Capsule	78 bc	100 a	100 a	99 a	94 a	77 a	47 a	90 b	100 a	100 a	100 a	99 a	85 a	60 a	38 d	2.8 a
Broadcast	87 ab	66 c	36 b	16 b	5 c	2 b	2 c	97 ab	92 b	75 b	68 b	44 c	6 cd	2 b	89 ab	1.1 b
Foliar spray	78 c	46 d	18 c	5 c	3 c	2 b	1 c	100 a	66 c	46 c	5 c	4 d	2 d	2 b	100 a	0.0 c
Control	1 d	3 e	3 d	2 c	2 c	2 b	1 c	3 c	5 d	5 d	4 c	2 d	5 cd	3 b	100 a	0.0 c

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]All treatments at 0.75 kg a.i./ha. [c]The numbers indicate days after treatment with carbofuran. Insect mortality was determined 48 h after infestation. [d]Just before transplanting. [e]Insecticide was applied 5 days after transplanting.

were caged on bouquets of cotton leaves sprayed with small quantities of the extract.

In choice tests, extreme repellency of the extract to the red cotton bugs was manifested by almost total avoidance of the extract-treated cotton seeds and almost exclusive feeding on untreated seeds by fourth-instar nymphs. Developmental abnormalities such as adultoids retaining nymphal characters to varying degrees or supernumerary instars resulted when late-instar nymphs were topically treated with the extract. A few died on different days after application without completely emerging from the old cuticle. Vapor of the extract from treated cottonwool pads, kept in the bottom compartment of a test chamber, disrupted the normal growth and development of first-instar nymphs that were caged in the upper compartment.

The cowpea weevil had a significantly higher mortality than the control even at the lowest dose (1 μg/insect) tested. The weevil's ovipositional response and hatchability of eggs were greatly reduced on mungbean seed treated with the extract at $\geq$20 mg/500 seed. Hatchability was reduced further if the extract was sprayed directly on weevil eggs.

High doses of the extract were required to cause any appreciable mortality of adults of the laboratory-reared, local housefly. However, in tests of choice, oviposition by gravid flies was significantly lower on extract-treated substrates than on the untreated control.

On local strains of *Aedes aegypti* and *Culex quinquefasciatus* mosquitoes the extract applied at $\geq$50 μg/10 ml water in a 5-cm-diam dish reduced the hatchability of *A. aegypti* eggs laid singly. Hatchability of *C. quinquefasciatus* eggs, which stick together and form rafts, was not affected even at high doses. Mortality of *C. quinquefasciatus* larvae emerging from eggs in the extract-treated water, or transferred directly to it from the stock culture, was high.

Gas chromatographic analysis of the extract has shown that it has seven or eight major constituents. Their isolation and identification are in progress, in collaboration with chemists at the International Centre of Insect Physiology and Ecology, Nairobi, Kenya. The important fractions will be evaluated for their biological effects on various insect and disease pests and beneficial organisms.

Table 34 Timing of BPMC spray for effective brown planthopper (BPH) control.[a] Victoria, Laguna, Philippines, 1980 dry season.

Treatment[b]	BPH[c] (no./hill) at indicated days after transplanting									Grain yield (t/ha)
	30	37	44	51	57	65	72	79	87	
Spray first-generation BPH (43 DT)	1.2 a	3.17 a	0 13 b	26 97 a	16 43 a	5 37 bc	8.08 cd	92 3 a	60 6 a	3.57 ab
Spray second-generation BPH (72 DT)	4.4 a	2 33 a	8 63 a	20.83 a	9.63 ab	12.22 ab	3 50 d	23 07 b	17 03 b	4 61 a
Spray when BPH av 20-30/ hill (55 DT)	1 9 a	5 77 a	10 83 a	27.07 a	0 80 c	10.43 ab	7.83 bcd	5 72 c	9 37 b	4.48 ab
Spray when BPH av 30-40/ hill (78 DT)	1.5 a	4.00 a	7.97 a	21.5 a	17 57 a	13 37 ab	34 13 ab	4 90 c	9 03 b	3.05 b
Spray when BPH av >40/ hill (78 DT)	3.5 a	3.17 a	11.73 a	15.17 a	14 70 a	20.33 a	44 47 a	8 65 bc	10 23 b	3 69 ab
Spray every 14 days (20, 34, 48, 62, 76 DT)	1.5 a	0 47 b	8 33 a	0.13 b	6 37 b	2 63 c	18.80 abcd	4.43 c	6 10 b	4 24 ab

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]All treatments received one application of 750 g a.i. BPMC/ha as foliar spray in 300 liters water, except calendar-based application which was 5 sprays at 14-day intervals starting 20 days after transplanting (DT). [c]Populations of hoppers were induced by 6 foliar sprays of 10 g a.i. Decis/ha at 10-day intervals. Populations were estimated by tapping 20 randomly selected hills per treatment and visually estimating the hoppers that fell on the water surface.

Table 35. Pest infestation and yield in rice fields treated with urea formulations containing neem cake and neem oil. IRRI, 1979-80.[a]

Treatment[b]	Whorl maggot damage rating[c] (1-9 scale)	Pest incidence (%)					Rice bugs (no./m²)	Yield (t/ha)
		Grassy stunt	Ragged stunt	Tungro	Dead-hearts	White-heads		
		Dry season						
10% NC + urea	7	1 a	20 b	10 a	3.2 a	0 3 a	0.2 a	2 00 a
20% NC + urea	7	0 a	18 b	3 a	2 6 a	0.4 a	0.2 a	2.80 b
NO + urea (133 ml/kg urea)	7	12 b	9 a	29 b	2 8 a	0.2 a	0.0 a	2.10 a
Urea (120 kg N)	7	20 b	15 ab	27 b	3.2 a	0.6 a	0 1 a	1.80 a
		Wet season						
10% NC + urea	7	5 a	0 a	26 a	0.6 a	0.8 a	0.5 a	3 14 bc
20% NC + urea	7	4 a	3 a	29 a	0.6 a	0.7 a	0 2 a	3 53 c
NO + urea (1 33 ml/kg urea)	7	8 a	1 a	24 a	0.3 a	0.8 a	0 3 a	2 92 ab
Urea (120 kg N)	7	15 a	5 a	26 a	0.4 a	0 5 a	0.8 a	2 49 a

[a]IR1917-3-17, a BPH-susceptible selection, was planted in 11- × 20-m plots; each treatment was replicated 4 times Separation of means by Duncan's multiple range test at the 5% level. [b]Neem cake (NC) and neem oil (NO) were blended with urea before applications. Split application of different urea formulations at 60, 30, 30 N was made at seedling, maximum tillering, and panicle initiation stages. [c]Based on the 1980 Standard Evaluation System for Rice

Table 36. Effect on development of the 5th-instar larvae of *Cnaphalocrocis medinalis* offered leaf cuts from TN1 rice plants sprayed with neem oil. IRRI, 1980.

Neem oil concn[a] (%)	Abnormal or dead insects[b] (%)
0 (1.66% detergent)	35 0 a
12	91 2 b
25	96 2 b
50	97.5 b

[a]Sprayed in 3 passes with an ultralow-volume applicator. [b]Av of 8 replications, 10 larvae/replication Abnormal insects included larval-pupal, pupal-adult, and adult monstrosities; the remaining insects emerged as apparently normal moths Separation of means by Duncan's multiple range test at the 5% level.

Table 37. Effects of topical application of neem oil on development of 5th-instar *Cnaphalocrocis medinalis* larvae. IRRI, 1980.[a]

Dose (μg/larva)	Abnormal or dead insects[b] (%)
0 (control)[c]	30.0 a
5	46.7 ab
20	70.7 b
50	76 7 b

[a]Separation of means by Duncan's multiple range test at the 5% level. Av of 3 replications, 10 larvae/replication. [b]Sprayed in 3 passes with an ultralow-volume applicator. [c]Treated with 0 2 μl acetone.

Table 38. Growth of first-instar brown planthopper nymphs caged on TN1 seedlings grown in soil or water treated with an indigenous plant extract.[a] IRRI insectary, 1980.

Quantity of extract incorporated (mg/9-cm-diam pot)	Growth on seedlings in soil treated with extract			Growth on seedlings in water treated with extract[b]		
	Nymps becoming adults (%)	Growth period (days)	Growth index[c]	Nymphs becoming adults (%)	Growth period (days)	Growth index[c]
0 (control)[d]	100 a	17.8 a	5 64 a	82 a	15 3 a	5 38 a
1	72 b	17.9 a	4.03 b	73 a	15.6 a	4.67 a
5	20 c	17 8 a	1.13 c	65 ab	15.6 a	4 16 a
10	14 d	14 8 a	0 77 c	70 a	15 2 a	4 65 a
20	0 e	0 b	0 00 d	35 b	15 7 a	2 20 b
50	—	—	—	10 c	16 1 a	1 29 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level Av of 4 replications, 10 nymphs/replication. [b]Seedlings were kept dipped in 30 ml water containing the desired quantity of extract during the experiment [c]Growth index = $\frac{\text{nymphs becoming adults (\%)}}{\text{growth period (days)}}$ [d]Treated with acetone

SEX PHEROMONES

Research on sex pheromones in collaboration with the Tropical Products Institute, London, UK, continued.

Development of pheromone traps. A large water surface is important in obtaining high catches in pheromone traps, but two small traps may be more economical and practical than one large trap. Water-oil traps, 60 cm in diameter, with 50 μg of attractant in a rubber septum caught only twice as many male moths of the leaf folder *Cnaphalocrocis medinalis* as a smaller water-oil trap, 20 cm in diameter.

Monitoring pest behavior with traps. The trend in sex-pheromone trap catches of male rice leaf folders was similar to that of leaf folder infestation and damage. Light trap catches did not show the same trend (Fig. 9), which indicated that pheromone traps may be helpful in timing insecticide treatments.

In 1979 (1979 annual report), similar trap-infestation data were obtained for the striped rice borer *Chilo suppressalis,* using pheromone traps suitable for that species. In a 1980 field trial, striped borer control with one spray 1 week after the peak in trap catches was as good as with two prophylactic granular-insecticide applications.

BIOLOGICAL CONTROL

Insects parasitic on spiders. The natural enemies of spiders that are natural enemies of rice insect pests

Table 39. Quantity of honeydew excreted by brachypterous brown planthopper (biotype 1) females caged on TN1 plants sprayed with an indigenous plant extract IRRI laboratory, 1980.

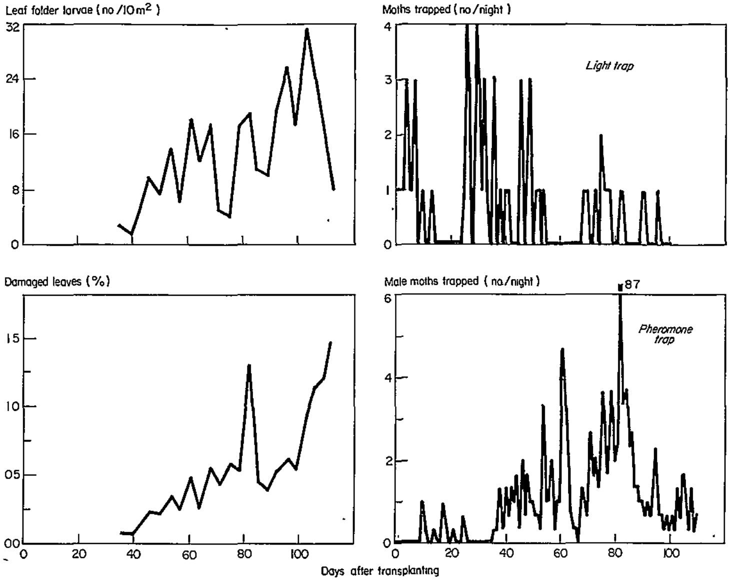
Quantity of extract sprayed (mg/plant)	Honeydew[a] (mg/female in 24 h)
0 (control)[b]	54.97 a
1	40 54 b
5	31 39 b
10	8 70 c
20	8 46 c
50	2 45 c

[a]Separation of means by Duncan's multiple range test at the 5% level Av of 8 replications. Honeydew on 1-month-old TN1 plants was collected in parafilm membrane sachets and weighed on a microbalance [b]Sprayed with acetone

Table 40. Ovipositional response of brown planthopper and egg hatchability on TN1 plants sprayed with an indigenous plant extract[a] IRRI insectary, 1980.

Quantity of extract sprayed (mg/5 tillers per pot)	Eggs laid[b] (no /10 females in 24 h)	Eggs hatched[c] (%)
0 (control)[d]	313 a	95 a
1	232 ab	91 a
5	174 b	93 a
10	155 bc	92 a
20	99 c	90 a
50	12 d	98 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level Av of 5 replications, 10 gravid females/replication [b]Based on number of nymphs that emerged up to 12 days after oviposition on 1-month-old TN1 plants; unhatched eggs were counted by dissecting the plant tissue. [c]Eggs hatched (%) = $\frac{\text{eggs hatched (no.)}}{\text{eggs laid (total no.)}} \times 100$. [d]Sprayed with acetone



9. Comparison of rice leaf folder density and damage on rice variety IR29 and moth catches in sex-pheromone and fluorescent-light traps. IRRI, 1980 wet season.

were found to be mainly parasites of eggs and larvae. Egg sacs obtained from laboratory colonies of 18 spider species were exposed in rice fields. The resulting parasitization was low (Table 41). Two sphecid wasps (*Sceliphron madraspatanum conspicillatum* and *Chalybion bengalense*) were the main predatory species aside from the spiders themselves, which are probably their own worst enemies.

Insects parasitic on hoppers. In farmers' fields near IRRI, hopper parasitization was usually higher than 30% and often higher than 40%. Both dryinids and strepsipterans attacked BPH and WBPH, but the most common parasites of GLH were pipunculids with strepsipterans of lesser importance.

Parasites of eggs. The most common parasite of WBPH eggs was *Anagrus flaveolus*. Parasitization of field-collected eggs averaged 8-9%, but on laboratory-reared eggs placed in rice fields at IRRI, parasitization averaged 26% in wetland fields and 19% in dryland.

Parasites of nymphs and adults. The most common parasites of WBPH nymphs and adults at IRRI were *Pseudogonatopus nudus* and *P. flavifemur,* family Dryinidae. Strong fluctuations in parasitization over time occurred, but the average was only 8%.

Insects parasitic on leaf folders. *Parasites of eggs.* Only one parasite of leaf folder eggs was found — *Trichogramma* sp. Egg parasitization appears to be a minor mortality factor.

Parasites of larvae and pupae. Many parasite species, almost all in the order Hymenoptera, were found to attack leaf folder larvae. A few species emerged from the host pupae. But despite the

Table 41. Percentage of parasitization and parasites on spider egg masses. IRRI, November 1979-March 1980.

Spider	Parasites	Egg masses (no.)	Parasiti-zation (%)
ARGIOPIDAE			
Argiope catenulata (Doleschall)	*Pierretia litsingeri* Shinonaga and Barrion	252	11
	Ichneumonidae sp. 1		
	Strepsimallus yasumatsui Momoi		
Araneus inustus (L Koch)	*Baieus* and *Idris*	186	1
Neoscona theisi (Walck.)	*Baieus* sp.	200	1
CLUBIONIDAE			
Clubiona japonicola Boes. et Str.	*Baieus* sp.	200	25
LYCOSIDAE			
Arctosa janetscheki Buchnar	None	106	0
Lycosa pseudoannulata Boes. et Str.	None	250	0
Pardosa birmanica (Thorell)	None	106	0
MICRYPHANTIDAE			
Callitrichia formosana Oi	*Strepsimallus yasumatsui* Momoi	200	10
OXYOPIDAE			
Oxyopes javanus (Thorell)	*Caenopimpla arealis* (Cushman) ? *Idris*	210	18
SALTICIDAE			
? *Bianor* sp.	*Pompilidae* (= Pepsinae)	2	50
TETRAGNATHIDAE			
Dyschiriognatha sp.	None	25	0
Leucauge decorata (Blackwall)	None	10	0
Tetragnatha japonica Boes. et Str.	Undet. Ichneumonidae (3 spp.)	200	13
T. javana (Thorell)	None	200	0
T. mandibulata Walck.	None	70	0
T. sp. D	None	86	0
T. virescens Okuma	Undet. Braconidae	59	3
THOMISIDAE			
Thomisus cherapunjeus	Undet. Braconidae	200	1

numerous parasite species, parasitization averaged only 14%, with braconids accounting for 50% of that.

Insect diseases. *Fungal pathogens of hoppers.* Control of BPH with fungi was investigated in collaboration with the Boyce Thompson Institute for Plant Research, Ithaca, New York, USA. Despite problems in formulation, the project aims to develop microbial insecticides from entomopathogenic fungi.

Diseased hoppers were collected in the Philippines, Malaysia, and Thailand, and the diseases cultured and bioassayed for pathogenicity against the major hopper species. Exotic fungal strains and species were also imported and bioassayed. Infection of exposed hoppers usually reached 10-30%. In a preliminary trial two species, *Entomophthora virulenta* and *Metarhizium anisopliae,* were applied with sprayers to a BPH-infested rice crop. Initially more than 50% of the BPH became infected with a pathogen.

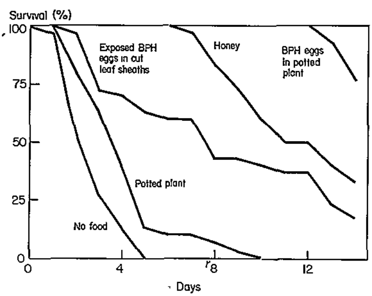
Microbial control with Bacillus thuringiensis. A commercial formulation of *Bacillus thuringiensis* (BT), called Bactospeine, was shown in 1979 to be very toxic to leaf folder and caseworm larvae (1979 annual report). A local form of Bactospeine, called Backie, was found to be very toxic in 1980; almost all leaf folders died in 2 days and nearly all caseworms in 3 days. Similar results were obtained with a sprayable brand called Dipel.

In a field trial, Bactospeine and Dipel were sprayed weekly in separate plots throughout the leaf folder infestation period. A low level of infestation was obtained in the trial, but at 94 DT, the level of leaf folder damage in the BT treatments (1.7%) was significantly lower than that in the control (2.8%). Further tests at higher infestation levels are needed.

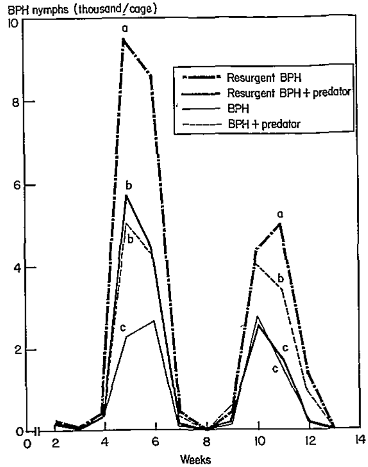
Predators of hoppers. *Bugs. Cyrtorhinus lividipennis* is a predator primarily of hopper eggs (1979 annual report). Its capability to survive without prey eggs was tested in an insectary where different foods were offered to newly emerged bugs. In all cases, the relative humidity was high. The presence of free water in a cage did not affect survival. Survival on potted plants was only slightly better than that with no food, demonstrating that *C. lividipennis* is not a rice feeder. BPH eggs exposed on cut pieces of leaf sheath were not as good a food as eggs normally situated in a living plant. Good survival on honey suggested an easy method of feeding caged bugs in the laboratory (Fig. 10).

Predation of WBPH eggs by *C. lividipennis* averaged 20% in wetland fields and 43% in dryland. Predation accounted for one-half the mortality of eggs in the field.

A small predacious water strider, *Microvelia atrolineata,* is common in IRRI's wetland rice fields. It may reach a density of 770/m^2. Its capability to reduce a caged brown planthopper population significantly was demonstrated for the first time in 1980. After 5 female planthoppers had laid eggs in plants, 100 *Microvelia* adults were released in a 0.13-m^2 greenhouse cage as the eggs were hatching. When the next generation of nymphs emerged, the predator substantially suppressed pest density. This suppression continued to the third generation (Fig. 11). To create resurgent pest populations, plants treated 10 days earlier with the insecticide methyl parathion were fed to the planthoppers. Again the predator reduced the pest density, despite a large population (Fig. 11).



10. Survival of newly emerged adults of the predatory bug *Cyrtorhinus lividipennis* on different foods. IRRI insectary, 1980.



11. Density of brown planthopper (BPH) nymphs on unsprayed plants and on those sprayed with the insecticide methyl parathion to cause BPH resurgence. Densities at 5 or 11 wk with a common letter are not significantly different at the 5% level. Populations were initiated with 5 pairs of adult BPH/cage. In some cases, 100 predatory adult *Microvelia atrolineata* were introduced in each cage when BPH eggs were hatching. IRRI greenhouse, 1980.

Spiders. Lycosa pseudoannulata is an important predator of hoppers, but male and female spiders are not equally important. A comparison of predatory behavior showed that, when one spider was caged with 20 BPH adults each day for 8 days, males killed only 5 BPH/day but females killed significantly more (9/day). The predation capacity in cages of *Lycosa* was compared with that of another, but smaller spider, *Callitrichia formosana. Lycosa* killed 8 BPH/day (first- to third-instar BPH nymphs), but *Callitrichia* killed only 1 BPH in 1 or 2 days.

A study in wetland fields showed a numerical relationship between spider and BPH densities. Fields with higher BPH densities also showed higher spider densities. Spearman's coefficient for spider numbers and BPH numbers was 0.929. The correlation of spider saturation density with BPH survival was -0.9, suggesting that spiders were involved in density-dependent BPH survival. The results suggest that spider populations grew until the available prey no longer supported them. As prey density increased relative to predator density, the predator operated more efficiently (functional response). This was followed by increased predator reproduction (numerical response).

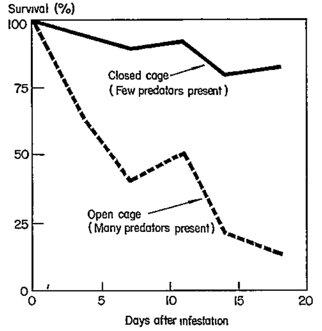
Spiders appeared to be the most important predators of WBPH nymphs and adults. In greenhouse trials, *L. pseudoannulata* killed 1.5 WBPH/day, and *Oxyopes javanus* killed 2.3/day. *Argiope catenulata* and *Tetragnatha japonica* were less important spider predators of WBPH, killing <1/day.

Ducks. A comparison of the predation capacity of adult ducks and ducklings suggested, as expected, that adult ducks ate more BPH than ducklings. The number of ducks needed to control a BPH infestation was studied earlier (1979 annual report). Further research indicated that prolongation of herding time could compensate for fewer ducks, assuming the pest problem was not urgent. The largest reduction in BPH density occurred on the first day of herding.

Other predators. The damselfly *Agriocnemis pygmaea* was one of the best predators of WBPH, killing about 2 nymphs/day in greenhouse cages. A larva of the ladybird beetle *Coccinella arcuata* killed one BPH nymph or adult in 1-2 days.

General hopper predation. The serological technique (1979 annual report) used in 1980 demonstrated that the predators mentioned earlier actually fed on hoppers in the field.

The total impact of predation on WBPH nymphs was shown by a simple physical exclusion trial. Survival of nymphs placed in closed cages or in cages with bottom edges lifted (to permit entry of predators) in a wetland field differed significantly — survival after 18 days was 82% in closed cages but only 12% in open cages (Fig. 12). About 4 times as many predators were found in the open cages as in the closed (19 vs 5). Predation was the major mortality factor — causing up to 80% mortality — for WBPH nymphs. The field densities of WBPH



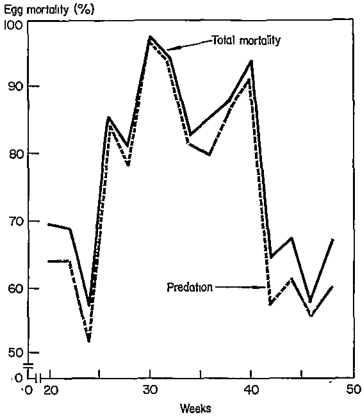
12. Survival of whitebacked planthopper nymphs in closed or open (bottom edges lifted) 4-hill cages initially infested with 20 second-instar nymphs in wetland fields. IRRI, 1980 dry season

and the various predatory species, and the latter's predation capacities were analyzed. The predators appear to have the ability to kill all the WBPH in 1 or 2 days.

Predators of leaf folders. *Predators of eggs.* Earlier studies suggested that LF egg predation is high (1979 annual report). Research in 1980 demonstrated the importance of predation in egg mortality. When LF eggs on potted plants were placed in rice fields, survival after 24 hours in a cage was 95%, but outside a cage and exposed to predation egg survival dropped to 25 or 30%, a highly significant reduction. Because LF eggs do not normally hatch until at least 4 days have passed, such severe pest reduction in only 1 day revealed the importance of egg predation. Estimates of egg predation in 24 hours varied considerably every 2 weeks, but the means were 69% in wetland fields and 73% in dryland. Total egg mortality was only slightly higher (Fig. 13).

Cage experiments in a greenhouse confirmed that at least three species were voracious predators of LF eggs: the spider *Tetragnatha japonica,* ladybird beetle *Coccinella arcuata,* and ant *Solenopsis germinata.* Each adult predator could kill 12-15 eggs/day.

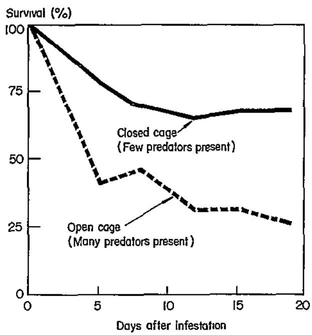
Predators of larvae. When first-instar larvae were placed in cages, survival after 19 days was 25% in open cages and 67% in cages with bottom edges lifted (Fig. 14). This difference was highly



13. Total mortality and predation of eggs of rice leaf folder according to biweekly monitoring (1-day field exposure) in dryland rice fields IRRI, 1979.

significant. At the time of comparison, only 70% of the larvae had pupated, so total larval survival was probably 20% or less. The 80% mortality suffered was evidently due to larval predation.

Cage experiments in a greenhouse confirmed that larvae of at least two beetle species were predacious on LF larvae: *Chlaenius* sp. (Carabidae) and *C. arcuata.* Each predator killed one LF larva/day. Adult spiders *Lycosa pseudoannulata* were even better predators, one spider killing 2.5 larvae/day.



14. Survival of rice leaf folder larvae in closed or open (bottom edges lifted) 4-hill cages initially infested with 20 first-instar larvae in wetland fields IRRI, 1980 dry season.

ECOLOGY

Alternative weed host of rice caseworm. The rice caseworm cannot survive without water. Eggs are laid on the undersides of leaves floating on water and the larvae possess tracheal gills. In rainfed environments, the rice caseworm occurs in rice fields during the rainy season, but nothing is known about how it survives the dry season.

Twelve common wetland rice field weeds were tested as alternative rice caseworm hosts for one complete generation in an open-air headhouse at IRRI. Weed species were collected in the vegetative stage.

Upon hatching, larvae were transferred into caged potted plants immersed in individual basins of water. Larval survival to the pupal stage and developmental periods were recorded. Pupae were held for adult emergence and eggs per female were counted from a maximum of 5 females/treatment on cut rice leaves.

There was low larval survival on rice because of the small volume of water used for each potted plant in the experiment. Despite this deficiency, the rice caseworm survived and laid eggs on 9 of the 12 weed species (Table 42). *Paspalum conjugatum* was equal to rice as a host in terms of larval survival. Although larval survival was significantly less than on rice, the caseworm was also successfully reared on *Echinochloa colona, E. glabrescens, Cynodon dactylon, Paspalum distichum, Leptochloa chinensis,* and *Dactyloctenium aegyptium.*

Population dynamics. BPH, WBPH, and GLH tend to have different field population characteristics at IRRI. To determine if the differences are inherent to their population growth capabilities, or due to other factors, the three species were reared separately in the greenhouse. After 3 generations, no noteworthy differences among the 3 populations were found after 3 months.

Brown planthopper. The population dynamics of BPH was studied in a series of crops from 1977 to 1979. It was found that an increasing BPH density led to:

- production of a greater number of macropter-

Table 42. Suitability[a] of rice and 12 weed species as alternative hosts for the rice caseworm. IRRI headhouse, 1980.

Host species	Egg incubation[b] period (days)	Survival[c] (%)	Egg-larval developmental period[d] (days)
Oryza sativa	3.0 a	52 a	17.2 a
Paspalum conjugatum	3.0 a	38 ab	20.0 a
Echinochloa colona	3.0 a	28 b	18.4 a
Echinochloa glabrescens	3.0 a	25 b	19.4 a
Cynodon dactylon	4.2 cd	25 b	18.6 a
Paspalum distichum	4.6 d	7 c	19.5 a
Leptochloa chinensis	3.6 abc	5 c	20.0 a
Dactyloctenium aegyptium	3.8 abcd	11 c	29.7 ab
Eleusine indica	4.6 d	8 c	23.8 ab
Cyperus rotundus	4.2 cd	1 c[e]	35.0 b[e]
Cyperus difformis	3.2 ab	0 c	—
Cyperus iria	4.0 bcd	0 c	—
Fimbristylis littoralis	4.0 bcd	0 c	—

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]20 eggs in each of 5 replications/plant species. [c]First instar to pupation. Twenty larvae in each of 5 replications/plant species. [d]From oviposition to pupation. [e]One larva survived but did not pupate within 35 days, after which the study was terminated.

ous adults (more than 50% of the adults in a field were macropters, partly because immigrants were all macropters),

- reduction in fecundity (this density-dependent effect was probably due mainly to competition for oviposition sites), and
- increase in nymph mortality rates, probably because natural predators, especially spiders, were highly density dependent. In the experimental fields observed, natural enemies kept the BPH population below hopperburn densities and usually below economic damage levels. It was also found that egg parasitization increased with time in a crop period.

BPH outbreaks have been attributed, among other things, to area-wide resurgence caused by insecticides (1979 annual report). Further analysis of BPH populations showed that nymph and adult survival was higher in sprayed than in unsprayed fields. Because predators (*Microvelia* and possibly spiders) were killed by the insecticide spray (decamethrin), this strongly suggests that predator mortality is one of the factors in resurgence. In two experiments in farmers' fields, it was also observed that fecundity increased in sprayed plots.

Whitebacked planthopper. A series of crops was intensively observed to monitor WBPH population changes. WBPH entering a field soon after planting initiated the population. One or two generations developed within a crop period. Average survival of eggs and nymphs was 52 and 23%, with a combined survival of 12% (Table 43). But studies on WBPH nymph survival in field cages suggested that survival was as low as 10%, making the combined survival a low 5%. This high mortality rate was due largely to predation.

Leaf folder. LF population changes were observed in the same crops used for BPH. There was usually only one LF generation per crop. Average survival of eggs and larvae was only 4% (Table 43). But studies on egg survival using laboratory-reared eggs suggested that survival was about 25%, making the combined survival a very low 1%. This high mortality was evidently due mostly to predation. Natural biological control appeared to contain population growth easily.

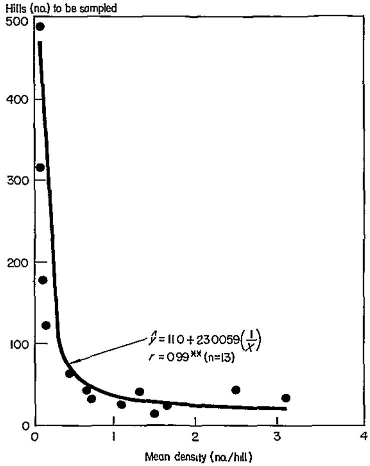
Insect distribution and sampling methods. *Whitebacked planthoppers.* A wetland rice field was intensively sampled to measure the insect distribution and determine the appropriate WBPH sample size. The hill-to-hill distribution of nymphs and

Table 43. Survival at each stage of whitebacked planthopper (WBPH) and leaf folder (LF) (more than 18 generations for WBPH and 5 generations for LF) on rice selection IR2307-247-2-2-3 in wetland fields. IRRI, 1979-80.

Insect stage	Survival rate (%) (mean ± S E)	
	WBPH	LF
Egg	0.52 ± 0.05	0.75 ± 0.01
Nymph or larva	0.23 ± 0.02	0.06 ± 0.01
1st-instar nymph or larva	0.86 ± 0.02	0.77 ± 0.02
2d-instar nymph or larva	0.79 ± 0.02	0.77 ± 0.02
3d-instar nymph or larva	0.81 ± 0.02	0.77 ± 0.03
4th-instar nymph or larva	0.73 ± 0.02	0.68 ± 0.04
5th-instar nymph or larva	0.57 ± 0.03	0.61 ± 0.02
6th instar larva	—	0.30 ± 0.06
Egg + nymph or larva	0.12 ± 0.02	0.04 ± 0.01

adults was usually not random but aggregated to varying degrees at different times. Aggregation was often greater for nymphs than for adults, and increased with higher insect density. The required sample size (using one hill as the sample unit) to achieve 20% precision depended on insect density and variance. Sampling 40 hills individually usually resulted in an adequate precision level if the density was about 1 or more WBPH per hill (Fig. 15). In these cases the coefficient of variation was just over 100%. It was observed that the mean insect density was not the same in all parts of a 0.25-ha rice field, confirming the need for blocking in the experimental design.

Leaf folder. Hills in wetlands were visually inspected for the presence of LF larvae. The distribution of larvae was aggregated. The required sample size to achieve 20% precision varied, but sampling 40 hills usually resulted in an adequate precision level if the density was about 1 or more larvae per hill.



15. Relationship between sample size and mean density of whitebacked planthopper in a wetland field IRRI, 1979 dry and wet seasons.

BROWN PLANTHOPPER MIGRATION

Short-distance migration. Studies continued to monitor aerial activity of BPH and other major delphacid and cicadellid rice pests in relation to population fluctuations on a 2-ha farm in Liliw, Laguna province, Philippines.

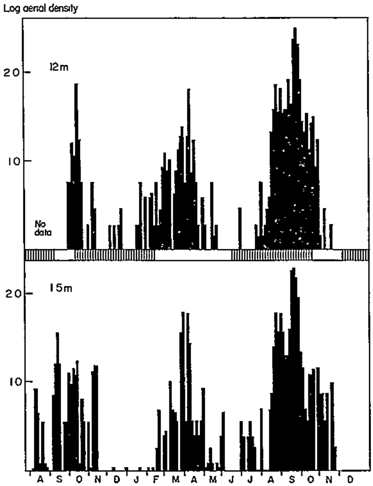
Fluctuations in aerial density of BPH measured at heights of 12 m and 1.5 m are shown in Figure 16. Marked peaks of abundance were evident in March-April and September-October. IRRI light trap records for several years show that such peaks occur annually. Figure 16 also shows that the peaks of activity do not occur in any constant relation to cropping seasons at Liliw. They thus do not represent a site-specific phenomenon but are characteristic of a considerably wider area.

Insects caught in suction traps at both heights may be either immigrants or emigrants. Some of those caught at 12 m may also be migrants passing over the site, but the correspondence between the two trapping heights in catch periodicity suggests that this is not a frequent occurrence. Insects caught at 1.5 m may be involved in trivial flights within the site, but data from other trapping methods indicate that such flights are rare. Most of the activity recorded in traps therefore represents insects moving into or out of the site.

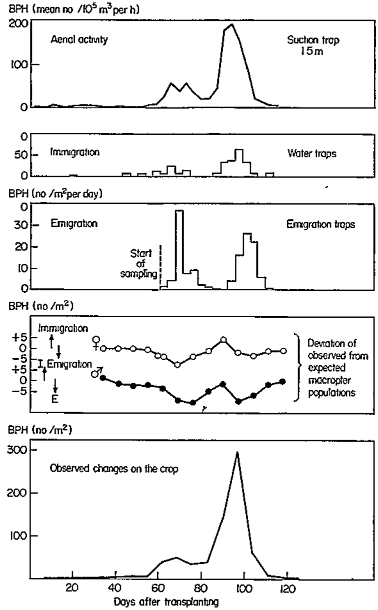
Distinguishing between immigration and emigration depends upon the assimilation of different data sets (Fig. 17). Water traps were used as indicators of arrival of insects at the site and D-Vac samples gave information on both current populations of macropterous (long-winged) adults and their potential production on the crop.

Direct estimates of emigration at Liliw were made using a trap designed for that purpose. The trap was set above the crop canopy to collect insects that had taken off from the plants. Collections made hourly showed strongly marked periodicity, with 75% taking off between 1700 and 2100 hours and 25% between 0400 and 0800 hours. Periodicity data from the 1.5-m suction traps showed that 40% of flight activity occurred outside these times. This may be attributable to immigration because short flights within the habitat seem to be rare.

Emigration activity was also monitored by continuous hourly catches of macropterous hoppers for 7 consecutive days in a partially hopperburned rice field near IRRI. Upwind and downwind catches were made using sweep nets 1 m above the



16. Aerial densities of brown planthopper recorded in suction traps at 12 m and 1.5 m, August 1979 to December 1980, in Liliw, Laguna, Philippines Hatched bars show cropping seasons at the site.

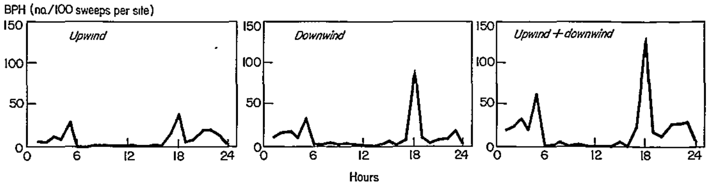


17. Summarized observations on the movement of macropterous brown planthopper (BPH) into and out of an IR20 rice crop. Liliw, Laguna, Philippines, 1980 wet season. Expected populations of macropters are calculated from wing morph ratios observed in the preceding fifth-instar nymphs. Note that both peaks of aerial activity shown in the suction traps involve both immigration and emigration although the net effect is usually loss of insects from the crop.

rice canopy at 5 sampling sites (20 sweeps/site). Cumulative catches at each hour indicated a distinctly crepuscular *bimodal* takeoff activity (Fig. 18). Males and females were caught in almost equal proportion. Light intensity of <10 lux, ambient temperature of 21-25° C, 80-100% relative humidity (RH), and weak winds of about 1.2 km/hour prevailed around dawn and dusk and seemed to favor BPH takeoff. Sporadic hopper catches during nighttime may be attributed to the waxing moon phase, which coincided with the observation period.

BPH immigration was also monitored in IRRI fields planted to IR1917-317, a BPH-susceptible selection, during two consecutive cropping seasons. Yellow pan and yellow board traps were used. Comparison of cumulative hourly catches during both cropping seasons showed that the maximum number of BPH macropters was recorded at about 0600 hours in both types of traps, indicating a *unimodal* invasion flight activity (Fig. 19). Light intensity at 0600 hours was about 100 lux during the first cropping season and about 6,000 lux during the second. Weak winds, relatively lower temperature, and correspondingly higher relative humidity prevailed at the time of BPH invasion into rice fields than at any other time of the day.

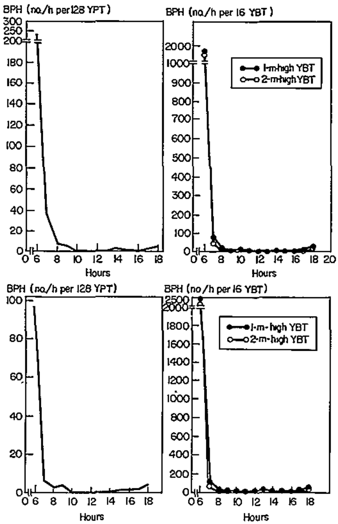
In 1980 the Liliw site was planted to a mosaic of IR20 (BPH susceptible) and IR36 (BPH resistant). The rate of immigration into both varieties was low. Despite that, large populations developed on IR20, giving a site mean of 30 BPH/hill at 80-90 days after transplanting (DT). Some plots reached more than 50 adults/hill by 90 DT. In contrast the



18. Trends in hourly takeoff of macropterous brown planthopper (BPH) from a partially hopperburned rice field. Hopper numbers are based on total catches in 7 consecutive days in 100 sweeps/hour at 5 upwind and 5 upwind and 5 downwind sampling sites. Masiit, Calauan, Laguna, Philippines. 13-19 Oct 1980.

mean number on IR36 for the same period was 3/hill and a maximum adult population of 5/hill was recorded. Although both varieties are susceptible, WBPH populations in IR36 were only half those in IR20.

Water trapping continued at a number of sites



19. Trends in hourly catches of immigrant macropterous brown planthopper (BPH) in IR1917-3-17 rice fields with yellow pan traps (YPT) and yellow board traps (YBT) Hopper numbers are based on cumulative hourly catches in 128 YPT, and on 16 1- and 2-m-high YBT, each set for 61 sampling days (Dec 1979 to March 1980, top) and 63 sampling days (May to Aug 1980, bottom). IRRI, 1980.

along a 15-km transect extending from irrigated rice on the shores of Lake Laguna de Bay to rainfed rice around Liliw. Data from these traps show that periods of immigration were generally the same for all sites despite differences in cropping pattern, with peaks of activity occurring at the same time as recorded in suction traps at Liliw.

Long-distance migration. Long-distance migration studies initiated in 1979 continued. The migrating BPH and other insects were monitored using 6 wind-propelled, revolving-type nylon nets (0.5 m diam, 2 m long) and 4 cross-shaped, sticky traps (0.45 × 0.45 m) on 4 successive interisland voyages made along fixed sea routes.

During the dry season, the first voyage was 26 January-2 February (Manila-Maasin, Maasin-Cebu, Cebu-Cagayan de Oro, Cagayan de Oro-Maasin, and Maasin-Manila). The second voyage was 7-15 May (Manila-Masbate, Masbate-Cebu, Cebu-Iligan, Iligan-Masbate, and Masbate-Manila).

On the first dry season voyage, 124 insects and a tetragnathid spider were collected. Among the insects caught, the most numerous were dipterans (52%), followed by hymenopterans (29%), hemipterans (15%), and coleopterans and orthopterans (4%).

Among the hemipterans caught, 37% belonged to four species of the family Delphacidae, 16% each belonged to families Aphididae and Miridae, and the remainder were representatives of other hopper and bug families. The delphacids represented WBPH *Sogatella furcifera, S. panicicola,* an unidentified female delphacid, and a solitary *N. lugens* male which was caught on the Maasin-Cebu route on 28 January 1980.

On the second voyage, 234 insects, an argiopid and a tetragnathid spider, and an ixodid tick were caught. Among them were 55% dipterans, 18% hymenopterans, 13% each of hemipterans and coleopterans, and 1% lepidopterans and embiopteran. The hemipterans included cicadellids (47%), mirids (20%), psyllids (13%), aphids (7%), tingids (7%), and anthocorids and lygaeids (6%). No delphacid was caught.

The wet season voyages were 15-24 July (Manila-Masbate, Masbate-Cebu, Cebu-Iligan, Iligan-Masbate, and Masbate-Manila), and 17-25 October (Manila-Masbate, Masbate-Cebu, Cebu-Iligan, Iligan-Cebu, Cebu-Masbate, and Masbate-Manila).

They were characterized by relatively higher insect catches. On the first voyage, 335 insects and 5 araneids, representing spider families Argiopidae, Clubionidae, Dictynidae, and Tetragnathidae, were collected. Among them were 56% dipterans, 29% hemipterans, 8% hymenopterans; the remaining 7% were coleopterans and lepidopterans.

Among the hemipterans caught, 46% belonged to the family Aphididae, 21% belonged to Delphacidae, 7% each belonged to families Cicadellidae, Lygaeidae, and Miridae, and the remainder represented families Veliidae, Psyllidae, Alydidae, Reduviidae, and Tingidae.

The delphacid catches comprised *Harmalia* sp., *Nilaparvata bakeri, N. lugens, S. furcifera, S. panicicola, S. terryi, Sogatella* sp., *Sogatodes pusanus,* and an unidentified male delphacid. Among the delphacids caught, *S. furcifera* was the predominant species.

On the second wet season voyage, 311 insects and 16 araneids, representing families Clubionidae, Erigonidae, Micryphantidae, Tetragnathidae, and Theridiidae, were collected. Hemiptera comprised the biggest catches (50%), followed by dipterans (35%), hymenopterans (13%), and coleopterans and lepidopterans (2%).

The bulk of hemipterans caught comprised aphids (28%) and delphacids (28%), followed by mirids (20%) and cicadellids (12%); the remainder included representatives of families Meenoplidae, Lygaeidae, Pleidae, Veliidae, Corixidae, Aleyrodidae, Largidae, Membracidae, and Reduviidae.

The delphacids represented mostly BPH *N. lugens,* WBPH *S. furcifera, Sogatella kolophon,* and *S. pusanus.* The remaining delphacids included an unidentified male of *Nilaparvata* sp., a male of *Sogatella* sp., a female of *Opiconsiva* sp., a male of *Perkinsiella* sp., a female of *Toya* nr *Propinqua,* and a few other unidentified male and female delphacids.

The 26 January-2 February dry season voyage was characterized by the prevalence of the northeast monsoon, 20.5-32.7° C temperature, and 46-96% RH. The 7-15 May dry season voyage had variable winds, 24.0-35.1° C temperature, and 43-92% RH; no delphacids were caught on these voyages. However, catches of delphacids including BPH were high on the same routes during the 15-24 July (23.4° C, 59-98% RH) and 17-25 October (23.7-32.8° C, 53-99% RH) voyages, during which the southwest monsoon prevailed. These observations confirmed 1979 findings that hopper migration in the Philippines occurs mostly during the wet season.

INTEGRATED PEST MANAGEMENT

Economics of insect control. Studies in both seasons in farmers' fields in Talavera (Nueva Ecija) and Victoria (Laguna) determined the crop stage at which insects caused yield losses. Treatments are given in Table 44. The treatments were compared with 0.5 kg a.i. carbofuran/ha incorporated in the soil prior to transplanting, followed by applications when the economic threshold was reached and applications based on the economic threshold. In the dry season test at Nueva Ecija, insect populations were low and only two treatments had significantly higher yields than the control (Table 44).

In the wet season test, insects were monitored with a light trap (Table 45). The number of insects per week was low, which was reflected in the populations on the plants (Table 46). Insect damage and populations were much below the economic threshold in all treatments including the control. Despite the low insect pressure, yields in all treatments were significantly greater than that of the control (Table 47). Gross profit and net gain were highest for maximum protection except in the treatment with no seedbed protection, but benefit-cost for insecticide was highest with vegetative stage protection and integrated pest management treatment (IPM).

In a dry season test in Laguna province, insect- and virus-susceptible IR22 and resistant IR44 were compared. Whorl maggot damage and GLH counts

Table 44. Insect populations, damage, and yield of IR36 treated with insecticides during different growth stages. Integrated pest control pilot project, Talavera, Nueva Ecija, Philippines, 1980 dry season.

Treatment	Population or damage[a]							Yield (t/ha)	Cost of pesticide ($/ha)
	GLH in 10 sweeps/ plot	BPH (no./ hill)	WM damage	Defoliation (%)	LF-damaged leaves (%)	Stem borer (%)			
						Deadheart	Whitehead		
Maximum protection[b]	2.0 a	1.1 a	1.2 c	1.9 b	0.4 b	0.9 c	2.5 a	4.6 ab	115.62
No seedbed protection	1.8 a	0.9 a	1.5 bc	2.6 b	0.6 b	1.1 c	2.5 a	4.6 ab	114.11
No vegetative protection	1.8 a	1.8 a	2.7 a	4.7 a	0.6 b	1.3 c	3.0 a	4.7 a	50.82
No reproductive protection	2.5 a	1.1 a	1.3 c	2.5 b	1.2 b	1.5 bc	4.4 a	4.3 ab	83.29
No ripening protection	1.7 a	0.9 a	1.3 c	2.0 b	0.6 b	1.0 c	2.6 a	4.5 ab	98.63
Insect pest management[c]	2.2 a	1.2 a	1.3 c	2.0 b	0.8 b	1.4 c	2.8 a	4.5 ab	18.49
Vegetative protection only	2.2 a	1.2 a	1.5 bc	2.6 b	0.8 b	1.5 bc	3.9 a	4.7 a	18.49
Economic threshold level[d]	2.3 a	1.0 a	2.3 ab	5.2 a	2.6 a	2.4 b	2.7 a	4.2 ab	0
Control	2.5 a	1.5 a	2.7 a	5.5 a	2.4 a	2.9 a	3.4 a	3.9 b	0

[a]Data were from sampling when maximum pests or damage occurred. Separation of means in a column by Duncan's multiple range test at the 5% level. GLH = green leafhopper, BPH = brown planthopper, WM = whorl maggot (damage based on visual rating scale), LF = leaf folder. Defoliation was due to green caterpillar *Naranga aenescens* and caseworm *Nymphula depunctalis*. [b]Seedbed protection = 0.75 kg a.i. monocrotophos/ha sprayed at 5 and 20 days after sowing; vegetative stage protection = 0.75 kg a.i. chlorpyrifos + BPMC/ha sprayed 5 days after transplanting (DT), and 1.0 kg a.i. diazinon/ha broadcast 35 DT; reproductive stage protection = 0.75 kg a.i. azinphos ethyl/ha sprayed 50 and 65 DT; ripening stage protection = 0.75 kg a.i. carbaryl/ha sprayed 75 and 85 DT. [c]Soil incorporation of carbofuran 3 G (0.5 kg a.i./ha) followed by treatment when economic thresholds were reached. [d]No threshold was reached.

Table 45. Insect flight activity as indicated by light trap[a] collections in a farmer's field. Integrated pest control project, Nueva Ecija, Philippines, 1980 wet season.

Week	Green leaf-hopper (no.)	Brown plant-hopper (no.)	Whitebacked plant-hopper (no.)	Zigzag leaf-hopper (no.)	Case-worm (no.)	Green cater-pillar[b] (no.)	Stem borer (no.)	Leaf folder (no.)
First	75	81	205	5	8	319	7	0
Second	66	147	417	8	6	365	1	0
Third	51	74	228	7	0	228	0	0
Fourth	68	116	302	11	4	203	1	0
Fifth	52	105	304	28	0	224	1	2
Sixth	123	107	254	7	0	182	2	46
Seventh	330	75	183	11	0	546	9	30
Eighth	543	110	290	31	5	347	8	5
Ninth	105	35	139	8	2	99	10	0

[a]Kerosene light flame was on daily, 6 pm to 6 am from 24 July to 1 October 1980. [b]*Naranga aenescens*.

were generally lower in IR44 (Table 48). The IPM treatment (with soil incorporation of carbofuran) provided the best whorl maggot and GLH control. BPH and tungro virus were also lower in IR44; stem borer damage was slightly higher (Table 49). The IPM treatment provided the most effective tungro virus control, which was reflected in the IR22 yield (Table 50).

Because of its tungro resistance, all treatments of IR44 except for the IPM produced higher gross income than IR22 (Table 50). Control of tungro and other pests was effective; therefore, the IPM treatment in IR22 had a gross income about equal to that of the best treatment in IR44. Because of the low values of the insecticide input but high yields, net gain was highest in the IPM treatments for both varieties, especially for IR22. Gain from insecticides and the benefit-cost ratio for insecticide were also highest in the IPM treatment. However, the benefit-cost ratio for IR44 was too low to be attractive to farmers.

In the wet season test, susceptible IR22 and resistant IR50 were compared. GLH and BPH numbers and tungro virus incidence were higher than in the dry season test. Tungro incidence in the control treatment of IR22 was 79%; no tungro occurred in IR50.

Wet season yield losses were more severe than in

Table 46 Rice insect pest damage[a] on IR50 at various levels of protection in a farmer's field. Integrated pest control project, Nueva Ecija, Philippines, 1980 wet season.

Treatment	Whorl maggot (no.) 30 DT	Defoliation (%) 50 DT	Leaffolder (% damaged leaves) 62 DT	Stem borer: Deadhearts (%) 45 DT	Stem borer: Whiteheads (%) 50 DT	Green leafhopper (no./10 sweeps) 15 DT	Green leafhopper (no./10 sweeps) 50 DT	Brown planthopper (no./20 hills) 46 DT	Brown planthopper (no./20 hills) 53 DT	Brown planthopper (no./20 hills) 60 DT
Maximum protection[b]	1	0 51 c	0 b	0	0 5 d	1.00 a	0.75 abc	10.25 c	9.50 bc	2.75 b
Maximum protection except in seedbed	1	0.49 c	0 b	0	0.7 bcd	0.75 a	0 25 b	13.25 bc	6.00 c	1 50 b
Maximum protection except at vegetative stage	1	2.04 a	6 a	0	1.1 a	1.50 a	1.00 abc	20.25 ab	17 50 a	14.50 a
Maximum protection except at reproductive stage	1	0.78 c	1 b	0	0.7 bcd	0.50 a	0.25 bc	8.50 c	5 00 c	0.75 b
Maximum protection except at ripening stage	1	0.99 bc	0 b	0	0 8 abc	1.50 a	0.00 c	12.75 bc	6 75 c	3.25 b
Vegetative stage protection only[c]	1	1.92 ab	5 a	0	1.0 ab	2.00 a	2.00 a	23.00 a	13.75 ab	12.75 a
Booting stage protection[d]	1	1.84 a	5 a	0	1.0 ab	0.00 a	2 25 a	19.00 ab	15.25 a	14.50 a
Economic threshold level[e]	1	2.33 a	6 a	0	1.0 ab	1 50 a	2.00 ab	19.50 ab	16 75 a	17.00 a
Integrated pest management[f]	1	2.60 a	5 a	0	1.2 a	1.00 a	2.50 a	20.00 ab	17 50 a	14.25 a
Untreated check	1	2.81 a	6 a	0	1.0 ab	1.25 a	0.75 abc	18.75 ab	15 50 a	19.00 a

[a]Rated at maximum infestation. Whorl maggot damage score based on 1980 Standard Evaluation System for Rice DT = days after transplanting Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Seedbed protection (0 75 kg a i monocrotophos/ha 5 and 20 days after emergence, vegetative protection (0 75 kg a i. monocrotophos/ha 5, 15, and 25 DT, reproductive stage protection (1.0 kg a i chlorpyrifos + BPMC/ha 40 and 50 DT (panicle initiation to flowering), ripening stage protection (1.5 kg a i carbaryl/ha at 65 DT) [c]Soil incorporation of carbofuran 3 G (0 5 kg a i./ha). [d]Chlorpyrifos + BPMC (1 kg a i /ha at 40 DT) [e]Based on thresholds [f]Carbofuran soil incorporated at 1 kg a.i./ha followed by applications at economic thresholds

the dry season (Table 51). Yields in the control treatments were 1.42 t/ha for IR22 and 3.2 t/ha for IR50. Gross income was highest from IPM for IR22 and from maximum protection except in the reproductive stage for IR50. Failure to protect the vegetative stage resulted in lowest net gains for both varieties, but more significantly for IR22. The benefit-cost ratio for insecticide in the wet season IPM treatments was higher than in the dry season.

IPM vs farmers' insect control practices. A dry season and a wet season study in a farmer's field in Nueva Ecija compared the profitability of IPM and of farmers' practices. Plots were adjacent and agronomic practices were identical. Only pest control methods varied.

In the IPM plots, soil incorporation of carbofuran before transplanting was followed by applications based on economic thresholds (no threshold was reached in either the dry or the wet season). The farmer applied insecticides as he would usually.

In the dry season, yields and net returns were similar for IPM and farmers (Table 52).

In the wet season, two treatments were added (Table 53). Yields and gross income again were similar for the various treatments; benefit-cost ratio was highest in the IPM treatment.

Both seasons' tests indicated that with resistant varieties and low insect populations, a low level of insecticide input by the farmers is equally as profitable as the IPM treatment.

Selective toxicity of insecticides. Tests of commercially available selective insecticides were made to determine those that can be used in an IPM program. Toxicity of insecticides to BPH, GLH, and WBPH in relation to that to their predators *C. lividipennis* and *L. pseudoannulata* was determined by topical application. Insecticides varied greatly in relative toxicity to the various pests (Table 54).

Seventeen insecticides were tested for their toxicity to three predators of the BPH (Table 55). Perthane and the growth regulator NNI 750 were relatively nontoxic. Some insecticides, such as FMC 35001, were toxic to all three predators; others, such as methyl parathion, were toxic to *M. atrolineata* and *C. lividipennis* but not to the spider *L. pseudoannulata*. In general, the spider had low mortality.

Moderate resistance to BPH and chemical control. To integrate chemical control and varietal

Table 47. **Economics of various levels of rice insect control when different growth stages of IR50 are protected. Farmer's field, integrated pest control pilot project, Nueva Ecija, Philippines, 1980 wet season.**

Treatment	Yield[a] (t/ha)	Gross income[b] ($)	Cost of insecticide[c]	Labor[d] ($)	Net gain[e]	Benefit-cost ratio for insecticide[f]
Maximum protection[g]	5 86 a	1113	152	25	936	0.82
Maximum protection except in seedbed	5 87 a	1115	149	24	942	0.88
Maximum protection except at vegetative stage	4 96 bc	942	72	13	857	0.79
Maximum protection except at reproductive stage	5.49 ab	1043	98	17	928	1 20
Maximum protection except at ripening stage	5.22 bc	992	138	21	833	0 27
Vegetative protection[h]	4.99 bc	948	17	2	929	7.32
Integrated pest management[i]	5.04 bc	958	17	2	939	7 84
Control	4.16 d	790	—	—	790	—

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level One ton is equivalent to 1000 kg Weight adjusted to 14% of moisture content. Price of palay: $0.19/kg Yield area was 25 m²; plot size, 10 × 10 m. [b]Gross income = yield × $0.19 per kilogram. [c]Seedbed = $3 21 (400 ml monocrotophos 30 EC sprayed 5 and 20 days after seeding [DS]), vegetative stage (10 liters monocrotophos 30 EC costing $80.33 sprayed 5, 15, and 25 days after transplanting [DT]), reproductive stage = $54.55 (6.4 liters chlorpyrifos + BPMC 31.5 EC sprayed 40 and 50 DT); ripening stage = $14.12 (1.76 kg carbaryl 85 WP sprayed 65 DT). Cost of insecticides = monocrotophos 30 EC at $8 03/liter; chlorpyrifos + BPMC 31.6 EC at $8 45/liter; carbaryl 85 WP at $8.00/kg. [d]Seedbed: $0.64; vegetative stage: $12; reproductive stage: $8; ripening stage: $4; cost of labor: $2/day. [e]Net gain = gross income – (cost of insecticides + labor). [f](Net gain for treatment – net gain for untreated control) ÷ (cost of insecticides + labor). [g]Sprayed at 5 and 20 days after seeding and at 5, 15, 25, 40, 50, 65 DT. [h]Soil incorporation of carbofuran 3 G at 0.5 kg a.i./ha [i]Carbofuran soil incorporated at 0.5 kg a.i./ha followed by applications at economic thresholds.

Table 48. Whorl maggot and green leafhopper populations[a] in plots of IR22[b] and IR44[c] receiving insecticide applications at various growth stages.[d] Victoria, Laguna, Philippines, 1980 dry season

Treatment	Whorl maggot damage[e]				Green leafhopper (no /10 sweeps)							
	16 DT		30 DT		20 DT		27 DT		34 DT		41 DT	
	IR22	IR44	IR22	IR44	IR22	IR44	IR22	IR44	IR22	IR44	IR22	IR44
Maximum protection[f]	2 4 c	1 8 b	2.9 b	2 7 bc	3 3 a	4.3 a	2.3 a	4 5 a	20 5 a	6 5 a	15 0 a	4 8 a
Maximum protection except in seedbed	2 1 c	1 5 b	3 1 b	2 1 c	2.3 a	2 0 a	3 5 a	1 8 a	8.3 bc	7 8 a	8 5 a	9 0 a
Maximum protection except at vegetative stage	3 7 b	4 2 a	5 4 a	5 0 a	3 8 a	3 5 a	3 0 a	2 8 a	20.0 a	11 0 a	19 5 a	12.0 a
Maximum protection except at reproductive stage	2.2 c	1 9 b	3 1 b	2 9 b	3 0 a	5 3 a	2 8 a	4.3 a	14 8 abc	6 8 a	8.3 a	8.8 a
Maximum protection except at ripening stage	2 2 c	1 7 b	2.9 b	2 7 bc	3 8 a	3 8 a	2 8 a	2 0 a	18 5 ab	4.8 a	18 5 a	5 0 a
Integrated pest management[g]	0 7 d	0.2 c	0 8 c	0 6 d	4.5 a	4.3 a	3 0 a	3.3 a	6 8 c	5 8 a	9.3 a	6 5 a
Control	4 6 a	3 5 a	5 2 a	4 8 a	4 5 a	3.3 a	2 8 a	1 8 a	19.3 a	6 0 a	11.5 a	10 5 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Susceptible to whorl maggot, green leafhopper, brown planthopper, and tungro virus [c]Susceptible to whorl maggot and moderately susceptible to green leafhopper, resistant to brown planthopper, and tungro virus [d]DT = days after transplanting [e]Score based on 1980 Standard Evaluation System for Rice [f]Seedbed protection = 0 75 kg a i monocrotophos spray/ha 5 days before transplanting; vegetative stage protection = 0 75 kg a i monocrotophos spray/ha 5 DT and 1 kg a i diazinon granules/ha 20 and 35 DT; reproductive stage protection = 0 75 kg a i. chlorpyrifos + BPMC spray/ha at 55 and 75 DT, and ripening stage protection = 0 75 kg a i carbaryl spray/ha at the soft dough stage [g]Integrated pest management = soil incorporation of 0 5 kg carbofuran/ha prior to transplanting, followed by applications based on economic thresholds Leafhopper threshold was reached and 0 75 kg a i BPMC/ha was sprayed once on both IR22 and IR44

Table 49. Brown planthopper population, stem borer damage, and tungro virus[a] in plots of IR22 and IR44 (insect and virus resistant) receiving insecticide applications at various growth stages. Victoria, Laguna, Philippines, 1980 dry season.

Treatment	Brown planthopper (no./hill)				Stem borer					
	30 DT		57 DT		Deadheart damage (%) 45 DT		Whitehead damage (%) 97 DT		Tungro virus (%) 97 DT	
	IR22	IR44	IR22	IR44	IR22	IR44	IR22	IR44	IR22	IR44
Maximum protection[b]	1 ab	0 a	0 c	0 a	0 b	0 b	0 a	2 a	32 a	0 a
Maximum protection except in seedbed	1 ab	0 a	0 c	0 a	0 b	0 b	0 a	4 a	17 ab	0 a
Maximum protection except at vegetative stage	1 ab	0 a	0 c	0 a	1 a	1 a	0 a	3 a	40 a	0 a
Maximum protection except at reproductive stage	1 a	0 a	1 a	0 a	1 ab	0 b	0 a	3 a	17 ab	0 a
Maximum protection except at ripening stage	1 ab	0 a	0 c	0 a	0 b	0 b	0 a	3 a	15 ab	0 a
Integrated pest management[c]	1 b	0 a	1 ab	0 a	1 ab	0 b	0 a	2 a	1 b	0 a
Control	2 ab	1 a	1 b	0 a	1 ab	2 a	0 a	3 a	19 ab	0 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level Identical number may be followed by different letters because of rounding. [b]Seedbed protection = 0.75 kg a.i. monocrotophos spray/ha 5 days before transplanting; vegetative stage protection = 0 75 kg a.i. monocrotophos spray/ha 5 days after transplanting (DT) and 1 kg a.i. diazinon granules/ha 20 and 35 DT; reproductive stage protection = 0.75 kg a.i. chlorpyrifos + BPMC spray/ha at 55 and 75 DT; and ripening stage protection = 0.75 kg a i. carbaryl spray/ha at the soft dough stage. [c]Integrated pest management = soil incorporation of 0.5 kg carbofuran/ha prior to transplanting, followed by applications based on economic thresholds. Leafhopper threshold was reached and 0.75 kg a.i BPMC/ha was sprayed once on both IR22 and IR44.

Table 50. Yields and economics of rice insect control in 2 rice varieties with calendar-based insecticide application or integrated pest management. Victoria, Laguna, Philippines, 1980 dry season.

Treatment	Yield[a] (t/ha)	Yield gain or loss[b] (t/ha)	Gross income[c] ($)	Cost of insecticide application[d] ($)	Net gain[e]	Gain from insecticide[f]	Benefit-cost ratio[g]
			IR22[i]				
Maximum protection[h]	3.83 b	−1.02	728	171	557	−108	−0 6
Maximum protection except in seedbed	4 21 ab	−0 64	800	169	631	− 34	−0 2
Maximum protection except at vegetative stage	3 83 b	−1 02	728	53	675	10	0.2
Maximum protection except at reproductive stage	3 71 b	−1.14	705	151	554	−111	0.7
Maximum protection except at ripening stage	4 14 b	−0 71	787	163	624	− 41	0.3
Integrated pest management	4.85 a	—	922	28	894	229	8.2
Control	3.50 b	−1.35	665	0	665	—	—
			IR44[j]				
Maximum protection[h]	4.91 a**	0.24	933	171	762	− 55	−0.3
Maximum protection except in seedbed	4 77 a	0.10	906	169	737	− 80	−0.5
Maximum protection except at vegetative stage	4.66 a*	−0 01	885	53	832	15	0.3
Maximum protection except at reproductive stage	4.67 a**	0.00	887	151	736	− 81	−0.5

CONTINUED ON NEXT PAGE

Maximum protection except at ripening stage	5 01 a**	0.34	952	163	789	– 28	0.2
Integrated pest management	4 67 a	—	887	28	859	42	1.5
Control	4 30 a*	–0 37	817	0	817	—	—

[a]Separation of means for each variety by Duncan's multiple range test at the 5% level [b]Yield in treatment indicated – yield in integrated pest management treatment. [c]Yield at 14% moisture × $0.19 per kilogram [d]Cost of insecticide + labor ($2 20/ha per application); cost of seedbed protection = $2.40; vegetative stage protection = $50 40; reproductive stage protection = $20.40; ripening stage protection = $8.60; integrated pest management = $28 23. [e]Gross income – cost of insecticide. [f]Net gain from treatment – net gain from control. [g]Gain from insecticide – cost of insecticide application. [h]Seedbed protection (0.75 kg a.i. monocrotophos spray/ha 5 days before transplanting, vegetative stage protection (0.75 kg. a.i. monocrotophos spray/ha 5 days after transplanting (DT) and 1 kg a i diazinon granules/ha 20 and 35 DT, reproductive stage protection (0 75 kg a i chlorpyrifos + BPMC spray/ha 55 and 75 DT), ripening stage protection (0.75 kg a i. carbaryl spray/ha at soft dough stage). [i]Susceptible to insects and virus diseases. [j]Resistant to brown planthopper and tungro virus and moderately susceptible to green leafhopper Asterisks denote significantly higher yield than the same treatment in IR22 at the 5% (*) and 1% (**) level.

Table 51. Yields and economics of rice insect control in 2 rice varieties with calendar-based insecticide applications or integrated pest management. Victoria, Laguna, Philippines, 1980 wet season

Treatment	Yield[a] (t/ha)	Yield gain or loss[b] (t/ha)	Gross income[c]	Cost of insecticide application[d]	Net gain[e]	Gain from insec- ticide[f]	Benefit- cost ratio[g]
			IR22[i]				
Maximum protection[h]	3 43 a	–0 49	652	82	570	300	3.7
Maximum protection except in seedbed	3.85 a	–0 07	732	79	653	383	4.9
Maximum protection except at vegetative stage	1 53 b	–2 39	291	58	233	–37	–0 6
Maximum protection except at reproductive stage	3.63 a	–0 29	690	61	629	359	5.9
Maximum protection except at ripening stage	3 69 a	–0.23	701	73	628	358	4 9
Integrated pest management[k]	3 92 a	—	745	28	717	447	16 0
Control	1.42 b	–2.50	270	0	270	—	—
			IR50[j]				
Maximum protection[h]	4.12 a	0.08	783	82	701	93	1.1
Maximum protection except in seedbed	4.21 a	0.17	800	79	721	113	1.4
Maximum protection except at vegetative stage	3 23 b	–0 81	614	58	556	–52	–0.9
Maximum protection except at reproductive stage	4 28 a	0 24	813	61	752	144	2 4
Maximum protection except at ripening stage	4 00 a	–0.04	760	73	687	79	1.1
Integrated pest management[k]	4 04[l] a	—	768	16	752	144	9 0
Control	3.20 b	–0 84	608	0	608	—	—

[a]Separation of means in a column for each variety by Duncan's multiple range test at the 5% level. [b]Yield in treatment indicated – yield in integrated pest management treatment [c]Yield at 14% moisture × $0 19 per kilogram. [d]Cost of insecticide + labor ($2.20/ha per application); cost of seedbed protection = $2.40, vegetative stage protection = $118.33; reproductive stage protection = $35 73, ripening stage protection = $15 00, integrated pest management = $28.23 for IR22 and $16 03 for IR50 [e]Gross income – cost of insecticide application. [f]Net gain from treatment – net gain from control [g]Gain from insecticide – cost of insecticide application [h]Seedbed protection = 0 75 kg a i. monocrotophos spray/ha in the seedbed 5 days before transplanting; vegetative stage protection = 1 kg a i. monocrotophos spray/ha at 5, 15, and 25 days after transplanting (DT) and 1 kg a.i chlorpyrifos + BPMC spray/ha 35 DT; reproductive stage protection = 1 kg a i. chlorpyrifos + BPMC spray/ha 45 DT for IR50 and 50 DT for IR22 and 0.75 kg a i. BPMC spray/ha for IR50 at 55 DT and at 65 DT for IR22; ripening stage protection = 1.5 kg a.i carbaryl spray/ha at the soft dough stage [i]Susceptible to hoppers and tungro virus [j]Resistant to hoppers and tungro virus [k]IPM = 0 5 kg a.i carbofuran/ha soil incorporated before transplanting followed by applications based on economic thresholds The green leafhopper population surpassed the threshold of 5 hoppers/10 sweeps in IR22 at 35 DT and BPMC at 0.75 kg a i /ha was sprayed 39 DT. [l]Av of 3 replications only.

Table 52. Comparison of integrated pest management (IPM) and farmer's practices to control insects on insect- and disease-resistant varieties.[a] Integrated pest control project, Nueva Ecija, Philippines, 1980 dry season

Treatment[b]	Yield[c] (t/ha)	Gross income[d] ($/ha)	Insecticide applications: Number Av	Range	Cost[e] ($/ha)	Net returns[f] ($/ha)
IPM[g]	5.19 ± 0.18	986	1	1	21	965
Farmer's practices	5.21 ± 0.23	990	2.9	1-6	28	962

[a]IR36 and IR42. [b]Both treatments were in adjacent paddies owned by the same farmer. All agronomic practices were identical, except for pest control. Treatments were replicated over 15 farms. [c]Weight adjusted to 14% moisture content, value after "±" is the standard error of the mean. [d]Gross income = yield × $0.19 per kilogram. [e]Insecticide costs and labor for application ($2.00/day) were based on local prices in Nueva Ecija, Aug-Nov 1980. [f]Net returns = gross income − cost of insecticide application. [g]Soil incorporation of carbofuran 3 G (0.56 kg a.i./ha) before transplanting, followed by applications based on economic thresholds. No threshold was reached.

Table 54. Relative toxicity of some insecticides to brown planthopper (BPH), green leafhopper (GLH), and whitebacked planthopper (WBPH) and their predators. IRRI laboratory, 1980.

Insecticide	Relative toxicity[a]: *Cyrtorhinus lividipennis* BPH	*Cyrtorhinus lividipennis* GLH	*Cyrtorhinus lividipennis* WBPH	*Lycosa pseudoannulata* BPH	*Lycosa pseudoannulata* GLH	*Lycosa pseudoannulata* WBPH
Acephate	4.10	4.60	7.26	7.35	8.24	13.01
Bendiocarb	1.05	1.44	0.82	2.78	3.81	2.19
Gamma-BHC	3.76	0.75	3.56	1.29	0.26	1.22
BPMC	1.70	0.78	1.39	11.01	5.06	9.04
Carbaryl	0.34	0.52	0.48	4.79	7.15	6.67
Carbofuran	1.09	1.40	1.84	1.75	2.26	2.97
Decamethrin	0.36	9.25	1.23	0.07	1.75	0.23
Diazinon	1.44	1.10	3.44	2.32	1.78	5.56
Chlorpyrifos	0.92	0.55	2.56	0.87	0.52	2.43
Endosulfan	12.36	6.43	62.79	0.94	0.49	4.79
FMC 35001	2.03	4.07	1.65	1.41	2.82	1.14
Methyl parathion	1.13	0.84	3.77	4.77	3.53	15.90
MIPC	1.86	1.88	1.56	8.39	8.51	7.05
Monocrotophos	0.95	1.28	2.24	29.24	39.33	69.12
MTMC	2.04	2.70	2.15	5.80	7.66	6.11
Perthane	21.14	3.16	7.50	65.45	9.80	23.22
Phosphamidon	0.90	0.71	2.00	23.55	18.75	52.67
Triazophos	0.24	0.38	4.33	6.41	10.09	114.33
UC 54229	4.05	3.71	4.05	4.13	3.79	4.13
Propoxur	1.32	0.75	0.49	35.43	20.24	13.05

[a]Based on LD_{50} values (μg/g). LD_{50} of predator ÷ LD_{50} of hopper. A selective toxicity value >1 indicates greater toxicity to the hopper.

resistance, laboratory and insectary studies compared the susceptibility to insecticides of BPH and WBPH reared on susceptible (S) and moderately resistant (MR) rice varieties.

In the BPH studies, insecticides were applied topically, in the Potter's spray tower, and as foliar spray to biotype 2 BPH reared on ASD7 (MR) and on IR26 (S). Insects reared on ASD7 had a lower LD_{50} value and thus were more susceptible to carbofuran, acephate, and Perthane than those reared on IR26 (Table 56). The LD_{50} value in the acephate treatment was six times higher in the insects reared on IR26 than in those on ASD7. Similar results were obtained in the Potter's spray tower and the foliar spray tests where mortality of BPH reared on ASD7 was higher at the three insecticide rates.

WBPH were treated topically and in the Potter's spray tower. Of the three insecticides applied topically, carbofuran was more toxic to the insects reared on N22 (MR) than on TN1 (S) and 95% limits overlapped for acephate and Perthane, indi-

Table 53. Comparison of integrated pest management (IPM) and farmers' practices to control insects on insect- and disease-resistant varieties.[a] Integrated pest control project, Nueva Ecija, Philippines, 1980 wet season

Treatment[a]	Yield[b]	Gross income[c] (US$/ha)	Insecticide applications: Number Av	Range	Rate/application (kg a.i./ha)	Cost ($/ha)	Net returns[d] ($/ha)	Benefit-cost ratio[e]
IPM	4.45 ± 0.40	842	1.0	1	0.50	19	823	2.0
Farmer's practice	4.32 ± 0.32	821	2.1	1-3	0.55	21	800	0.7
Control	4.21 ± 0.35	785	0	—	—	—	785	—
Other farmers' practice	3.79 ± 0.25	722	2.0	1-4	0.40	23	699	—

[a]The plots for IPM, farmer's practices, and control were adjacent and received the same agronomic practices, except for pest control. Pest control in the IPM plot was conducted by an IRRI researcher. Carbofuran was soil incorporated before transplanting, followed by applications based on economic thresholds. However, no threshold was reached. The farmer used his insect pest control techniques without advice from the IRRI researcher. Other farmers refer to farmers in the IPC project area but not adjacent to the other treatments. [b]Weight adjusted to 14% moisture content. For IPM, farmer's practices, and control, data are average of 11 replications, each is based on 25-m² crop-cuts. For other farmers' practice, data are from interview of 15 farmers. Values after "±" are standard errors of the means. [c]Gross income = yield × $0.19 per kilogram. [d]Net returns = gross income — cost of insecticide application. [e]Benefit-cost ratio = (net returns for treatment — net returns for control) ÷ cost of insecticide.

Table 55. Contact toxicity of insecticides to 3 predators of the brown planthopper when sprayed with insecticide in a Potter's spray tower. IRRI insectary, 1980.

Insecticide[a]	Mortality[b] (%)											
	Lycosa pseudoannulata				*Microvelia atrolineata*				*Cyrtorhinus lividipennis*			
	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT
FMC 35001 20 EC	63 a	90 a	97 a	97 a	23 bc	35 cd	65 bc	83 ab	58 bc	65 bc	73 bc	100 a
Carbofuran 12 F	53 ab	90 a	90 ab	90 ab	20 bcd	23 def	48 cd	50 cde	78 ab	80 ab	85 ab	100 a
UC 54229 100 Tech	40 ab	70 b	77 bc	77 bc	3 cd	3 fg	3 f	20 ef	75 abc	80 ab	85 ab	100 a
BHC 26 WP	37 ab	53 bc	57 cd	57 cd	20 bcd	20 defg	48 cd	68 bcd	8 gh	20 g	25 g	43 e
UC 27867 50 WP	30 b	50 bc	53 cd	53 cd	0 d	0 g	33 cde	43 cde	55 bcd	58 bcd	58 cde	100 a
Decamethrin 2.5 EC	30 b	33 c	33 de	37 de	83 a	88 a	90 a	95 a	33 de	35 defg	40 efg	65 cd
UCSF-1 48 F	10 c	33 c	37 de	37 de	0 d	0 g	15 ef	20 ef	60 bc	63 bc	70 bc	100 a
MIPC 50 WP	7 c	7 d	7 fg	7 fg	0 d	5 efg	35 cde	45 cde	58 bc	58 bcd	65 cd	98 a
Carbaryl 85 WP	3 c	13 d	13 fg	13 fg	10 bcd	13 defg	48 cd	65 bcd	13 fg	25 fg	35 efg	43 e
Perthane 45 EC	3 c	3 d	3 fg	3 fg	0 d	0 g	13 ef	23 ef	15 fg	23 efg	32 fg	50 de
Methyl parathion 50 EC	3 c	3 d	3 fg	3 fg	30 b	58 bc	85 ab	85 ab	53 cd	58 bcd	58 cde	95 ab
Azinphos ethyl 40 EC	0 c	47 bc	60 cd	63 cd	0 d	0 g	10 ef	33 de	8 gh	50 cd	68 c	100 a
Chlorpyrifos 40 EC	0 c	3 d	17 ef	17 ef	20 bcd	28 de	40 cd	68 bcd	25 ef	40 cdef	43 defg	63 de
Propoxur 20 EC	0 c	7 d	7 fg	7 fg	78 a	78 ab	83 ab	83 ab	88 a	90 a	95 a	100 a
Diazinon 20 EC	0 c	0 d	0 g	3 fg	0 d	8 efg	33 cde	70 bc	13 fg	45 cde	50 cdef	85 bc
Acephate 30 EC	0 c	0 d	0 g	3 fg	5 cd	5 efg	18 def	23 ef	8 gh	23 efg	65 cd	100 a
NNI 750 25 WP	0 c	0 d	0 g	0 g	0 d	3 fg	8 ef	23 ef	0 h	0 h	5 h	15 f
Control	0 c	0 d	0 g	0 g	0 d	0 g	5 f	5 f	0 h	0 h	0 h	3 g

[a]Applied at the rate of 0.75 kg a.i./ha, except for decamethrin (0 0125 kg a.i./ha). [b]Separation of means in a column by Duncan's multiple range test at the 5% level. HT = hours after insecticide treatment.

Table 56. Response to topically applied insecticides of brown planthopper reared on susceptible IR26 and moderately resistant ASD7. IRRI laboratory, 1980.

Insecticide	IR26		ASD7	
	LD_{50}(μg/g)	95% limits	LD_{50}(μg/g)	95% limits
Carbofuran	0.46	0.32-0.67	0.17	0.13--0.22
Acephate	6.82	3.49-13.34	1.07	0.73-1.58
Perthane	4.63	3.33-6.46	1.12	0.86-1.45

Table 57. LD_{50} of insecticides applied topically to the whitebacked planthopper reared on susceptible TN1 and moderately resistant N22 rice varieties. IRRI laboratory, 1980.

Insecticide	TN1		N22	
	LD_{50}(μg/g)	95% limits	LD_{50}(μg/g)	95% limits
Carbofuran	0.46	0.36-0.55	0.24	0.18-0.29
Acephate	1.15	0.26-3.62	0.44	0.25-0.68
Perthane	9.42	4.75-31.41	2.77	1.68-4.98

cating similar susceptibility of the two groups of insects (Table 57). The Potter's spray tower test (Table 58) indicated that the susceptibility of insects reared on the S and MR varieties did not significantly differ when sprayed with acephate.

Biological control and insecticides. Insecticidal toxicity to beneficial parasites must be considered when planning an IPM program. Earlier field observations indicated that egg parasitization was not affected by some insecticides (1979 annual report). Observations in a farmer's field in 1980 did not reveal any adverse effects of methyl parathion on *Anagrus* parasitization. In a greenhouse study where decamethrin was sprayed on plants either before or after the introduction of the egg parasite *Anagrus flaveolus,* neither parasitization of BPH eggs nor parasite emergence decreased, compared with the water-sprayed control. But mortality of *Anagrus* adults 24 hour after treatment increased a significant but small amount — from 10% (in the control) to 25% — because of insecticide application. In the experiment, the small decrease in parasite density did not affect egg parasitization.

Preliminary observations in farmers' fields near IRRI indicated that parasitization of nymph and adult hoppers by dryinids, strepsipterans, and pipunculids did not decrease as a result of the insecticide treatments. This is a positive contribution to combining natural biological control and insecticides in IPM.

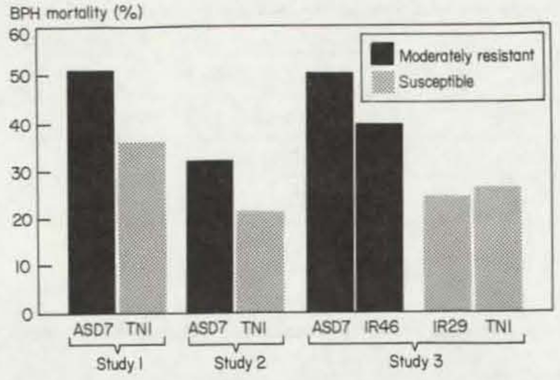
Removing *Microvelia* from a closed system significantly and dramatically increased the BPH population, doubling it in the second generation.

In a dry season experiment where methyl parathion was sprayed regularly, *Cyrtorhinus* and *Microvelia* were significantly fewer in sprayed plots, and spider densities were not affected. As a consequence, BPH eggs in sprayed plots were much less preyed upon by *Cyrtorhinus* than those in unsprayed ones. Methyl parathion also killed *Microvelia* in this trial. But because the reduced predation by these two species did not result in

Table 58. Contact toxicity of insecticides applied with a Potter's spray tower against the whitebacked planthopper reared on susceptible TN1 and moderately resistant N22 rice varieties. IRRI insectary, 1980.

Insecticide	Rate (kg a.i./ha)	HT[a]	Mortality[b] (%)	
			TN1	N22
Carbofuran 12 F	0.25	1	41.3 a	46.8 a
		4	62.5 a	53.2 a
		24	67.5 a	94.7 b
		48	83.6 a	96.0 b
Acephate 75 SP	0.75	1	0.0 a	1.3 a
		4	7.5 a	17.7 a
		24	96.1 a	98.7 a
		48	98.6 a	100.0 a
Perthane 45 EC	0.75	1	0.0 a	0.0 a
		4	0.0 a	10.1 b
		24	18.2 a	44.7 b
		48	39.7 a	85.3 b

[a]Hours after insecticide treatment. [b]Av of 4 replications. Adjusted using Abbott's formula. Separation of means in a row by Duncan's multiple range test at the 5% level.



20. Brown planthopper (BPH) mortality due to predation by the spider *L. pseudoannulata* when feeding on moderately resistant and susceptible rice varieties. IRRI greenhouse, 1980.

improved BPH survival, the BPH resurgence that occurred could not be clearly related to predator kill.

Varietal resistance to brown planthopper and biological control. Three studies determined whether efficiency of spiders feeding on BPH increased when the BPH feed on a MR variety. BPH mortality due to spider feeding was greater on a MR than on a S variety (Fig. 20). The study indicated that the use of MR varieties can be integrated with naturally occurring biological control.

Effect of whorl maggot and artificial defoliation on yield components. Six tests with whorl maggot were conducted. In the first test, insect-caused defoliation was simulated by removing 16-100% of

Table 59. Tiller number, plant height, and yield loss of 2 rice varieties in field tests as affected by the extent of leaf removal.[a] IRRI, 1980 dry season.

Leaf area removed[b] (%)	Tiller no. at 45 DT with various cutting dates			Plant ht (cm) 45 DT with various cutting dates			Yield (t/ha) with various cutting dates		
	10 & 20 DT	15 & 25 DT	20 & 30 DT	10 & 20 DT	15 & 25 DT	20 & 30 DT	10 & 20 DT	15 & 25 DT	20 & 30 DT
					IR40				
0	20 a	21 a	23 a	58 a	57 a	63 a	5.0 a	5.1 a	5.4 a
16	18 a	19 a	19 b	54 bc	55 ab	56 b	5.3 a	5.5 a	5.0 a
33	18 a	19 a	21 ab	55 ab	52 bc	54 bc	4.9 a	5.1 a	5.1 a
50	19 a	19 a	20 b	52 bc	52 bc	51 cd	5.1 a	5.0 a	5.3 a
65	17 ab	18 a	19 b	50 cd	50 c	48 de	5.1 a	5.3 a	5.5 a
75	16 ab	18 a	17 bc	47 d	45 d	45 e	5.0 a	5.0 a	4.8 a
100	14 b	12 b	15 c	41 e	41 d	39 f	4.9 a	4.7 a	4.7 a
					IR36				
0	25 a	23 a	22 a	55 a	56 a	59 a	4.2 b	4.0 b	4.9 a
16	23 a	23 a	22 a	52 a	52 ab	52 b	4.0 b	4.3 ab	4.7 a
33	22 ab	23 a	20 ab	53 a	53 a	50 bc	5.1 a	4.5 ab	4.7 a
50	20 bc	21 ab	20 ab	47 b	49 b	48 bc	4.7 ab	4.9 a	4.9 a
65	19 bc	22 ab	21 a	45 b	47 bc	46 cd	4.5 ab	4.6 ab	4.7 a
75	18 c	19 b	17 bc	45 b	43 cd	42 d	4.4 ab	4.2 ab	5.2 a
100	14 d	15 c	16 c	39 c	39 d	36 e	4.6 ab	3.9 b	4.4 a

[a]Av of 4 replications. Separation of means in a column under each variety by Duncan's multiple range test at the 5% level. DT = days after transplanting. [b]Damage was simulated by leaf removal from the tip of the leaves down to the leaf sheaths.

Table 60. Yield components of 2 rice varieties[a] as affected by leaf removal[b] and artificial infestation with whorl maggot flies[c] in field tests. IRRI, 1980 dry season.

Treatment	Damage rating[d]	Tiller no.		Plant ht (cm)		Panicle length (cm)	Unfilled grains (%)	Yield (g/m²)
		45 DT	AH[e]	45 DT	AH[e]			
				IR40				
Without whorl maggot	0	20 ab	15 a	55 a	100 a	23 a	9 a	473 a
With whorl maggot	9	21 ab	16 a	46 b	97 a	23 a	10 a	503 a
50% leaf removal	9	22 a	15 a	52 a	97 a	23 a	14 a	510 a
100% leaf removal	9	19 b	16 a	47 b	96 a	23 a	9 a	485 a
				IR36				
Without whorl maggot	0	23 a	13 a	55 a	94 a	23 a	13 a	543 a
With whorl maggot	9	23 a	15 a	44 c	91 ab	21 b	12 a	563 a
50% leaf removal	9	22 a	15 a	49 b	91 ab	22 a	14 a	553 a
100% leaf removal	9	20 a	15 a	42 c	88 b	21 b	10 a	508 a

[a]Av of 4 replications. Separation of means in a column and under each variety by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. [b]Leaf removal from the tip of the leaves down to the leaf sheaths at 25 days after transplanting (DT). [c]Infested with 800 adult flies/49 hills 6 DT. [d]Scored by the 1980 Standard Evaluation System for Rice (SES). [e]At harvest.

the leaf area of IR40 (MR) and IR36 (S) with scissors at 10 and 20, 15 and 25, and 20 and 30 DT (Table 59). Although tiller number and plant height at 45 DT were decreased by leaf removal, plants recovered and yields were not affected.

In the second test, 50 and 100% leaf removal and artificial infestation of plants with whorl maggot flies were compared (Table 60). None of the treatments affected yield components. In a similar screenhouse test in the dry season (Table 61), 100% leaf removal significantly reduced yields of both IR40 and IR36. Whorl maggot did not affect yield. Similar results were obtained in a wet season field test in which IR40 and IR36 were infested with whorl maggot flies (Table 62).

In a wet season field test, 100-800 whorl maggot flies/40 hills were set on IR40 and IR36 at 5 DT (Table 63). Despite severe whorl maggot damage, IR36 had significantly more tillers than the control at harvest, indicating that the whorl maggot damage stimulated tillering. Yields were equal in all treatments.

Two tests using IR36 were made to determine if time of whorl maggot infestation would affect extent of yield loss (Table 64). In test 1, tiller number at harvest was higher in the treatments infested with whorl maggot. Whorl maggot reduced plant height in both tests, but damage did not cause yield losses.

It is apparent that whorl maggot reduces plant height and delays maturity about 2 weeks. However, the damage sometimes stimulates tillering and yield is not decreased. It is possible, however, that damage from a combination of whorl maggot and other early season insects, such as stem borers and caseworms, could cause yield losses.

Plant injury by brown planthoppers. Blockage of carbohydrate transfer as a possible mechanism of plant damage was studied by feeding radioactive carbon dioxide to leaves of seedlings. Labeled pho-

Table 61. Yield components of 2 rice varieties[a] as affected by leaf removal[b] and artificial infestation with whorl maggot flies[c] in the screenhouse. IRRI, 1980 dry season.

Treatment	Damage rating[d]	Tiller no.		Plant ht (cm)		Panicle length (cm)	Unfilled grains (%)	Yield (g/m²)
		45 DT	AH[e]	45 DT	AH[e]			
			IR40					
Without whorl maggot	0	11 a	11 ab	79 a	103 a	23 a	6 a	410 ab
With whorl maggot	9	12 a	13 a	74 ab	98 ab	23 ab	6 a	450 a
50% leaf removal	9	9 a	11 ab	71 b	93 bc	22 b	6 a	293 bc
100% leaf removal	9	6 b	10 b	55 c	91 c	22 ab	5 a	260 c
			IR36					
Without whorl maggot	0	11 a	12 a	85 a	104 a	22 a	9 a	513 a
With whorl maggot	9	11 a	12 a	77 a	97 a	22 a	8 a	510 a
50% leaf removal	9	8 a	10 a	73 a	89 ab	22 a	7 a	390 ab
100% leaf removal	9	6 a	10 a	53 b	78 b	22 a	7 a	305 b

[a]Av of 3 replications. Separation of means in a column and under each variety by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. [b]Leaf removal from the tip of the leaves down to the leaf sheaths at 20 and 30 days after transplanting (DT). [c]Infested with 800 adult flies/49 hills 5 DT. [d]Based on 1980 Standard Evaluation System for Rice. [e]At harvest.

Table 62. Yield comparison of 2 rice varieties with and without whorl maggot infestation.[a] IRRI, 1980 wet season.

Treatment	Damage rating[b]	Tiller no.		Plant ht (cm)		Panicle length (cm)	Unfilled grains (%)	Yield (g/m²)
		20 DI	AH[c]	20 DI	AH[c]			
			IR40					
Without whorl maggot	0	12 a	10 a	56 a	121 a	26 a	10 a	415 a
With whorl maggot	9	12 a	11 a	40 b	118 a	26 a	14 a	427 a
			IR36					
Without whorl maggot	0	12 a	11 a	80 a	98 a	21 a	9 a	395 a
With whorl maggot	9	10 b	11 a	67 b	91 b	21 a	13 a	392 a

[a]Av of 5 replications. Separation of means in a column and under each variety by Duncan's multiple range test at the 5% level. DI = days after infestation. Plants were infested with 800 adult flies/49 hills in the screenhouse 5 days after transplanting. [b]Scored with the 1980 Standard Evaluation System for Rice. [c]AH = at harvest.

Table 63. Yield loss components of 2 rice varieties[a] as affected by levels of artificial infestation with whorl maggot flies. IRRI, 1980 wet season.

Treatment[b]	Damage rating[c] 20 DI	Leaves (no./hill) 20 DI	Damaged leaves (%) 20 DI	Tillers (no./hill) 20 DI	Tillers (no./hill) AH[d]	Plant ht (cm) 20 DI	Plant ht (cm) AH[d]	Panicle length (cm)	Unfilled grains (%)	Yield (g/m^2)
IR40										
Control (no flies)	1 a	43 a	1 a	12 a	12 a	52 c	118 a	25 ab	25 a	408 a
100 flies/49 hills	5 b	50 b	44 b	13 a	15 ab	43 ab	117 a	24 a	28 a	430 a
200 flies/49 hills	6 b	46 ab	46 b	13 a	17 b	44 b	117 a	25 ab	27 a	459 a
400 flies/49 hills	8 c	46 ab	60 c	13 a	14 ab	41 ab	117 a	25 b	29 a	450 a
600 flies/49 hills	9 c	47 ab	69 c	13 a	15 ab	41 ab	117 a	25 ab	29 a	438 a
800 flies/49 hills	9 c	44 ab	72 c	12 a	14 ab	40 a	116 a	25 ab	35 a	428 a
IR36										
Control (no flies)	1 a	68 a	1 a	15 a	14 a	50 b	98 b	21 ab	20 a	465 a
100 flies/49 hills	6 b	69 a	31 b	18 ab	15 b	46 ab	96 ab	21 b	24 a	463 a
200 flies/49 hills	7 bc	71 a	44 c	17 ab	18 b	41 a	92 a	21 b	22 a	518 b
400 flies/49 hills	8 cd	84 a	54 cd	19 b	18 b	40 a	91 a	21 b	21 a	503 ab
600 flies/49 hills	8 d	88 a	58 d	18 ab	19 b	41 a	92 a	21 ab	23 a	505 ab
800 flies/49 hills	9 e	88 a	65 d	18 ab	18 b	39 a	90 a	20 a	20 a	508 ab

[a]Av of 4 replications. Separation of means in a column and under each variety by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. DI = days after infestation. [b]Plants were infested with flies 5 days after transplanting. [c]Based on the 1980 Standard Evaluation for Rice (SES). [d]AH = at harvest. Visual rating based on 1980 SES.

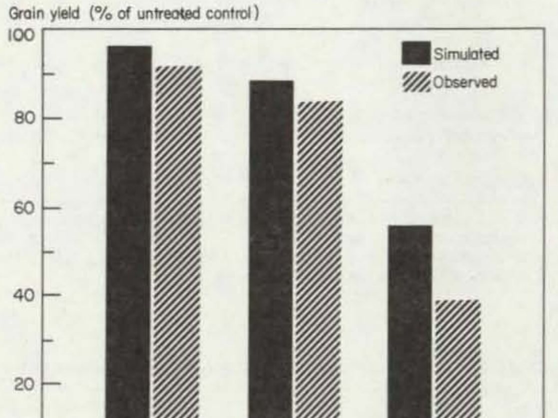
tosynthate was transferred from the treated leaves to the newest leaf in control plants. Seedlings that had previously been infested with BPH did not show evidence of labeled photosynthate transfer. Apparently hopper feeding blocked carbohydrate translocation, starving the growing leaves. The experiment suggested that blockage was restricted to the leaves on which BPH had fed.

Prediction of yield loss from BPH. Research was initiated to predict yield loss from a BPH infestation. Field estimates of yield loss from various levels of BPH infestation were made at IRRI. A simulation crop growth model using historical weather data and BPH feeding rates (as plant dry matter removed) was used to predict yield loss.

Heavy BPH feeding enhanced the rate of panicle production but slowed panicle filling (making smaller grains) and kept the crop at the vegetative stage longer. The highest BPH densities caused the greatest yield reduction, and early infestations at comparable rates reduced yield more than later infestations. The trend of lower accumulated dry matter with increased BPH feeding was clear and significant. Low solar radiation in the wet season tends to prevent crops from compensating for biomass reduction, resulting in lower yields.

To link the plant growth model to BPH plant damage, estimates of feeding rates at each life stage were made. Taking into account the daily BPH age structure, the effective total BPH feeding rate per day (in mg plant dry matter) was computed. Actual records of hopper feeding were taken from insects caged on plants in the field; both insects and excreted honeydew were weighed.

Simulated and observed percentages of yield reduction were similar in most cases (Fig. 21).



21. Comparison of simulated grain yield reductions (as a percentage of the uninfested control) resulting from brown planthopper (BPH) feeding at indicated densities at the reproductive stage (50-80 days after transplanting) with reductions observed in a field experiment using variety IR20. IRRI, 1978 wet season. Simulated yields were obtained from a computer model of plant growth.

Table 64. Reactions of IR36[a] with (WM) and without (no WM) whorl maggot flies[b] at different days after seeding and transplanting. IRRI, 1980 wet season.

Treatment[c]	Damage rating[d] (visual)			Damaged leaves (%)			Tillers/hill (no.) 20 days after infestation			Tillers/hill (no.) At harvest			Plant ht (cm 20 days after infestation			Plant ht (cm At harvest			Yield (g/m²)		
	WM	No WM	Diff.	WM	No WM	Diff	WM	No WM	Diff.	WM	No WM	Diff.	WM	No WM	Diff.	WM	No WM	Diff.	WM	No WM	Diff.
Test 1																					
35 DS	9 a	1 a	8 **	68 a	2 a	66 **	20 a	22 b	−2 ns	20 a	16 a	4 *	37 a	55 a	18 **	94 a	101 a	−7 *	465 a	478 a	−13 ns
21 DS	9 a	1 a	8 **	70 a	1 a	69 **	24 a	23 b	1 ns	20 a	17 a	3 *	40 a	58 a	−18 **	99 a	100 a	−1 ns	483 a	495 a	−12 ns
14 DS	9 a	1 a	8 **	69 a	3 a	66 **	24 a	25 a	−1 ns	20 a	16 a	4 *	39 a	57 a	−18 **	100 a	101 a	−1 ns	460 a	435 a	25 ns
Test 2																					
30 DT	4 c	2 a	2 ns	15 c	3 a	12 ns	17 b	14 a	3 ns	—	—	—	69 a	82 a	−13 **	—	—	—	—	—	—
15 DT	7 b	2 a	5 **	43 b	3 a	40 **	21 a	15 a	6 *	16 a	15 a	1 ns	61 a	69 a	−8 ns	92 a	96 a	−4 ns	355 a	345 a	10 ns
5 DT	9 a	2 a	7 **	72 a	4 a	68 **	16 b	17 a	−1 ns	17 a	14 a	3 ns	36 b	49 b	−13 **	98 a	97 a	1 ns	493 a	355 a	138 ns

[a]Av of 4 replications. Separation of means in a column and under the same test by Duncan's multiple range test at the 5% level. The dash (—) indicates no data were taken because of rat damage. [b]Plants were infested with 800 adult flies/49 hills 5 days after transplanting. [c]DS = days after seeding, DT = days after transplanting. [d]Scored with the 1980 Standard Evaluation System for Rice.

Control and management of rice pests

Weeds

Agronomy and Agricultural Engineering Departments

WEED CONTROL IN RICE FIELDS

Agronomy Department

Research to identify herbicides that would complement other methods of weed control in wetland rice continued at IRRI and at the Maligaya, Bicol, and Visayas research stations of the Philippine Bureau of Plant Industry.

Transplanted rice. Infestations of *Echinochloa crus-galli* ssp. *hispidula, Echinochloa glabrescens, Cyperus difformis,* and *Monochoria vaginalis* were common at all sites. *Scirpus maritimus* and *Paspalum paspalodes* were present at IRRI and *Cyperus imbricatus* and *Sphenoclea zeylanica* at Bicol.

All herbicide-treated plots, except those treated with naproanilide – thiobencarb and pendimethalin at IRRI and R-22523 at Bicol, yielded significantly more than the untreated check (Table 1). There was no significant yield increase at Maligaya.

In the wet season all herbicide treatments, except naproanilide – thiobencarb, piperophos – 2,4-D, and R-22523 at IRRI and chlomethoxynil – 2,4-D at Maligaya, gave significantly higher yields than the untreated control (Table 2). A few treated plots at IRRI, Bicol, and Visayas yielded significantly less than the hand-weeded check.

Direct-seeded irrigated rice. In the dry season at all sites, plots treated with molinate – simetryn –

Table 1. Effects of granular herbicides applied before weed emergence—4 days after transplanting (DT)—on rice yield of IR42 at IRRI, the Maligaya Rice Research and Training Center, and the Bicol Rice and Corn Experiment Station of the Philippine Bureau of Plant Industry, 1980 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha)		
		IRRI	Maligaya	Bicol
Hand-weeded check	—	6.3 a	4.5 a	5.8 a
Bifenox – 2,4-D EE	2.0 – 0.66	6.3 a	4.5 a	5.0 ab
Pretalachlor	0.5	6.2 a	4.3 a	5.3 ab
Chlomethoxynil — 2,4-D IPE	2.1 – 0.75	5.7 a	4.2 a	5.6 ab
Naproanilide – thiobencarb	1.0 – 0.7	5.2 ab	4.6 a	5.3 ab
Molinate – simetryn – MCPB	1.8 – 0.1 – 0.1	5.4 a	4.4 a	5.2 ab
2,4-D IPE	0.8	5.7 ab	4.6 a	4.6 ab
R-22523	1.5	5.7 a	4.2 a	4.4 bc
Pendimethalin	0.75	5.1 ab	4.2 a	4.6 ab
KCO_{23}	1.0	6.1 a	—	—
KCO_{25}	1.0	5.7 a	—	—
Untreated check		4.0 b	4.0 a	3.3 c

[a]Hand-weeded check = weeded 20 and 40 DT. A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. EE = ethyl ester. IPE = isopropyl ester. [b]Active ingredient. [c]Av of 4 replications/site. Separation of means in a column by Duncan's multiple range test at the 5% level. A dash indicates no test.

Table 2. Effects of granular herbicides applied before weed emergence—4 days after transplanting (DT)—on rice yield of IR36 at IRRI, the Maligaya Rice Research and Training Center, the Bicol Rice and Corn Experiment Station, and the Visayas Rice Experiment Station of the Philippine Bureau of Plant Industry, 1980 wet season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha)			
		IRRI	Maligaya	Visayas	Bicol
Hand-weeded check	—	4.5 a	5.3 a	6.1 a	5.1 a
Bifenox – 2,4-D EE	2.0 – 0.66	4.1 ab	5.6 a	5.7 ab	4.6 ab
Pendimethalin	0.75	3.7 ab	5.6 a	6.0 ab	4.3 ab
2,4-D IPE	0.8	4.0 ab	5.5 a	5.5 b	4.7 ab
Chlomethoxynil — 2,4-D IPE	2.1 – 0.75	4.3 ab	5.0 ab	5.7 ab	4.3 ab
Molinate – simetryn – MCPB	1.8 – 0.1 – 0.1	4.3 ab	5.2 a	5.5 ab	4.2 b
R-22523	1.5	3.5 abc	5.3 a	5.9 ab	4.5 ab
Piperophos – 2,4-D IPE	0.33 – 0.17	3.0 bc	5.3 a	5.9 ab	4.6 ab
Naproanilide – thiobencarb	1.0 – 0.7	3.2 bc	5.6 a	5.7 ab	4.0 b
KCO_{25}	1.0	4.0 ab	—	—	—
KCO_{23}	1.0	3.8 ab	—	—	—
Untreated check		2.2 c	4.6 b	4.4 c	3.0 c

[a]Hand-weeded check = weeded 20 and 40 DT. A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. EE = ethyl ester. IPE = isopropyl ester. [b]Active ingredient. [c]Av of 4 replications/site. Separation of means in a column by Duncan's multiple range test at the 5% level. A dash indicates no test.

Table 3. Effect of early postemergence (6 days after seeding) application of granular herbicides on yield of direct-seeded, flooded IR42 rice at IRRI, the Maligaya Rice Research and Training Center, and the Bicol Rice and Corn Experiment Station of the Philippine Bureau of Plant Industry, 1980 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha) IRRI	Maligaya	Bicol
Molinate – simetryn – MCPB	1.8 – 0.1 – 0.1	5.6 a	6.0 a	5.8 ab
Naproanilide – thiobencarb	1.0 – 0.7	5.9 a	2.6 de	6.2 a
Butachlor + 2,4-D IPE	0.75 + 0.5	4.9 ab	4.3 bc	3.3 cd
Thiobencarb – 2,4-D IPE	1.0 – 0.5	5.4 ab	3.2 cd	3.7 bc
R-22523	1.5	4.8 ab	5.2 ab	1.6 e
Piperophos – 2, 4-D IPE	0.33 – 0.17	5.7 a	1.6 ef	4.0 bc
Chlomethoxynil — 2,4-D IPE	2.1 – 0.75	5.3 ab	3.0 d	1.8 de
Pretalachlor	0.5	4.8 ab	0.1 g	5.0 abc
Bifenox – 2,4-D EE	2.0 – 0.66	5.7 a	1.8 ef	2.1 de
KCO_{25}	1.0	6.0 a	—	—
KCO_{23}	1.0	5.4 ab	—	—
Untreated check		3.9 b	1.1 fg	2.1 de

[a]A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. A plus (+) means the chemicals were applied separately at about the same time. IPE = isopropyl ester. EE = ethyl ester. [b]Active ingredient. [c]Av of 4 replications/site. Separation of means in a column by Duncan's multiple range test at the 5% level. A dash indicates no test.

Table 4. Effects of early postemergence (6 days after seeding) application of granular herbicides on yield of direct-seeded, flooded IR36 rice at IRRI, the Maligaya Rice Research and Training Center, the Bicol Rice and Corn Experiment Station, and the Visayas Rice Experiment Station of the Philippine Bureau of Plant Industry, 1980 wet season

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha) IRRI	Maligaya	Visayas	Bicol
Naproanilide – thiobencarb	1.0 – 0.7	2.6 abcd	4.9 a	4.8 b	5.4 a
Bifenox – 2,4-D EE	2.0 – 0.66	3.4 ab	3.4 c	4.9 b	5.5 a
Chlomethoxynil — 2,4-D IPE	2.1 – 0.75	2.8 abcd	3.9 bc	4.9 b	5.5 a
Piperophos – 2,4-D IPE	0.33 – 0.17	3.0 abc	4.8 a	4.2 d	5.1 a
Thiobencarb – 2,4-D IPE	1.0 – 0.5	3.1 abc	3.8 bc	4.6 bc	5.5 a
Butachlor + 2,4-D IPE	0.75 + 0.5	3.2 abc	3.4 c	4.0 d	5.6 a
Pendimethalin	0.75	2.5 abcd	4.5 ab	5.7 a	3.3 b
Molinate – simetryn – MCPB	1.8 – 0.1 – 0.1	2.1 bcd	3.5 c	5.4 a	4.9 a
R-22523	1.5	1.9 cd	2.0 d	4.2 cd	5.1 a
KCO_{25}	1.0	3.6 a	—	—	—
KCO_{23}	1.0	3.2 abc	—	—	—
Untreated check		1.6 d	2.3 d	4.3 cd	3.9 b

[a]A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. EE = ethyl ester. IPE = isopropyl ester. A plus (+) means the chemicals were applied separately at about the same time. [b]Active ingredient. [c]Av of 4 replications/site. Separation of means in a column by Duncan's multiple range test at the 5% level. A dash indicates no test

MCPB and naproanilide–thiobencarb gave significantly higher yields than the untreated control (Table 3). Plots treated with butachlor + 2,4-D and thiobencarb – 2,4-D at Maligaya and Bicol, and those treated with piperophos – 2,4-D at IRRI and Bicol yielded significantly more than the untreated plots.

During the wet season, yields of plots treated with bifenox – 2,4-D were significantly higher than those of the untreated plots at all sites (Table 4). But several treated plots at IRRI and Bicol had yields not greatly different from the yield in the untreated plot. Except those treated with R-22523 at Maligaya and pendimethalin at Visayas, all herbicide-treated plots at both sites yielded significantly more than the untreated check.

Dryland rice. Herbicides trials in dryland rice continued in a farmer's field in Batangas during the 1980 wet season. Seven herbicides were applied at preemergence with and without a propanil follow-up treatment. The rates of the herbicides were reduced when these were applied as combinations. Propanil was applied at the 3- to 5-leaf stage of the weeds. The principal weed species were *Digitaria sanguinalis, Dactyloctenium aegyptium, Echinochloa colona, Commelina benghalensis, Celosia*

Table 5. Effects of liquid herbicides on weed control, crop tolerance, and yield of IR52 rice grown in dryland conditions in a farmer's field in Batangas Province, Philippines, 1980 wet season.

Treatment[a]	Application[b] Rate (kg a.i./ha)	Application[b] Time	Weed wt[c] (g/m²)	Toxicity rating[d]	Yield[c] (t/ha)
Oxadiazon fb propanil	0.75 fb 2 0	PE fb 12 DE	171 bc	4	4.0 a
Butralin fb propanil	1.5 fb 2 0	PE fb 12 DE	323 cd	4	3.5 ab
Dinitramine fb propanil	1 0 fb 2 0	PE fb 12 DE	205 bc	4	3 2 abc
Dinitramine	1.5	PE	111 b	8	2 9 abcd
Butachlor fb propanil	1.5 fb 2.0	PE fb 12 DE	312 cd	4	2.8 abcd
Oxyfluorfen fb propanil	0 35 fb 2.0	PE fb 12 DE	315 cd	6	2.8 abcd
Thiobencarb fb propanil	2 0 fb 2 0	PE fb 12 DE	227 bcd	4	2 8 abcd
Butachlor	2.0	PE	290 cd	4	2.5 bcde
Oxadiazon	1.0	PE	287 cd	4	2.4 bcde
Two hand weedings		12 fb 38 DE	10 a	0	2 4 bcde
Pendimethalin fb propanil	1 0 fb 2.0	PE fb 12 DE	256 cd	4	2 3 bcde
One hand weeding		28 DE	245 bcd	0	2 2 cde
Thiobencarb	3.0	PE	185 bc	4	1.9 de
Pendimethalin	1 5	PE	295 cd	6	1 6 de
Oxyfluorfen	0.5	PE	420 d	6	1 4 e
Propanil	3 0	12 DE	454 d	3[e]	0.0 f
Untreated check			493 d	0	0.0 f

[a]fb = followed by. [b]a.i. = active ingredient. PE = preemergence. DE = days after emergence. [c]Av of 3 replications Separation of means in a column by Duncan's multiple range test at the 5% level. [d]Rated 5 DE on a scale of 0-10 where 0 = no toxicity and 10 = complete kill. [e]Rated 1 week after propanil application

argentea; Ipomoea triloba, and *Cyperus iria.*

Weed infestation was so heavy that no yield was obtained from the untreated plot (Table 5). All herbicide treatments, except propanil alone, gave significantly high yields. Propanil as a sole treatment failed to control the weeds. Propanil follow-up after preemergence herbicide treatments slightly increased yields over those treated with preemergence herbicides alone. The oxadiazon – propanil combination gave the only yield that was significantly higher than that from the hand-weeded checks. The crop suffered injury from all preemergence herbicides but recovered completely.

HERBICIDE SCREENING

Agronomy Department

Herbicide screening in transplanted and wet-seeded (direct-seeded) rice in irrigated and rainfed fields continued during the 1980 wet season. The important weeds common in all these cultures were *E. glabrescens, E. crus-galli* ssp. *hispidula, M. vaginalis, S. maritimus, C. difformis,* and *C. iria.*

Irrigated transplanted rice. Among the herbicide formulations tested, 2,4-D, perfluidone – bifenox, HOE 30374, perfluidone – molinate, tiocarbazil – 2,4-D BE, and SN 80870 looked promising for irrigated transplanted rice (Table 6). They controlled weeds adequately and showed excellent selectivity to rice when applied before emergence of weeds. Yields of these treatments were significantly higher than the yield of the untreated control and comparable with those of the hand-weeded and the standard chemical (thiobencarb - 2,4-D) checks.

Rainfed transplanted rice. Perfluidone – bifenox, oxyfluorfen, and bifenox as preemergence treatments and perfluidone – molinate as an early postemergence (1- to 2-leaf stage of the weeds) treatment showed promise for rainfed transplanted rice (Table 6). Yields of plots treated with those herbicides were markedly higher than the yield of the untreated check.

Irrigated wet-seeded rice. All herbicide treatments provided generally good weed control of the grasses and gave yields 2-4 times those of the untreated check (Table 7). Yields of plots treated with perfluidone – molinate, tiocarbazil – 2,4-D, and bifenox were significantly higher than the yield of the untreated plot. Bifenox applied at 10 days after seeding was moderately effective against *S. maritimus,* which was the dominant sedge. Tiocarbazil – 2,4-D, oxyfluorfen, and MC 10108 were slightly toxic to rice. Yields were generally low because the crop lodged at grain-filling.

Rainfed wet-seeded rice. All herbicide treatments were completely safe to the crop and gave yields significantly higher than the yield of the untreated control (Table 7). Tiocarbazil – 2,4-D

Table 6 **Effect of herbicides on weed control, crop tolerance, and yield of transplanted IR42 rice in irrigated and rainfed fields IRRI, 1980 wet season.**

Treatment[a]	Application[b]		Weed wt[c] (g/m²)			Visual toxicity rating[d]	Yield[c] (t/ha)
	Rate (kg a.i./ha)	Time	Broadleaf weeds	Grasses	Sedges		
Irrigated transplanted rice							
2, 4-D BE WP	0.5	3 DT	0 a	0 a	65 b	0	5 6 a
Hand-weeded check	Twice	15 & 30 DT	8 ab	12 ab	7 a	0	5 4 a
Perfluidone – bifenox G	0 3 – 2.7	3 DT	0 a	0 a	77 b	0	5.4 a
HOE 30374 EC	0.6	3 DT	1 a	0 a	171 b	0	5 1 a
Perfluidone – molinate G	1 1 – 2.75	3 DT	1 a	0 a	72 b	2	5.1 a
Tiocarbazil – 2,4-D IBE G	1 5 – 0.5	3 DT	0 a	2 ab	114 b	0	5 0 a
SN 80870 EC	0.5	PP	34 b	92 b	83 b	0	4.9 ab
Thiobencarb – 2, 4-D IPE G	1 0 – 0 5	3 DT	10 b	20 ab	96 b	0	3 9 ab
Untreated check			47 b	15 ab	76 b	0	2.8 b
Rainfed transplanted rice							
Perfluidone – molinate G	1 1 – 2.75	8 DT	4 a	0 a	57 bc	0	5.8 a
Perfluidone – bifenox G	0.3 – 2 7	3 DT	0 a	7 a	12 ab	0	5.7 a
Oxyfluorfen G	0.15	3 DT	0 a	0 a	30 bc	0	5 6 a
Bifenox F	2.0	3 DT	0 a	3 a	50 bc	0	5 5 a
Hand-weeded check	Twice	15 & 30 DT	6 a	2 a	6 a	0	5.6 a
Thiobencarb – 2,4-D IPE G	1 0 – 0 5	3 DT	0 a	0 a	107 c	0	4 3 ab
Untreated check			8 a	33 a	70 bc	0	3 5 b

[a]A spaced dash (–) means 2 herbicides were formulated on the same carrier and applied as a single treatment. BE = butyl ester. IBE = isobutyl ester. IPE = isopropyl ester. [b]a.i. = active ingredient DT = days after transplanting. PP = preplant application [c]Av of 2 replications Separation of means in a column under each planting condition by Duncan's multiple range test at the 5% level. [d]Rated 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

Table 7. **Effect of herbicides on weed control, crop tolerance, and yield of wet-seeded IR42 rice grown under irrigated and rainfed conditions. IRRI, 1980 wet season.**

Treatment[a]	Application[b]		Weed wt[c] (g/m²)			Visual toxicity rating[d]	Yield[c]
	Rate (kg a i /ha)	Time (DS)	Broadleaf weeds	Grasses	Sedges		
Irrigated wet-seeded rice							
Perfluidone – molinate G	0 55 – 1.38	6	2 a	6 a	44 b	0	2 6 a
Tiocarbazil – 2,4-D IBE G	1 5 – 0 5	6	0 a	6 a	32 b	2	2 3 a
Bifenox F	2.0	10	2 a	7 a	4 a	0	2.3 a
Bifenox F	2.0	6	3 a	6 a	37 b	0	2.2 a
Perfluidone – bifenox G	0 15 – 1.35	6	5 a	15 a	35 b	0	2.0 ab
Oxyfluorfen G	0.1	6	2 a	16 a	56 b	2	1.9 ab
Thiobencarb – 2,4-D IPE G	1.0 – 0 5	6	0 a	3 a	56 b	0	1 9 ab
MC 10108 EC	0.25	10	6 a	39 a	8 ab	3	1 8 ab
Untreated check			8 a	57 a	26 ab	0	0.6 b
Rainfed wet-seeded rice							
Tiocarbazil – 2,4-D IPE G	0 75 – 0.5	6	2 a	20 bc	5 abc	0	4.0 a
Perfluidone – molinate G	0 55 – 1.38	10	16 ab	7 ab	7 abc	0	3.7 a
Perfluidone – bifenox G	0.15 – 1.35	10	4 ab	21 bc	5 abc	0	3.7 a
Oxyfluorfen G	0.10	10	19 ab	14 bc	12 abc	0	3.6 a
SN 81259 EC	1.5	6	5 ab	1 a	10 bc	0	3.6 a
Thiobencarb – 2,4-D IPE G	1.0 – 0 5	10	5 ab	2 ab	2 ab	0	3 4 a
Bifenox F	2.0	6	9 ab	0 a	1 a	0	3.3 a
SN 80870 EC	1.0	10	4 ab	28 c	15 c	0	3 2 a
Oxyfluorfen G	0 15	6	20 b	6 abc	7 abc	0	3.1 a
R-56575	2.0	10	8 ab	34 c	21 c	0	3.1 a
Untreated check	—	—	24 ab	18 bc	8 abc	0	1 6 b

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. IBE = isobutyl ester. IPE = isopropyl ester. [b]a.i. = active ingredient DS = days after seeding. [c]Av of 3 replications Separation of means in a column under each planting condition by Duncan's multiple range test at the 5% level [d]Rated 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity, and 10 = complete kill.

Table 8. Effects of new preemergence herbicides on weed control, crop tolerance, and yield of IR43 rice grown under dryland conditions. IRRI, 1980 wet season.

Treatment	Application[a]		Weed wt[b] (g/m²)			Visual toxicity rating[c]	Yield[b] (t/ha)
	Rate (kg a.i./ha)	Time	Broadleaf weeds	Grasses	Sedges		
Hand-weeded check	—	15 & 30 DE	2 a	16 ab	3 ab	0	3 4 a
RH 8254	2.0	PE	3 ab	15 a	27 c	8	2.9 a
RH 8254	1 0	PE	1 a	10 a	17 bc	2	1 6 bc
MC 10108	0 75	PE	21 abc	56 bc	9 abc	6	1 4 bc
Butachlor check	2 0	PE	31 bc	377 cd	1 a	0	0.5 cd
Untreated check	—	—	68 c	452 d	1 a	0	0 d

[a]a.i. = active ingredient. DE = days after emergence. PE = preemergence [b]Av of 3 replications Separation of means in a column by Duncan's multiple range test at the 5% level. [c]Rated at 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

controlled the broadleaf weeds almost completely.

Dryland rice. During the 1980 wet season, field tests to identify new herbicides for dryland rice continued at IRRI. The major weeds were *Rottboellia exaltata, Eleusine indica, Cleome rutidosperma, Cyperus rotundus,* and *Calopogonium mucunoides.*

Among new liquid herbicides tested, RH 8254 and MC 10108 provided reasonable control of *R. exaltata,* which fast became the dominant weed (Table 8). The rice plants totally recovered from severe stunting caused by RH 8254 applied at 2.0 kg/ha. The standard herbicide check, butachlor, failed to control *R. exaltata.*

EFFECT OF BUTACHLOR FORMULATIONS ON WEED CONTROL

Agronomy Department

During the 1980 wet season, different butachlor formulations were compared for weed control and selectivity in transplanted and wet-seeded IR36 rice in irrigated plots. The major weeds common to both cultures were *E. glabrescens, M. vaginalis, C. difformis,* and *S. maritimus.*

Transplanted rice. Significant reduction in weed stand in transplanted rice was obtained with butachlor, regardless of the formulation used. However, the treated plots did not yield significantly more than the untreated because the crop lodged (Table 9).

Wet-seeded rice. Among the formulations tested, flowable butachlor – 2,4-D IBE provided best weed control and gave significantly higher yields than the untreated control (Table 10). All formulations, together with thiobencarb – 2,4-D, were slightly to severely toxic to wet-seeded rice, but the crop recovered quickly. Yields were low because the crop lodged.

MANAGEMENT AND CONTROL OF *SCIRPUS MARITIMUS*

Agronomy Department

A field experiment that began in the 1974 dry season continued in 1980. During the dry season, the rotary-weeded and herbicide-treated transplanted rice plots yielded significantly more than the untreated control (Table 11). A yield of 2.3 t/ha from plots that were rotary-weeded twice was not significantly different from the 1.9 t/ha yield from plots treated with bentazon. The untreated check

Table 9. Effect of different formulations of butachlor applied before weed emergence — 3 days after transplanting (DT) — on weed control and yield of irrigated transplanted IR36 rice IRRI, 1980 wet season

Treatment[a]	Rate (kg a.i.[b]/ha)	Weed wt[c] (g/m²)	Yield[c] (t/ha)
Hand-weeded check	—	11 ab	3 2 a
Butachlor G	1 0	39 c	3 1 a
Butachlor EC	1 0	29 abc	2.7 a
Butachlor F	1.0	44 c	2.6 a
Thiobencarb – 2,4-D IPE G	1.0 – 0.5	41 cd	2 6 a
Butachlor – 2,4-D IBE F	0.75 – 0 62	36 bc	2.4 a
Butachlor G + 2,4-D IPE G	0 75 + 0 5	11 a	2.3 a
Untreated check	—	116 d	2.0 a

[a]Hand-weeded check = weeded 15 and 30 DT. A spaced dash (–) means 2 herbicides were formulated on the same carrier and applied as a single treatment. IPE = isopropyl ester. IBE = isobutyl ester A plus (+) means the chemicals were applied separately at about the same time. [b]Active ingredient [c]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 10. Effect of early postemergence (8 days after seeding) application of butachlor formulations on weed control, crop tolerance, and yield of wet-seeded IR36 rice grown under irrigated conditions. IRRI, 1980 wet season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Weed wt[c] (g/m²)	Visual toxicity rating[d]	Yield[c] (t/ha)
Butachlor – 2, 4-D IBE F	0.75 – 0 62	29 a	8	1.6 a
Butachlor EC	1.0	68 ab	4	1.4 ab
Butachlor G + 2, 4-D IPE G	0.75 + 0 5	92 b	6	1.0 ab
Thiobencarb – 2, 4-D IPE G	1 0 – 0 5	112 b	4	1 0 ab
Butachlor G	1 0	117 b	2	0 9 ab
Butachlor F	1.0	106 b	3	0.8 b
Untreated check	—	136 b	0	0.8 b

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. A plus (+) means that the chemicals were applied separately at about the same time IBE = isobutyl ester; IPE = isopropyl ester [b]Active ingredient. [c]Av of 3 replications Separation of means in a column by Duncan's multiple range test at the 5% level [d]Rated 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill

Table 11. Effects of weeding methods and cropping patterns on crop yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1980 dry season.

Cropping pattern and weeding treatment[a]	Yield per ha[b]		Weeds (no /m²)				
			Grasses	Broadleaf weeds	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous transplanted rice:	Rice (t)						
Rotary weeding	2.3 a		10	4	12	14	0
Bentazon (2 kg a i /ha)	1.9 a		300	1	57	16	0
No weeding	0.0 b		227	12	172	288	0
Dryland crops — transplanted rice	Maize + (ears)	Soybean (kg)					
Hand weeding	49,500 a	474 a	19	2	6	6	4
Butachlor (2 kg a i./ha) fb bentazon (1 kg a.i./ha)	27,000 a	238 b	156	3	0	1	2
No weeding	22,000 a	88 b	298	55	170	3	5
Dryland crop — dry-seeded, rainfed-bunded rice	Maize (ears)						
Butachlor (2 kg a i /ha) fb bentazon (1 kg a.i./ha)	47,000 a		63	9	24	17	36
Hand weeding	41,000 a		24	2	10	7	6
No weeding	33,000 a		499	60	65	6	29

[a]a.i. = active ingredient fb = followed by. [b]Av of 2 replications. Separation of means within each cropping pattern by Duncan's multiple range test at the 5% level

gave no yield because the population of annual weeds and *S. maritimus* was high.

In the maize + soybean intercrop, the yield of maize did not vary significantly among weed control treatments. Yields were best, however, in the hand-weeded plots.

Where maize was planted alone during the dry season, the yield differences between treatments were not significant (Table 11). Heavy infestation of grasses in the untreated plots did not substantially affect maize yield.

In the continuous transplanted rice pattern during the wet season, yields of the bentazon-treated and rotary-weeded plots were significantly higher than the yield of the untreated plot (Table 12). High density of *S. maritimus* and annual sedges resulted in no yield from the untreated check.

Shifting cropping patterns from continuous transplanted rice to dryland crop — transplanted rice reduced the stand of *S. maritimus* in the untreated plot by more than 50% (Table 12). But because of the high incidence of grasses and annual sedges, the yield in the untreated plot was significantly less than in the rotary-weeded plots.

In the pattern dry-seeded, rainfed bunded rice following maize, all the treated plots yielded significantly more than the untreated plots (Table 12). High infestation of annual weeds resulted in no

Table 12. Effects of weeding method and cropping pattern on rice yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1980 wet season.

Cropping pattern and weeding treatment[a]	Yield[b] (t/ha)	Weeds (no./m²)				
		Grasses	Broadleaf weeds	Sedges	*Scirpus maritimus*	*Cyperus rotundus*
Continuous transplanted rice						
Bentazon (2 kg a.i./ha)	3.0 a	225	0	18	16	0
Rotary weeding	2.9 a	67	3	19	28	0
No weeding	0.0 b	166	6	387	360	0
Dryland crops — transplanted rice						
Rotary weeding	3.2 a	112	8	72	14	0
Bentazon (2 kg a.i./ha)	1.9 ab	352	0	150	5	0
No weeding	0.9 b	375	18	261	154	0
Dryland crop — dry-seeded, rainfed-bunded rice						
Hand weeding	2.8 a	6	0	32	4	23
Butachlor (2 kg a.i./ha)	1.6 b	259	62	2	4	40
No weeding	0.0 c	572	196	214	4	7

[a]a.i. = active ingredient [b]Av of 2 replications. Separation of means within each cropping pattern by Duncan's multiple range test at the 5% level.

yield in the untreated control. Some growth of *C. rotundus* occurred because of poor accumulation of water in the plot.

Control of *S. maritimus* with tillage and herbicide. The effect of time of reharrowing and herbicide treatments on the control of *S. maritimus* was studied during the dry season. Plowing and first harrowing were followed by a final harrowing at 3 different times — 5 days, 10 days, and 15 days after the first harrowing. Plowing and first harrowing were adjusted so that transplanting was done on the same day. 2,4-D at 0.5 and 1.0 kg/ha was applied on each tillage treatment before and after weed emergence. Besides *S. maritimus*, *E. glabrescens*, *E. crus-galli* ssp. *hispidula*, and *M. vaginalis* were also present.

Degree of *S. maritimus* control varied significantly with time of 2,4-D application, regardless of when reharrowing was done (Table 13). Control of the weed was not affected by varying reharrowing schedule. Plots treated with a follow-up of 2,4-D after weed emergence (26 DT) generally had significantly less growth of *S. maritimus* and gave higher yields than those treated with 2,4-D before weed emergence (4 DT) and the untreated checks (Table 13). As a sole postemergence treatment, 2,4-D controlled *S. maritimus* adequately, but it did not control the grassy weeds. On the other hand, as a

Table 13. Effects of time of reharrowing and 2,4-D treatments on *Scirpus maritimus* control and yield of transplanted IR50 rice. IRRI, 1980 dry season.

Herbicide treatment[a]	Application[b]		Weed wt[c] (g/m²) at given reharrowing time[d]				Yield[c] (t/ha) at given reharrowing time[d]			
	Rate (kg a.i./ha)	Time (DT)	5 d	10 d	15 d	Mean	5 d	10 d	15 d	Mean
Hand-weeded check	—	20 fb 35	1	1	2	1 a	4.6	4.5	4.8	4.6 a
Butachlor fb 2,4-D	1.0 fb 0.5	4 fb 26	40	63	91	65 de	4.4	4.2	4.2	4.3 ab
Butachlor fb 2,4-D	1.0 fb 1.0	4 fb 26	8	9	17	12 b	4.5	4.2	3.7	4.1 ab
2,4-D fb 2,4-D	1.0 fb 0.5	4 fb 26	22	97	12	44 bc	4.7	3.4	4.0	4.0 abc
2,4-D fb 2,4-D	0.5 fb 1.0	4 fb 26	18	29	26	24 bc	3.3	3.8	4.4	3.8 bcd
2,4-D fb 2,4-D	0.5 fb 0.5	4 fb 26	67	74	64	68 de	3.8	3.4	4.2	3.8 bcd
2,4-D	1.0	26	26	82	40	49 cd	3.1	3.7	3.9	3.6 bcde
2,4-D	1.0	4	58	131	132	107 ef	3.6	3.0	3.2	3.3 cdef
Butachlor	1.0	4	140	198	222	187 f	3.7	2.9	3.1	3.2 cdef
2,4-D	0.5	26	91	90	59	80 de	2.9	3.3	3.2	3.1 def
2,4-D	0.5	4	173	170	129	157 ef	3.2	3.0	2.6	2.9 ef
Untreated check	—	—	262	177	149	196 f	2.3	2.6	2.6	2.5 f
Mean			75	93	79		3.7	3.5	3.7	

[a]fb = followed by. [b]a.i. = active ingredient, DT = days after transplanting. [c]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [d]After the first harrowing.

Table 14. Effects of 2, 4-D applied at various growth stages of *Scirpus maritimus* on its control and on yield of transplanted IR36 rice. IRRI, 1980 dry season.

Growth stage treatment[a]	*S. maritimus* dry wt[b] (g/m²)		Yield[b] (t/ha)
	Maximum tillering	Crop maturity	
Hand-weeded check	21 a	10 a	5.5 a
6-leaf stage	86 b	160 bc	3.9 b
8-leaf stage	138 cd	127 b	3.8 bc
10-leaf stage	166 d	157 bc	3.6 bc
4-leaf stage	104 bc	202 bcd	3.5 bc
2-leaf stage	90 b	206 bcd	3.4 bc
Shoot emergence	100 b	237 cd	3.4 bc
Untreated check	173 d	312 d	2.7 c

[a]Butachlor was applied at preemergence to control annual weeds. [b]Av of 3 replications, 2 formulations, and 2 rates of 2,4-D. Separation of means in a column by Duncan's multiple range test at the 5% level.

sole preemergence treatment, 2,4-D controlled the grasses effectively but did not control *S. maritimus.*

Control of *S. maritimus* at different growth stages with 2,4-D. To identify the growth stages that are susceptible to 2,4-D, dimethylamine salt and isopropyl ester formulations were applied at 0.5 and 1.0 kg/ha to *S. maritimus* at 6 growth stages. Annual weeds were controlled with butachlor.

2,4-D provided adequate initial control of *S. maritimus* at all stages, irrespective of the formulation and the rate used. However, degree of control later varied slightly with time of application of the herbicide (Table 14). Application at the 6-leaf stage apparently provided longer weed control duration and gave yields significantly higher than the yield of the untreated check. Applications earlier than at the 6-leaf stage led to a heavy regrowth of the weed, which went on unchecked by lack of rice crop canopy. Applications made later than at the 6-crop stage provided sustained control of *S. maritimus* until crop maturity.

LONG-TERM EFFECTS OF REDUCED TILLAGE

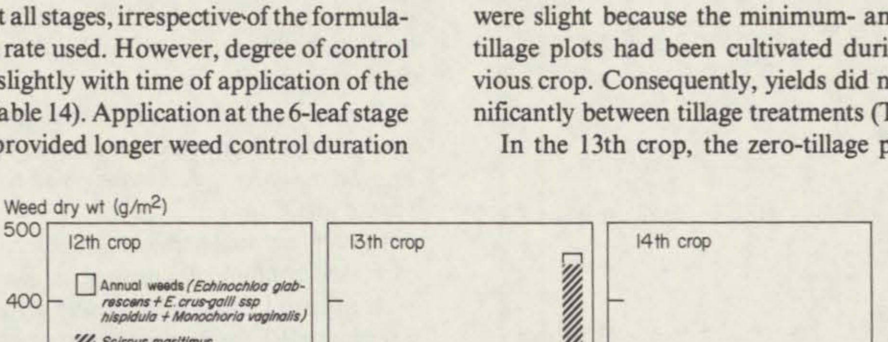
Agronomy Department

The study of the effects of reduced tillage on weed shift and population density in transplanted rice continued on the 12th to the 14th crops. IR34, IR40, and IR42 were planted in plots prepared by conventional tillage, minimum tillage, and zero tillage. Conventional tillage was one plowing and two harrowings, minimum tillage was one harrowing, and for zero tillage, weed stubbles of the previous crop were cut and paraquat was applied.

Annual weeds consisted of *E. glabrescens, E. crus-galli* ssp. *hispidula,* and *M. vaginalis*; the perennials were *P. paspalodes* and *S. maritimus.* Butachlor was applied to control annual weeds.

In the 12th crop, incidence of the perennial weeds increased as tillage was reduced from conventional to zero (Fig. 1). However, weed increases were slight because the minimum- and the zero-tillage plots had been cultivated during the previous crop. Consequently, yields did not vary significantly between tillage treatments (Table 15).

In the 13th crop, the zero-tillage plots had a



1. Weed dry weights at harvest of the 12th, 13th, and 14th crops as indices of weed control by conventional tillage (CT), minimum tillage (MT), and zero tillage (ZT). IRRI, 1980 crop season .

Table 15. Effects of tillage treatments on weed control and yield of the 12th, 13th, and 14th crops. IRRI, 1980 dry and wet seasons.

Treatment	IR34				IR40				IR42			
	Weed wt[a] (g/m²)				Weed wt[a] (g/m²)				Weed wt[a] (g/m²)			
	Annual	Perennial	Total	Yield[b] (t/ha)	Annual	Perennial	Total	Yield[b] (t/ha)	Annual	Perennial	Total	Yield[b] (t/ha)
12th crop, 1980 dry season												
Conventional tillage	15	26	41	5.6 a	0	14	14	4.9 a	3	84	91	4.0 a
Minimum tillage	7	64	72	5.2 a	3	20	23	5.0 a	3	76	78	3.8 a
Zero tillage	25	71	96	5.5 a	20	37	57	5.0 a	5	110	114	3.8 a
13th crop, 1980 wet season												
Conventional tillage	1	1	2	3.5 a	1	59	60	1.8 a	5	70	75	3.9 a
Minimal tillage	0	18	18	3.2 a	3	80	83	1.8 a	2	64	66	3.4 a
Zero tillage	3	149	152	2.4 a	30	254	284	0.0 b	14	446	460	0.0 b
14th crop, 1980 late wet season												
Conventional tillage	0	18	18	2.1 a	6	31	37	2.4 a	1	39	40	2.7 a
Minimum tillage	8	24	32	1.8 a	2	37	39	2.3 a	1	36	37	2.5 a
Zero tillage	15	223	238	1.2 b	21	184	205	0.4 b	10	244	254	0.4 b

[a]Taken 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 4 replications. Separation of means in a column within a crop by Duncan's multiple range test at the 5% level.

heavy buildup of perennial weeds, which varied significantly with variety (Fig. 1). No-tillage plots planted to the medium-statured IR34 had the lowest weed population, mainly of *S. maritimus.* Plots planted to semidwarf IR40 and IR42 had moderate to severe infestation of *P. paspalodes* and *S. maritimus* and gave zero yield (Table 15). Degree of total weed population and grain yield between the conventional- and minimum-tillage plots did not differ significantly, regardless of variety.

In the 14th crop, a marked increase in *P. paspalodes* occurred in the zero-tillage plots of IR34, which was similar in magnitude to those of IR40 and IR42 (Fig. 1). As a result, yields of the zero-tillage plots were significantly less than those of the cultivated plots, regardless of variety (Table 15). The results suggest that in areas heavily infested with *P. paspalodes,* the use of intermediate-statured varieties as a control measure may not be feasible for more than two successive crops on zero tillage.

DRY-SEEDED WETLAND RICE

Agronomy and Agricultural Engineering Departments

Herbicides *(Agronomy).* In general, a single application of a preemergence herbicide has not given sustained weed control in dry-seeded wetland rice. In 1980, combinations of herbicides at different times were tested.

The major weeds in a 1979 trial and in the preemergence and postemergence trials in 1980 were *Eriochloa procera, E. glabrescens, E. colona, E. indica,* and *C. iria.*

In 1979, residual herbicides (butachlor, thiobencarb, and pendimethalin) were tank-mixed either with propanil or oxadiazon and applied at preemergence (PE) or 7 days after emergence (DE). A sequential application of 2,4-D 20 DE after the application of the residual herbicides was also tested (Table 16).

Among the herbicide combinations tested, significant reductions in weed weight were observed only in plots with a sequential application of a residual herbicide and 2,4-D, and in the thiobencarb + oxadiazon-treated plot. The weed weights obtained from the rest of the herbicide combinations were reduced but were not significantly different from that of the untreated check.

Table 16. Effect of herbicide combinations on weed weight and yield of dry-seeded wetland rice.[a] IRRI, 1979 wet season.

Treatment[b]	Herbicide rate[c] (kg a.i./ha)	Time of application[d]	Weed wt 40 DE (g/0.5 m²)	Grain yield (t/ha)
Thiobencarb + propanil	2.5 + 1.25	7 DE	21.6 bc	2.4 a
Weeding 3 times	—	—	2.1 a	2.2 ab
Butachlor fb 2,4-D	2.0 fb 0.5	PE fb 20 DE	3.4 a	2.0 ab
Butachlor + oxadiazon	1.5 + 0.25	PE	23.2 bc	2.0 ab
Pendimethalin fb 2,4-D	2.0 fb 0.5	PE fb 20 DE	14.1 ab	1.9 ab
Pendimethalin + oxadiazon	1.5 + 0.25	PE	17.8 bc	1.8 ab
Thiobencarb fb 2,4-D	3.0 fb 0.5	PE fb 20 DE	7.6 ab	1.6 ab
Thiobencarb + oxadiazon	2.0 + 0.25	PE	12.7 ab	1.6 ab
Pendimethalin + propanil	1.5 + 1.5	7 DE	17.2 bc	1.6 ab
Butachlor + propanil	1.5 + 1.5	7 DE	16.7 bc	1.4 ab
Propanil	3.0	15 DE	29.1 bc	1.1 bc
No weeding	—	—	85.1 c	0.0 c

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]fb = followed by; + means that the herbicides were tank-mixed and applied at the same time. [c]a.i. = active ingredient. [d]DE = days after emergence, PE = preemergence.

The plot treated with thiobencarb + propanil yielded the highest. The yield was not significantly higher than that of the plots treated with the other herbicide combinations or the weeded check, but it was significantly higher than that of the plot treated with propanil alone. The yields from all plots treated with herbicide combinations were superior to the yield of the unweeded check.

In 1980, contrary to the results obtained in 1979, the combinations of either thiobencarb or butachlor with oxadiazon failed to control the weeds adequately (Table 17). Although the weed weights obtained from these treatments were significantly lower than those in the unweeded plot, the grain yield was significantly lower than that from the weeded plots.

When propanil was applied alone or in combination with thiobencarb, butachlor, pendimethalin, or oxadiazon applied 8 DE, excellent weed control was obtained (Table 18). Except for the oxadiazon + propanil treatment which was toxic to the rice, yields from these plots were not different from the yield of the hand-weeded check. Butachlor applied

Table 17. Effect of herbicide combinations applied preemergence on weed weight and yield of dry-seeded wetland rice.[a] IRRI, 1980 wet season.

Treatment[b]	Herbicide rate[c] (kg a.i./ha)	Weed wt (g/0.5 m²) 40 DE[d]	Grain yield (t/ha)
Oxadiazon fb 1 hand weeding	0.75	5.9 ab	3.9 a
Pendimethalin + oxadiazon	1.5 + 0.25	14.0 abc	3.9 a
Butachlor fb 1 hand weeding	2.0	7.8 ab	3.4 a
Weeding 3 times	—	5.9 a	3.4 a
Pendimethalin fb 1 hand weeding	2.0	3.4 a	3.2 a
Thiobencarb fb 1 hand weeding	3.0	35.8 bc	3.1 a
Thiobencarb + oxadiazon	2.0 + 0.25	37.0 cd	1.5 b
Butachlor	2.0	115.7 de	0.7 bc
Butachlor + oxadiazon	1.5 + 0.25	39.6 cd	0.3 c
No weeding	—	171.6 e	0.0 c

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]fb = followed by; + means that the herbicides were tank-mixed and applied at the same time. [c]a.i. = active ingredient. [d]DE = days after emergence.

Table 18. Effect of postemergence herbicide combinations on weed weight and yield of dry-seeded wetland rice.[a] IRRI, 1980 wet season

Treatment[b]	Herbicide rate[c] (kg a.i./ha)	Weed wt (g/0.5 m²) 40 DE[d]	Grain yield (t/ha)
Propanil	3.0	5.2 a	3.6 a
Thiobencarb + propanil	2.5 + 1.25	7.1 a	3.6 a
Weeding 3 times	—	5.5 a	3.2 a
Butachlor + propanil	1.5 + 1.5	13.9 a	3.2 a
Propanil	2.0	17.4 a	3.2 a
Pendimethalin + propanil	1.5 + 1.5	9.1 a	2.7 ab
Butachlor fb 1 hand weeding	2.0	7.5 a	2.6 ab
Oxadiazon + propanil	0.5 + 1.5	10.3 a	2.0 bc
Butachlor[e]	2.0	89.3 b	1.1 cd
No weeding	—	362.3 c	0.3 d

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]fb = followed by; + means that the herbicides were tank-mixed and applied at the same time. [c]a.i. = active ingredient. [d]DE = days after emergence. [e]Applied at preemergence.

Table 19 Effect of various treatments on weeding time, weed weight, and yield of dryland IR50 rice.[a] IRRI, 1980 wet season.

Treatment[b]	Time of application[c] (DE)	Weeding time (h/ha)	Weed wt (g/m²) 56 DE	Yield (t/ha)
Weed free	as necessary	3692	25.7 a	2.4 a
Manual weeding	14 fb 35	1965	25.9 a	1.8 b
Rolling weeder	14 fb 35	19	155.5 bc	1.5 bcd
Manual weeding	14	1100	211.3 bc	1.4 bcd
Herbicide[d]	7	4	208.1 bc	1.4 bcd
Herbicide[d] fb rolling weeder	7 fb 35	14	125.4 bc	1.3 bcd
Rolling weeder + hand weeding in rows	14 fb 35	450	93.7 b	1.1 cdef
Rolling weeder + hand weeding in rows	14	329	254.1 c	0.8 def
No weeding	—	—	250.1 c	0.6 ef
Rolling weeder	14	9	294.3 c	0.6 f

[a]Av of 3 replications Separation of means in a column by Duncan's multiple range test at the 5% level. [b]fb = followed by; + means treatments were applied separately at about the same time. [c]DE = days after emergence. [d]Butachlor + propanil at 1.5 + 1.5 kg a i /ha, 7 DE

alone performed poorly. But when it was followed by a hand weeding, the yield obtained was not significantly different from that of the weeded check.

In another trial where the important weed species were *C. rotundus, E. colona, C. mucunoides,* and *E. indica,* sequential applications of residual herbicides applied at PE or propanil applied 8 DE and 2,4-D applied 15 DE were compared with butachlor applied at PE and hand-weeded and unweeded checks. The best weed control was achieved with thiobencarb fb 2,4-D. Yields from plots that received sequential herbicide applications were not significantly different from each other or from yield of the hand-weeded check.

Butachlor applied alone failed to give adequate weed control, and yields from that treatment were not significantly better than those from the unweeded check.

Interrow cultivation *(Agronomy and Agricultural Engineering).* A preliminary trial in conjunction with the Agricultural Engineering Department studied the efficiency of a prototype of a weeder, called the rolling weeder, for interrow cultivation in dryland rice. The major weeds were *C. rotundus, E. colona, E. indica, Portulaca oleracea,* and *R. exaltata.*

The hours of labor per hectare required when the rolling weeder was used were less than 1% that required for manual weeding with a scythe (Table 19). Removal of within-row weeds by hand to reduce intrarow competition following the use of the rolling weeder increased the time required for weeding appreciably, but the total time required with that technique was considerably less than that with hand weeding alone.

The use of the rolling weeder, herbicide, or one manual weeding 14 DE did not significantly reduce weed weight 56 DE. Because the rolling weeder pushed the weeds down instead of uprooting them, two or more manual weedings were needed to achieve a significant reduction in weed weight.

The yield obtained when the rolling weeder was used twice was not significantly different from that obtained when the rice was manually weeded twice (Table 19). Both treatments yielded significantly less than the weed-free check.

Within-row weeding following use of the rolling weeder did not result in a significant increase in yield. Using the rolling weeder once was no better than doing no weeding at all.

CULTIVAR TOLERANCE FOR HERBICIDES

Agronomy Department

Herbicide injury is influenced by the position of the first node (coleoptile node) in relation to the soil surface. A cultivar with a short mesocotyl has its first node relatively deep into the soil; a cultivar with a long mesocotyl has its first node at a correspondingly shallow depth. Thus nodal position helps determine herbicide tolerance for PE herbicides applied to the soil surface.

In greenhouse screening of the International Upland Rice Observational Nursery (IURON) for herbicide tolerance, correlations among herbicides and seedling node depths were determined (Table 20). There appears to be a difference in cultivar

Table 20. Correlation between node depths of rice cultivars planted 4 cm deep and herbicide injury ratings in 1979 International Upland Rice Observational Nursery.[a] IRRI, 1980.

Herbicide	Correlation coefficient (n = 117)
Butachlor	–.60**
Pendimethalin	–71**
Thiobencarb	–72**

[a]Greenhouse injury rating at 24 days after seeding: 1-2 = very resistant, 3-4 = resistant, 5-6 = moderately susceptible, and 7-9 = very susceptible.

tolerance for herbicides that is more strongly related to node depths in some classes of herbicides than in others. When the node depths of the 1979 IURON were rated against three herbicides on an injury rating scale (Table 20), differences among herbicides in relation to node depth of the cultivars and herbicide tolerance were observed. The positional effect of node depth in determining herbicide tolerance is more important with pendimethalin and thiobencarb than with butachlor. This implies a greater biochemical or physiological tolerance in seedlings that escape injury with butachlor.

There also appears to be a relation between plant height at maturity and mesocotyl length of seedlings as measured at the seedling stage (Table 21). This correlation also implies a relation between plant height and herbicide tolerance (Table 22). Thus, in the selection of semidwarfs for dryland rice culture there has been a tendency to select for herbicide tolerance.

Herbicide antidotes and the soil incorporation of herbicides. A factor that appears to cause erratic performance of surface-applied PE herbicides is photodecomposition or volatilization of the herbicide from the soil surface. In a dry season field experiment with sprinkler irrigation, the level of herbicide that could be incorporated without causing significant stand reduction was studied.

Incorporation of butachlor at 8 kg a.i./ha did not result in stand reduction if the seed was treated with naphthalic anhydride (NA) (Table 23). Thiobencarb incorporated into the soil was more toxic to the NA-treated seed than was butachlor at the higher rates. Surface application of the herbicides was safe at all rates if the antidote was used, but the difference in stand count in the controls indicated a slight loss in stand from the use of the antidote if herbicides are not present.

High temperatures during the experiment resulted in low herbicide injury from surface application, even at the high rates. The untreated seed was not significantly damaged when 4 kg a.i. butachlor/ha was applied, and was only slightly damaged when 4 kg a.i. thiobencarb/ha was applied.

The crop was damaged by sheath blight and rats, but the field results confirmed greenhouse trials on the effectiveness of treating seeds with

Table 21. Correlation between node depth of rice cultivars planted 4 cm deep at IRRI and plant height at maturity for the same cultivars planted at different sites for the 1979 International Upland Rice Observational Nursery. IRRI, 1980.

Site	Observations (no.)	Correlation coefficient
Cuttack, India	116	–.53**
Parwanipur, Nepal	116	–.55**
Cuenca, Philippines	117	–.52**

Table 22. Correlation between herbicide injury rating and plant height at maturity for the 1979 International Upland Rice Observational Nursery.[a] IRRI, 1980.

Herbicide	Correlation coefficient (r) (n = 117)
Butachlor	.14
Thiobencarb	.50**
Pendimethalin	.40**

[a]Greenhouse injury ratings at 24 days after seeding: 1-2 = very resistant, 3-4 = moderately resistant, 5-6 = moderately susceptible, and 7-9 = very susceptible

Table 23. Effect of rate and method of herbicide application and treatment with naphthalic anhydride (NA) on number of plants per meter 21 days after seeding of dry-seeded IR36 rice. IRRI, 1980 dry season.

Herbicide and rate[b] (kg a.i./ha)	Plants (no./m) Soil-incorporated herbicide: With NA	Soil-incorporated herbicide: Without NA	Surface-applied herbicide: With NA	Surface-applied herbicide: Without NA
Butachlor				
0	74 a	85 a	93 a	91 a
2	77 a	54 b	92 a	89 a
4	82 a	47 b	84 a	85 a
8	71 a	33 c	85 a	75 b
Thiobencarb				
0	74 a	85 a	83 a	91 a
2	72 a	45 b	93 a	93 a
4	71 a	47 b	78 a	72 b
8	56 b	29 c	93 a	79 ab

[a]Separation of means in a column within a herbicide treatment by Duncan's multiple range test at the 5% level. [b]a.i. = active ingredient.

Table 24. Weed weight 45 days after seeding as affected by cultivar and weed control treatment. Cale, Batangas, Philippines, 1980 wet season.

Cultivar	Weed species	Weed wt (g/m²)		
		Butachlor	Thiobencarb	Farmers' weed control
Kinandang Patong	*Cyperus rotundus*	54	78	31
	Others	1	3	3
	Total	55	81	34
Dagge	*C. rotundus*	4	17	3
	Others	0	1	3
	Total	4	18	6

antidote to escape herbicide injury.

Herbicide antidote trials with traditional dryland rice cultivars. NA was used as a 1% (wt/wt) seed coating on the traditional cultivars Dagge and Kinandang Patong in 2 demonstration fields in Cale, Batangas. Treatments were not replicated but plot size was 0.2 ha for ease of farmer evaluation. One day after seeding (DS), twice the recommended rate of butachlor or thiobencarb was applied at preemergence. Control plots received interrow cultivation and supplemental hand weeding; the herbicide-treated areas received no further weeding.

No herbicide injury was observed in any of the treated plots. The weed population was heavier in the Kinandang Patong fields, but weed control with both the traditional cultivation practices and herbicides in both fields was good. Essentially the only weed in all plots 45 DS was *C. rotundus.* Other weeds were controlled by the weed control practices used. The tall traditional cultivars competed well against sedges and the yields were good (Table 24, 25).

Table 25 Effect of herbicide treatment (4 kg a.i. herbicide/ha) on yield of plants from rice seeds treated with naphthalic anhydride. Cale, Batangas, Philippines, 1980.

Cultivar	Yield (t/ha)		
	Butachlor	Thiobencarb	Farmers' weed control
Kinandang Patong	2.2	2 4	1.6
Dagge	3 4	2 8	2.4

Irrigation and water management

Irrigation Water Management and Agricultural Economics Departments

EVALUATING EFFICIENCY OF TUBE WELL SYSTEM OPERATION

Irrigation Water Management Department

To be economically viable, tube well irrigation systems must operate at a high level of efficiency. That means highly effective use of rainfall during the cropping season, operating pumps only to meet the field irrigation water requirement, and water use with minimum losses and equitable distribution. During 1980, data for the 1979 dry and wet seasons from a study were analyzed. The study, done jointly with the National Irrigation Administration (NIA), Philippines, in two deep tube well systems, tested alternative methods of determining effective rainfall in the systems and established a methodology to evaluate their efficiency.

Discharge from each tube well was measured at the discharge pipe. Time of pump operation was recorded to allow calculation of amount of irrigation water pumped. Each tube well service area was divided into sectors, with a boundary identified by the existing water delivery and distribution channels. Irrigation inflow into a sector was measured by cutthroat flumes or vane devices. Seepage and percolation (S&P) were measured for each tube well system by the daily water budgeting technique. With U. S. Class A pan evaporation data for a site adjacent to each tube well site, the daily crop-water requirement for evapotranspiration (ET) was calculated by using an average pan factor of 1.2 for the period from transplanting to terminal drainage. Rainfall at each site was measured daily.

Effective use of rainfall. The effective use of rainfall in the two tube well systems was determined by three methods:

- *The freeboard model.* In the freeboard model the amount of effective rainfall (R_e) for a time period was determined by the freeboard or additional water storage capacity available in the paddy for that time. Available freeboard for a period was computed as the difference between the height of the paddy spillway and the depth of water in the paddy. The depth of water used by ET plus S&P during the period was added. Thus

$$FB_t = SH_{to} - DW_{to} + (ET + S\&P)_t$$

where:

FB = available freeboard in mm

SH = paddy spillway height in mm

DW = water depth (mm) in the paddy

ET = water loss (mm) by evapotranspiration

$S\&P$ = water loss (mm) by seepage and percolation

to = beginning of period t

R_e was then computed as a fraction of total rainfall (R) within the period according to the following guidelines:

for $R_t \leqslant FB_t$, $R_{e_t} = R_t$;
for $R_t > FB_t$, $R_{e_t} = FB_t / R_t$;
for $R_t = 0$, $R_{e_t} = 0$.

The 16 sample paddies of each tube well system used for the measurement of S&P water loss were also used for data on water depth and spillway height for the computation of R_e by the freeboard model.

Because measurements of the paddy water depth and spillway height were made once every 24 hours and the occurrence of rainfall was at any time during that period, use of water by ET and S&P was generally overestimated in computing for FB. That resulted in a higher R_e value, especially when high intensity rainfall occurred early in the day.

- *Modified freeboard model.* To test the magnitude of the possible overestimation, a modified freeboard model was introduced — water depth in the paddy and the spillway height were measured just before a rainfall. Thus the earlier equation was modified to:

$$FB_t = SH_b - DW_b + d\,(ET + S\&P)_t$$

where

SH_b is paddy spillway height just before rainfall;

DW_b is depth of water in the paddy just before rainfall; and

d is the duration of rainfall.

To determine R_e from known R and FB, the guidelines for the freeboard model were followed. If more than one rain occurred during a day, each occurrence was considered separately. The data for the modified freeboard model were collected at five selected sample paddies for each tube well system.

- *Water use-rainfall ratio method.* With the

Table 1. Service area, mean seasonal effective rainfall computed by 3 methods, and mean paddy spillway height in T-2 and T-6 tube well irrigation systems, Tarlac, Philippines, 1979 wet season [a]

Tube well system	Service area (ha)	Effective rainfall[b] (%)			Paddy spillway ht (mm)
		Freeboard model	Modified freeboard model	Water use-rainfall ratio method	
T-2	61	89	83	86	79
T-6	52	85	81	86	69
Mean	56.5	87 (519)	82 (328)	86 (90)	74 (519)

[a]The numbers in parentheses indicate total number of samples used. [b]The mean effective rainfall values by the 3 methods are not significantly different from each other at 5% level

water use-rainfall ratio, R_e for a particular period or a group of consecutive days was computed as the ratio of the sum of ET and S&P to the amount of rainfall during that period. The period or group of consecutive days was selected on the basis of the soil texture. For the loam soils of both the tube well systems, a period of 3 days was used. The R_e values computed for the series of 3-day periods were added and averaged to obtain weekly, monthly, or seasonal R_e. Periods without any rainfall were excluded from the computation for the average.

The 1979 mean values of R_e by the three methods were high and were not significantly different from each other (Table 1). Effectivity was high because daily rainfall intensities were low during the season — only 8.5% of the total number of rainy days had a daily rainfall of more than 30 mm — but the average spillway height maintained by the farmers in their paddies was 74 mm (Table 1) and daily water requirement for ET and S&P was about 8 mm. As expected, the freeboard model gave higher R_e than the modified model. The difference, however, was low because with the low-intensity daily rainfall the effect of overestimation of ET and S&P in the computation of the R_e by the freeboard method was very small.

The water use-rainfall ratio method also gave high R_e values. But the values for the two systems were the same because this method does not consider the farmers' paddy spillway management, a major factor affecting the amount of rainfall that can be stored in the paddy.

The effect of modifying the freeboard model became clear when R_e was calculated for higher intensity rainfalls. Table 2 indicates that as daily rainfall intensity increased, the mean R_e calculated by the modified freeboard model for the 2 spillway height ranges (5-8 cm and > 8-13 cm) was increasingly smaller than the corresponding value by the freeboard model. Despite that difference, the differences in seasonal mean values of R_e computed by the two methods were small because occurrences of higher intensity rainfall in the 1979 wet season were few.

The influence of paddy spillway height on the effectiveness of rainfall was determined by separately analyzing the data from paddies with three ranges of spillway heights and calculating the mean

Table 2. Mean effective rainfall calculated by two methods for different rainfall intensities in paddies with 2 ranges of spillway heights. T-2 and T-6 tube well systems, Tarlac, Philippines, 1979 wet season.

Rainfall intensity (mm/day)	Mean effective rainfall[a] (%) at spillway ht of					
	5-8 cm			>8-13 cm		
	Freeboard model	Modified freeboard model	Difference	Freeboard model	Modified freeboard model	Difference
10	100 a (117)	84 a (137)	16 ns	100 a (194)	93 a (35)	7 ns
10-20	90 ab (27)	76 b (25)	14*	100 ab (58)	83 b (11)	17*
20-30	85 bc (15)	55 c (12)	30**	95 bc (11)	70 c (9)	25**
30	71 c (37)	38 d (59)	33**	83 c (6)	46 d (4)	37**

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]The numbers in parentheses indicate the number of samples.

Table 3. Mean effective rainfall[a] calculated by 2 methods in paddies of different spillway heights. T-2 and T-6 tube well irrigation systems, Tarlac, Philippines, 1979 wet season.

Spillway ht (cm)	Mean effective rainfall[b] (%)		
	Freeboard model	Modified freeboard model	Difference
<5	72 a (90)	No observation	—
5-8	86 b (196)	80 a (269)	6*
>8-13	95 c (233)	84 b (59)	11**

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Numbers in parentheses indicate the number of observations

Table 4. Irrigation efficiency for two tube well systems. Tarlac, Philippines, 1979 dry and wet seasons.

Tube well system	Irrigation efficiency[a] (%)	
	Wet season	Dry season
T-2	49	80
T-6	42	69
Mean	46	74

[a]The irrigation efficiencies of the two tube wells are significantly different at 1% level in the dry season and 5% level in the wet.

R_e for each range by the two freeboard models (Table 3). As expected, the modified freeboard model gave significantly smaller R_e values than the freeboard model, and the difference was greater for paddies with higher spillway height. The results confirmed earlier findings of the advantage of increasing spillway height for more effective use of rainfall on the farm.

Irrigation system efficiency. Two indicators — irrigation efficiency and distribution equity — are of primary importance in the evaluation of system efficiency or performance Irrigation efficiency (IE) was calculated by using the relationship

$$IE = \frac{(ET + S\&P) - R_e}{IR}$$

where ET is evapotranspiration rate, $S\&P$ is seepage and percolation rate, R_e is effective rainfall, and IR is the irrigation water supplied. IE is therefore the ratio between the field irrigation demand and irrigation supply.

To measure water distribution equity in each system, 32 paddies selected to represent the head, middle, and tail of the supply canal network were observed daily and their water status recorded. Half of the paddies were those used for the determination of daily S&P rates.

IE for both tube well systems was higher in the dry season than in the wet (Table 4) because water supplied from the tube wells exceeded field irrigation demands more in the wet season than in the dry (Fig. 1,2). A mean excess of 3.0 mm water/day was supplied from rainfall and tube well in the dry season; the corresponding wet season excess was 4.8 mm/day (Table 5).

A comparison of the two systems shows that in both seasons T-2 had a significantly higher IE (Table 4) because T-2 farmers made more effective use of the rainfall in the wet season by maintaining higher spillways (Table 1). There was also relatively greater control in the use of the pump in T-2 in both seasons (Table 5).

A sectoral analysis of IE for the wet season showed high variation from week to week in both systems (Table 6), which indicates a high degree of fluctuation in assessed field irrigation demand and the supply of tube well water to meet that demand. Because rainfall is unpredictable, high IE could be achieved only if pumping were timely. The effect on IE of nonsuspension of pumping is seen in week 32. Despite the occurrence of 89 mm of rainfall — 38% greater than the field water requirement — 13 mm of water was pumped (Fig. 1, 2), and IE for that week was zero.

Table 5. Mean daily water supplied and field water requirement for evapotranspiration plus seepage and percolation in 2 tube well systems. Tarlac, Philippines, 1979 dry and wet seasons.

Tube well system	Season	Water supplied (mm/day)			Field water requirement (mm/day)	Excess water supplied (mm/day)
		Pumped water	Rain-fall	Total		
T-2	Dry	10.1	0	10 1	8.1	2 0
	Wet	6 5	5 4	11 9	7 8	4 1
T-6	Dry	12 4	0	12 4	8.3	4.1
	Wet	8.0	5 4	13 4	7.9	5.5

Table 6. Irrigation efficiency values by sector for 2 tube well systems Tarlac, Philippines, 1979 wet season.

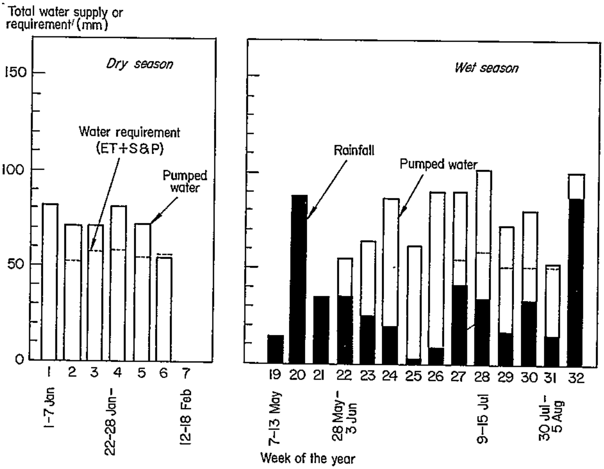
Sector, system	Irrigation efficiency (%) durıng wk no.						Mean (%)
	27	28	29	30	31	32	
1, T-2	—	41 4	52 5	30 3	91 5	0	43 1
1, T-6	70 2	41.0	63.4	25.9	39 6	0	41.7
2, T-2	—	43.1	59 8	32 8	100 0	0	47 1
2, T-6	56.7	28.9	59 3	24 3	44.7	0	35.6
3, T-2	—	51.6	72 4	35 6	75 8	0	47.1
3, T-6	63 1	47.5	64.6	29.3	52.5	0	42.8
4, T-2	—	52.8	65 6	49.4	100.0	0	53 5
4, T-6	69.2	56.5	73 6	27.0	59 6	0	47.6
5, T-2	—	54.0	73.3	50.0	100.0	0	55 5
Mean for T-2	—	48 6	64 7	39 6	93 5	0	49 3
Mean for T-6	64 8	43.5	65 2	26 6	51 6	0	41 9

Pump operators generally based irrigation water supplies on their judgment of irrigation water demand in the field, with no systematic procedure for scheduling and distribution of water in either season. They also responded to specific farmer requests for water.

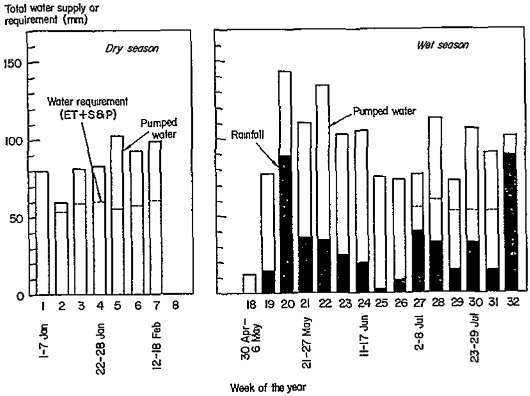
Farmers made no conscious efforts to reduce pumping requirement by reducing runoff losses from their paddies or making most effective use of rainfall. Some sample farmers maintained no spillway during certain rainy days of the wet season, and raınfall effectivıty on those farms was zero.

Farmers closest to the source always had the option to irrigate their fields any tıme water flowed in the main farm ditch, even though the water may have been meant for other farmers. As a result, the sectors nearest to the wells — sector 2 in T-6 and sector 1 in T-2 — generally received more water than the other sectors (Fig. 3, 4).

The water status data from the 32 selected paddies of each tube well service area showed no significant water shortage in any part of the field in



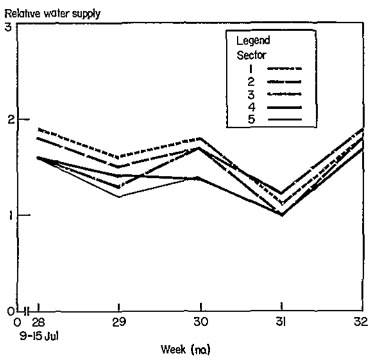
1. Weekly total water requirement, rainfall, and tube well water supplıes. T-2 tube well system, San Manuel Groundwater Pılot Project, Tarlac, Philıppınes, 1979 dry and wet seasons



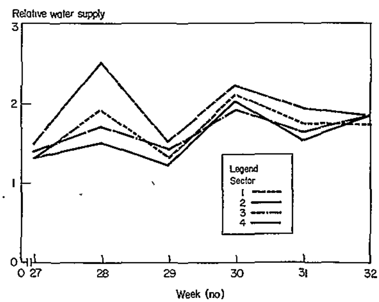
2. Weekly total water requirement, rainfall and pumped water supplies. T-6 tube well system. San Manuel Groundwater Pilot Project, Tarlac, Philippines, 1979 dry and wet seasons.

either season. Weekly values of relative water supply — the ratio of water supplied from rainfall and irrigation sources to the total water required for ET plus S&P — varied between 1.0 to 2.0 in system T-2 and between 1.2 to 2.5 in T-6 in the wet season, but remained toward the higher side of the range for most weeks in the season (Fig. 3, 4) indicating abundant water supply for both systems. Distribution equity was therefore not a problem. Because of that situation there was no occasion to test the degree of effectiveness of the water distribution procedure in the systems.

The study of the two systems indicated that if the pumps were operated with a greater control and a systematic schedule to strictly supplement R_e in the field, the IE in the wet season could be increased



3. Relative water supply by sector for T-2 tube well. Tarlac, Philippines, 1979 wet season



4. Relative water supply by sector for T-6 tube well. Tarlac, Philippines, 1979 wet season.

substantially from the average value of 46%. Because the conveyance losses in the channels were negligible and no water stress developed in the service area during the dry season it was assumed that the dry season IE (74%) could be increased by further reduction of surface runoff.

The study established a procedure that can be used to evaluate tube well or surface pump irrigation systems by determining R_e and then calculating the seasonal IE. The procedure used to calculate IE permitted measurement of the success achieved in delivering irrigation water to meet the irrigation demand. It also allowed estimation of irrigation system performance induced by planned changes in its operation as well as comparison of performances of different systems.

COSTS OF TYPES OF IRRIGATION SYSTEMS

Agricultural Economics Department

Of the irrigated areas in the Philippines in 1978, about 37% were irrigated by national systems, 47% by communal systems, and 16% by pump systems. To compare the magnitude and nature of costs of the types of irrigation systems, 12 irrigation projects representing a mix of the categories were selected in Central Luzon, Philippines. The choice of Central Luzon systems reduced the variability of environment. Because few systems had detailed cost records, the study was limited to a selected number. The systems and their major characteristics are presented in Tables 7-8.

Data on investment and operation and maintenance (O&M) costs were from records of NIA or the individual farmers. For the Prenza and Salapungan communal systems, the records lacked adequate details and a procedure to estimate current replacement costs, based on a complete physical inventory of the structures was developed. The replacement cost of each structure was calculated by applying 1978 prices to material and labor. Price indices were constructed to reflect the price

Table 7. Gravity irrigation systems selected for study, Central Luzon, Philippines, 1980.

System	Site	Year completed	Irrigated area (ha)	Cropping intensity
National				
San Fabian River Irrigation System	San Fabian, Pangasinan	1969	2,698	1 6
Communal				
Prenza	Marilao, Bulacan	1925	551	1.5
Salapungan	San Miguel, Bulacan	1970	378	na[a]
Caingin	Malolos, Bulacan	1976	30	1.0
Sibul	San Miguel, Bulacan	1976	16	2 0

[a]Data not available.

Table 8. Pump irrigation systems selected for study, Central Luzon, Philippines, 1980.

System	Site	Year constructed	Irrigated area (ha)	Cropping intensity	Size of pump (cm)[a]	Size of motor (hp)	Mean pump discharge (liters/s)
Surface pumps							
Buenavista Pump Irrigation Project (BPIP)	San Rafael, Bulacan	1976	297	2.0	40.6 (2)	75	883
Safari Pump System	San Miguel, Bulacan	1976	121	2 0	25.4 (2)	75	218
Halina Pump System	San Jose del Monte, Bulacan	1976	22	2 0	25 4	50	68
Small pumps[b]	San Rafael, San Ildefonso, and San Miguel, Bulacan	1974-78	2 7	1.6	10.2	5-10	na[c]
Deep well pumps							
GP-3	Manaoag, Pangasinan	1978	55	1 8	20 3	75	104
GP-4	Manaoag, Pangasinan	1978	56	1.6	20 3	75	107
GP-19	Binalonan, Pangasinan	1978	46	1 4	25.4	80	88

[a]Number in parentheses indicates number of pumps. [b]Av of 18 small pumps owned and operated by individual farmers [c]Data not available.

differences in major material and labor components of systems constructed at different points on time. Capital costs were deflated by the price index to convert costs of all systems to 1978 equivalent prices.

Project costs. Investment costs for national and communal gravity systems generally included expenses for the construction of a dam and other diversion structures, irrigation canals, and drainage facilities, and other related costs. Pump systems incurred similar costs except that instead of a dam or any diversion structure, they require a pump and a motor; deep tube wells have added costs for the well component. Investment cost for gravity systems was from $118 to $683 per hectare. Table 9 presents the costs for all systems.

Operation and maintenance costs include salaries and wages, equipment costs, supplies and materials, vehicle costs associated with the project, and energy costs of running the pumps on the pump projects.

O&M costs varied depending on type of system and the organization responsible for the management of the system. The NIA systems had higher per hectare labor cost for management than the communal systems.

Except for the Caingin communal system, O&M costs for gravity systems were lower ($3-21/ha) than those for pump systems ($42-135/ha). The difference was due in part to energy costs, which accounted for 60-80% of the O&M cost for pump systems. The Caingin system although classified as a communal gravity system used pumps to lift water from behind a diversion on the creek to the field.

The annualized cost of irrigation is the sum of the annual equivalent of capital invesment cost and annual O&M cost. The annual equivalent of the capital investment is the average amount to be paid annually, at a specified interest rate, to fully recover the capital invested during the life of the investment. It was calculated by multiplying the initial total capital investment (at 1978 prices) by a capital recovery factor appropriate for a given rate of interest and a specified investment life.

There were substantial differences in estimated annual costs among the projects (Table 9). The substantial variation in costs within each category was due to conditions unique to each system — among the communal systems, Sibul was favorably located relative to a good source of water. Caingin, on the other hand, required pumping, which greatly increased O&M costs. Among the pump systems, Halina had a relatively high cost because of a high lift of water and because it operated below capacity.

Table 9. Costs (at 1978 prices) for irrigation systems in Central Luzon, Philippines, 1980.

	Service area (ha)	Costs ($/ha)		Annualized total cost[a] ($/ha) at interest rate of	
		Capital investment	Operation and maintenance	6%	18%
Gravity systems					
National system					
San Fabian River Irrigation System	2698	451	21	52	103
Communal system					
Prenza	551	683	8	51	131
Silapungan	378	387	5	29	74
Caingin	30	118	45	53	66
Sibul	16	156	3	12	31
Pump systems					
Surface pumps					
BPIP	297	543	85	133	188
Safari	121	229	42	62	85
Halina	22	393	135	174	211
Small pump	2.7	562	43	127	180
Deep well pumps					
GP-3	55	1836	96	236	431
GP-4	56	1255	94	192	324
GP-19	46	1564	122	249	412

[a]Based on 60 years life span for dams, 30 years for canals, and 15 years for pumps and engines. $1 = ₱7.38

The cost data alone are of limited usefulness because benefits may vary substantially among projects. Benefit data for each system will be reported in 1981.

EVALUATION OF IRRIGATION MANAGEMENT CHANGES

Irrigation Water Management Department

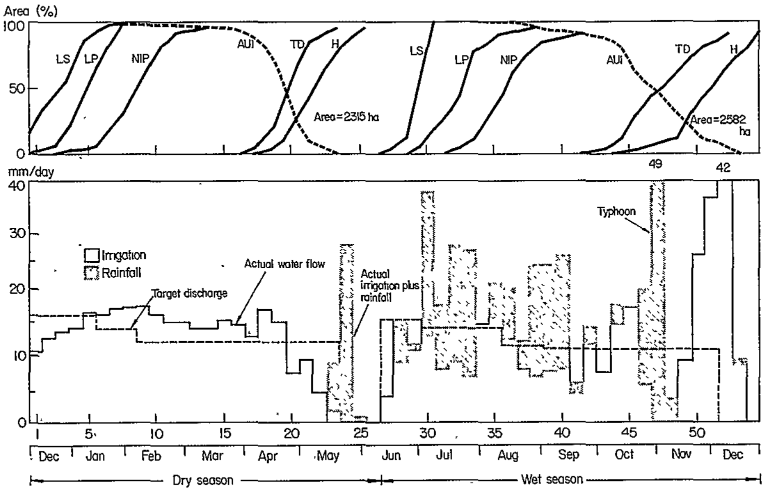
Irrigation management changes made in the Lower Talavera River Irrigation Systems (LTRIS) since 1975 were evaluated in 1980.

Target discharges were achieved in both seasons of 1980 (Fig. 5). Water supplied was adequate for farm requirements. Uniform rainfall provided a large part of the wet season requirement. A 4-week suspension of water supply was possible after the dry season because of a shortened duration of farming activities, and a corresponding shorter irrigation period. As the 1980 wet season progressed, rainfall became uniformly distributed, but LTRIS management did not totally suspend water supply except for 2 weeks after a typhoon. Rainfall, therefore, was not used effectively to conserve irrigation water.

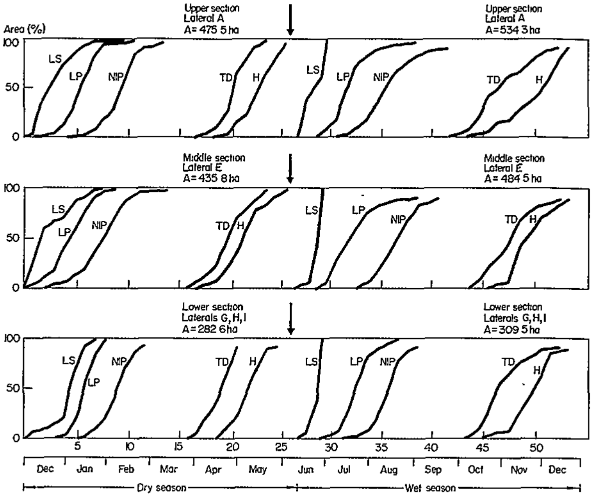
It took 14 weeks to transplant 95% of the program area during the dry season (Fig. 5). Time lag between land preparation and normal irrigation period was 4 weeks, which was almost double the gap between soaking and land preparation. Farmers at the lower section completed transplanting 2 weeks ahead of those in the upper and middle sections (Fig. 6).

On the other hand, 80% of the wet season program area was planted after 16 weeks. This shows farmers tended to slow down in their activity because they expected water supply from rainfall. Land soaking was completed in 4 weeks with rain water, 3 weeks earlier than in the dry season, but land preparation took longer than in the dry season.

A typhoon which hit the area in November (Fig. 5) when only 10% of the crop had been harvested reduced yield and affected grain quality because of crop submergence. Overall yields, however, showed no significant differences due to location except for section 1 where yield was consistently lower (Table 10) than in other sections. Farmers in section 1 usually planted late and rats in the area converged on the section.



5. Status of farming activities, actual water supply, and target discharges at Lower Talavera River Irrigation System, Nueva Ecija, Philippines, 1980 dry and wet seasons. LS = land soaking, LP = land preparation, NIP = normal irrigation period, AUI = area under irrigation, TD = terminal drainage, H = harvesting Numbers 1-50 are weeks from start of land soaking.



6. Farming activities at different parts of Lower Talavera River Irrigation System, Nueva Ecija, Philippines, 1980 dry and wet seasons. LS = land soaking, LP = land preparation, NIP = normal irrigation period, TD = terminal drainage, H = harvesting. Numbers 5-50 are weeks from start of land soaking.

Bacterial blight affected most of the wet season crop. During the dry season no major pest attacked the area.

Performance evaluation. An evaluation of the performance of the LTRIS over the duration of the project considered both the yield distribution corresponding to the water supply over the length of the system and the water use efficiency of the system as a whole. Of particular interest was the analysis of the yields in the formerly disadvantaged tail section.

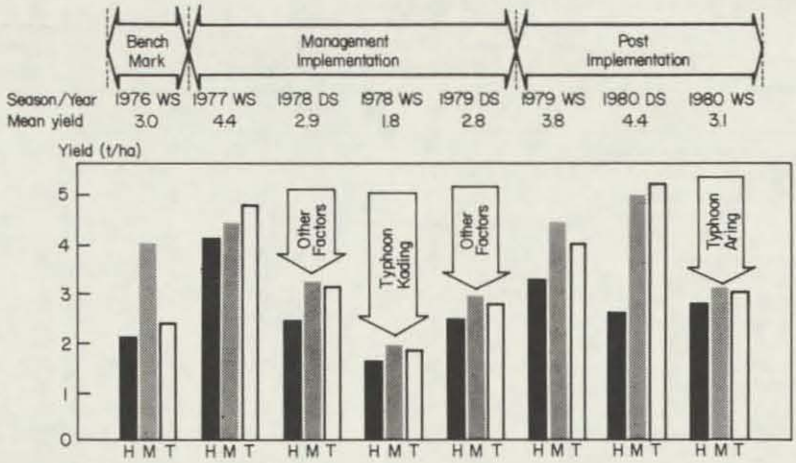
The management of water to avoid maldistribution resulted in tail-end farmers consistently advancing their cropping schedules, having a cropping intensity exceeding 200%, and obtaining annual total yields exceeding 8 t/ha (Fig. 7). Typhoons in the 1978 wet season and the 1980 wet season had damaging effects on the general level of yields obtained in the system. Other adverse factors were the significant insect and disease problems and asynchrony in the 1978 dry season and the dry season after the heavy typhoon damage when lack of cash forced the farmers to apply low levels of purchased inputs.

The low dry season yields led to the generalizations that the farmers are at the mercy of the extraordinary events of typhoons and the accompanying floods and drainage problems, and rice does not grow by water alone. This means water management programs must be integrated with agricultural production programs.

Table 10. Yield at different sections of Lower Talavera River Irrigation System, Nueva Ecija, Philippines, 1980 dry and wet seasons.

Section	Yield[a] (t/ha)	
	Dry season	Wet season
1	2 58 [b]	2.83 b
2	4.29 b	2 92 ab
3	4.77 ab	3.42 a
4	5.15 a	3 28 ab
5	5.28 a	3 01 ab

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Not compared with other sections because there was only one observation.



7. Mean seasonal yield performance by position in Lower Talavera River Irrigation System, Nueva Ecija, Philippines, 1976-80. Positions are head (H), middle (M), and tail (T) of the system. Other factors in 1978-79 dry season included insect and disease problems in 1978 and lack of cash to buy inputs after the typhoon in 1979. WS = wet season, DS = dry season.

Water use efficiency for the system stabilized at near 70% in the dry season (Table 11). In the wet season it fluctuated from 50 to 70% largely because of typhoons and because water use efficiency included all of the rainfall in the denominator of the equation, providing the major cause of the variability. The period of postimplementation evaluation (two wet seasons and one dry season) was characterized by good system performance. Yields averaged 3.8 t/ha, cropping intensity averaged 96%, and the water use efficiency averaged 63%. All those values were above the Upper Pampanga River Irrigation System (UPRIS) means.

Farmers' attitudes toward the improved system management implementation are generally positive (Table 12). More than 86% of all responses from 169 farmers reinterviewed throughout the study were positive. The only exception was the response to the question dealing with the possibility of the farmers sharing responsibility with the National Irrigation Administration (NIA) in the maintenance of the LTRIS.

Table 11. Seasonal water use efficiency for the duration of the project, Lower Talavera River Irrigation System, Nueva Ecija, Philippines, 1975-80.

Year	Water use efficiency (%)	
	Dry season	Wet season
1975	—	43
1976	51	—
1977	—	60
1978	60	50
1979	73	70
1980	69	50

IRRIGATION SYSTEM PERFORMANCE

Irrigation Water Management Department

Performance of the Pampanga River Irrigation System (PRIS) was observed for three seasons during 1979-80.

During the 1979 wet season, it took about 21 weeks before 92% of the area was transplanted, which reflected a problem in implementation of the farming schedule (Fig. 8). For the first 5 weeks no more than 50% of the area was prepared for planting although the entire area had been soaked since the first week by precipitation. Because of planting delays, farming activities overlapped 6 weeks with the 1980 dry season.

Throughout the three seasons PRIS was monitored, the only time the whole system had no standing crop for irrigation was one week at the end of the 1980 dry season. In the succeeding dry seasons and the 1980 wet season farming activities were relatively faster. The transplanting period was reduced to 15 weeks for the 1980 dry season and 17 weeks for the 1980 wet season, but the total area

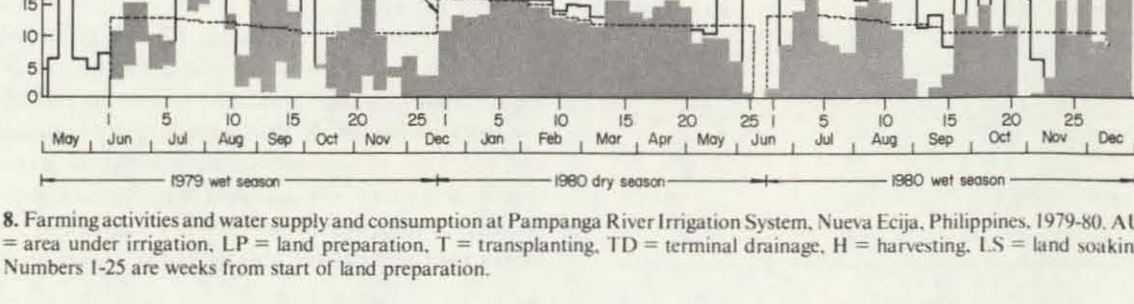
Table 12. Attitude of 169 farmers surveyed on aspects of systemwide irrigation management in the Lower Talavera River Irrigation System (LTRIS), Nueva Ecija, Philippines, 1979 dry season.

Management aspect	Uncertain		Strongly disagree		Disagree		Strongly agree		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Day-to-day management of LTRIS brings adequate supply of water	7	4	4	2	5	3	153	91	169	100
Close communication between water tender and farmer results in efficient water allocation	3	2	3	2	2	1	161	95	169	100
Measurement devices are useful in water allocation	9	5	5	3	1	1	154	91	169	100
Efficient use and allocation result in adequate supply of water for tail-end farmers	11	7	6	4	4	2	148	87	169	100
Water is the most important factor to increase farmer production	9	5	1	5	13	8	146	86	169	100
Farmers should not check canals and open or close control gates	10	6	5	3	0	0	154	91	169	100
Economize water use by doing farming activities at the same time	5	3	5	3	0	0	159	94	169	100
Farmers would prefer to do maintenance and operation at LTRIS	9	5	100	59	34	20	26	16	169	100
Implementation of rules and regulations of the National Irrigation Administration will result in efficient use of water	10	6	4	2	2	1	153	91	169	100

planted was much less than that in the 1979 wet season.

During the 1979 wet season there was a water shortage in the system and PRIS field staff worked at night to get water to the lower sections during October. Irrigation was not cut off between the 1979 wet season and the 1980 dry season because of standing crops that needed irrigation. Most of the between-season crops were heavily damaged by rats.

The major problem encountered during the 1980 dry season was minor maldistribution of water especially at the tail section of some laterals. Some farmers used 10-cm plastic pipes to siphon water into their farms and avoided use of turnouts constructed for their respective areas. That reflected



8. Farming activities and water supply and consumption at Pampanga River Irrigation System, Nueva Ecija, Philippines, 1979-80. AUI = area under irrigation, LP = land preparation, T = transplanting, TD = terminal drainage, H = harvesting, LS = land soaking. Numbers 1-25 are weeks from start of land preparation.

Table 13. Yield for various components and sections of the Pampanga River Irrigation System, Nueva Ecija, Philippines, for 1979 wet season (WS) and 1980 dry (DS) and WS.

Component	Yield (t/ha)								
	Head			Middle			Tail		
	WS 1979	DS 1980	WS 1980	WS 1979	DS 1980	WS 1980	WS 1979	DS 1980	WS 1980
Entire system	3.2	3.4	2.4	3.3	3.5	2.8	3.7	3.4	2.5
Lateral C	3.7	2.9	2.9	3.5	3.5	2.6	3.2	3.3	2.4
Lateral C1	3.0	2.3	2.5	3.8	4.2	2.0	2.8	4.1	2.8
Lateral G4	2.0	2.7	3.1	2.3	3.1	2.7	2.0	2.5	2.2
Lateral F	3.3	3.8	3.1	3.3	3.9	2.8	3.9	3.4	2.3

the farmers' desire to control water and resulted in an inadequate water supply for the tail section. This inadequacy was traceable also to some structural defects — structures that needed repair to increase capacities, and embankments that needed to be raised — that caused water spillage even during the dry season's peak demand.

Crop cuts from more than 100 farms/season showed a wet season yield of 3 t/ha and a dry season yield of 3.4 t/ha (Table 13). The system had uneven yields with the tail-end farmers showing the lowest yields in two of the three seasons. The farmers in the middle of the system consistently had the highest yields throughout the three seasons of observation.

IMPROVING THE MANAGEMENT OF A COMMUNAL IRRIGATION SYSTEM

Irrigation Water Management Department

The water allocation-distribution changes applied in the Peñaranda River Irrigation System (1974-76) were tried in the 1980 dry season in the Anayan River Irrigation System, which serves 355 ha of rice land and 374 farmers in Camarines Sur, Philippines. The Anayan System had maldistribution of water supply in different parts of the service area (Table 14).

Water allocation in the system was modified to provide a water rotation method (treatment) in the lateral B service area (Zone III), which allowed the tail end of the lateral to be supplied with the irrigation water first. That was followed by water supply to the middle section and then the head section. The service areas of laterals A and C (Zone I) and lateral A-1 (Zone II) served as controls.

Table 14. Water distribution pattern in the 3 zones of Anayan Communal Irrigation System, Camarines Sur, Philippines, 1980 dry season (pre-treatment period).

Zone[a]	% of total area served	% of total water supplied
I (laterals A and C)	25	46
II (lateral A-1)	24	22
III (lateral B)	51	32

[a]Laterals A and C are the shortest and closest to the water source, lateral B is the longest and serves the most distant areas.

Table 15. Relative water supply[a] in the control and treatment areas before and after implementation of tail-first rotation method of water distribution. Anayan Communal Irrigation System, Camarines Sur, Philippines, 1980 dry season.

Area	Relative water supply	
	Before	After
Treatment (Zone III)	1.36	1.43
Control (Zones I and II)	1.76	1.65

[a]The ratio of water supplied from irrigation plus rainfall sources to field water requirements for evapotranspiration and seepage & percolation.

Table 15 shows the reduction in the water supply disparity in Zone III that could be attributed to the treatment.

Farmers' satisfaction with the tail-first water rotation schedule in the dry season was surveyed. Their attitude and water management behavior were also documented. A high percentage of sample farmers in the treatment area favored the tail-first rotation method because of the ease in water distribution following that method (Table 16). A greater percentage also showed positive water management behavior (Table 17). The response could be attributed to the gains in water supply to the formerly disadvantaged tail-section farmers who were allowed first use of the irrigation water during the season.

INSTRUMENT DESIGN FOR WATER MEASUREMENT

Irrigation Water Management Department

A vane flow device was developed and adapted to the commonly occurring culvert sections, which are made in standard sizes (Fig. 9). The device is not subject to backwater effects because the vane plate integrates the effects of water depth and flow force. The device can be clamped inside existing

Table 16. Farmers' attitude toward the tail-first rotational water distribution. Anayan Communal Irrigation System, Camarines Sur, Philippines, 1980 dry season.

	Farmers (%)	
	Control zone	Treatment zone
Are you in favor of the rotational method of irrigation?		
Yes	86	90
No	14	10
If yes, why?		
Equity between upstream and downstream farmers	28	18
Water flow is in one direction without interruption	32	36
Ease in water distribution	12	22
Other reasons	14	10

Table 17. Farmers' attitudes toward the operation of the Anayan Communal Irrigation System, Camarines Sur, Philippines, 1980 dry season.

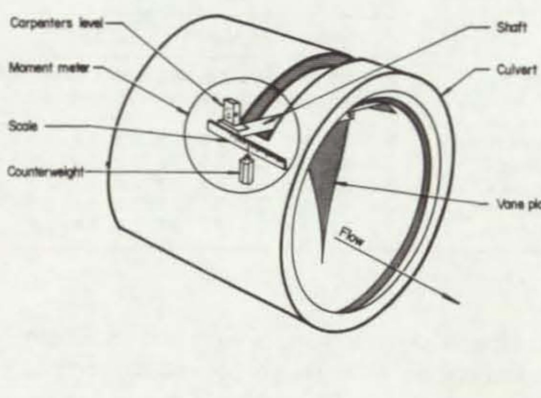
	Farmers (%)	
Item	Control (laterals A and C)	Treatment (lateral B)
Satisfied with the services of water tender and water master	32	44
Payment of irrigation fee for the season		
Paid in full	32	52
Paid partial	24	14
Did not pay	10	16
Did not plant	24	18
Reason for full payment made in the season		
Benefited by water	14	32
Assured of supply next season	20	10
Other reasons	18	10
No answer	48	48

culvert sections for flow readings when water depth is less than 7/8 of the culvert diameter. Calibrations were made for common culvert sizes with diameter of 30.5 to 91.4 cm (Fig. 10).

COLLABORATIVE RESEARCH AND TRAINING IN THAILAND

Irrigation Water Management Department

Studies of irrigation water management conducted jointly with the Royal Irrigation Department (RID) in Thailand were concluded in 1980. The



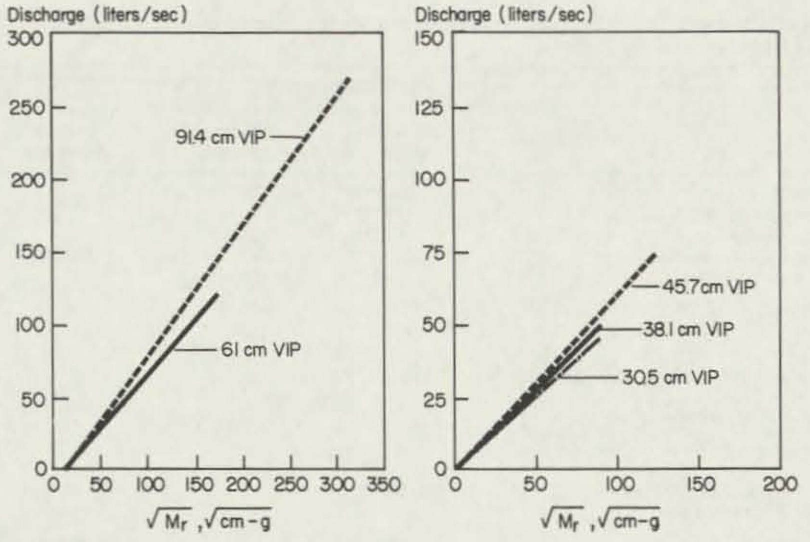
9. The vane in a pipe developed for flow measurement in commonly used culvert sections. IRRI, 1980.

research results were presented at a workshop in Khon Kaen.

Prediction of seepage and percolation requirements of rice lands. A study correlated the seepage and percolation (S&P) rate with the subsurface water recession rate (R_r), the in situ hydraulic conductivity (K), the depth below the ground surface of the water table (WT), and the percentages of sand (Sa), silt (Si), and clay (Cl) of the soil profile in three irrigated tank systems and at three sites in one large reservoir system (Table 18).

The S&P rate was determined as the daily water surface recession rate minus the rate of potential evapotranspiration from the paddy. The R_r rate was determined as the 4 to 6 hour rate of water recession in meters per day, one day after a 10-cm diameter hole was bored to 60 cm and presoaked. K was determined with the Tempe double tube permeameter installed to a depth of 60 cm and standard procedures. WT was the linear depth below the surface reached by the water surface 24 hours after a hole was bored to 1-m depth. The soil texture was determined by the standard hydrometer method on composite soil samples from the profiles.

Results from 42 sites tested were in the form of regression equations using the profile data for the wetland irrigated topographic landscape position to predict R_r as a function of the WT and percent



10. Calibration curves for 5 sizes of vane-in-a-pipe (VIP). M_r is the moment on the vane plate. IRRI, 1980.

Sa as:

$$R_r = 2.00\,(WT)^{0.326}\,(Sa)^{5.24} \quad \text{with } r^2 = 0.70.$$

Inclusion of the percentages of silt and clay in the regression equation improved the percentage of variability explained by the model from 70% to 75%. The R_r was also related to K and WT in:

$$R_r = 0.83\,(K)^{0.72}\,(WT)^{0.12} \quad \text{with } r^2 = 0.81.$$

The model relating the S&P rate to percentages of Sa, Si, and Cl in the soil profile, as well as K, was generally not able to explain a high proportion of the variability of the S&P rate. The S&P rate was related to R_r as:

$$S\&P = 4.38\,(R_r)^{0.24} \quad \text{with } r^2 = 0.42.$$

The S&P rate was then related to K and WT in the relationship:

$$S\&P = 4.76(K)^{0.071}\,(WT)^{0.37} \quad \text{with } r^2 = 0.79.$$

This latter multiple-regression result, which explained 79% of the S&P variability, was then used to predict the S&P rates of the study sites based on mean K and mean WT as compared to the mean measured S&P from four of the sites in Table 18.

In general, the model predicted the S&P rate within tolerable limits. This type of prediction equation would have to be applied to specific project areas to develop confidence in the prediction ability. With wide application landscape and soil profile variability would invalidate the model's applicability.

Cooperation and conflict among water users in tank irrigation systems. Three tank irrigation projects — small-scale water impoundment projects that developed small watersheds above a rice-growing or potentially rice-growing wetland area — in northeastern Thailand were surveyed to identify factors associated with participation, cooperation, and conflict relating to water use. It was

Table 18. Mean predicted seepage and percolation (S & P) rate in rice fields at different study sites in Thailand, 1980.

Site	Mean hydraulic conductivity (m/day)	Mean water table (m)	Predicted S & P (mm/day)	Actual S & P (mm/day)	Discrepancy from actual (%)	Soil texture
Huai Sathot	0.47	1.37	5.1	—		Loamy sand
Huai Kaeng	0.68	0.68	4.0	3.4	18	Loamy sand
Huai Aeng	0.42	0.71	3.9	3.8	3	Loamy sand
Lam Pao-1L1	0.27	0.72	3.8	3.3	5	Sandy loam
Lam Pao-RMC	0.22	1.11	4.4	2.6	69	Sandy loam
Lam Pao-LMC	0.37	0.71	3.9	0		Sandy loam

Table 19. Summary of relationship results between cooperation and conflict among water users and selected variables in 3 tank irrigation projects in Northeast Thailand, 1980.[a]

Independent variable	Participation: WUA activities	Participation: Maintenance	Cooperation among members	Conflict over water
Educational attainment	.2045**	.1980**		
Household membership number	.1973**			.1664*
Training attainment or experience	.2587**	.2005**		.3049**
Perceived benefit from ditch cleaning	.4000**	.3337**	.2525**	
Knowledge of irrigation practices	.2765**	.1514*		.1358*
Rice production income	.1712*	.1415*		.2143**
Family gross income	.2321**	.1853**		.1982**
Total farm area	.1612*			
Production of crop after constructing the irrigation system	.1936**			
Adoption of recommended farm practices		.1415*		.2095**
Agreement with the proposed rules and regulations of WUA				.1445*
Satisfaction with the work of WUA officer	.1741**		−.3206**	−.1369*
Satisfactory work by irrigation agent			.1506*	
Rating of irrigation service	.1503*		.2269**	−.1540*
Water users approached irrigation agent for help	.2754**	.2940**	.1811**	
Irrigation agent approached water users to help	.2884**	.3018**	.1630*	.1909**
Discussion with irrigation agent	.3560**	.2096**		.1756**
Exposure through communication channels	.1660*	.2099**	.1698*	

[a]WUA = water users association.

hypothesized that four categories of characteristics explain the relationships in the operation of the tank irrigation systems:

1. the farmers' demographic, experience, and personal knowledge characteristics;
2. farm production, practices, and returns;
3. degree of farmers' satisfaction with the water users association (WUA) activities, officers, and yield outcomes from irrigation; and
4. the rating of the irrigation service, the irrigation agent, and the sources of information on improved rice production practices and methods of irrigation.

The simple correlation results between the independent variables and the key elements are shown in Table 19. The relationship between 11 of the 18 variables was highly significant for participation in WUA activities. For participation in maintenance of the irrigation system, eight variables were highly significantly correlated. For cooperation among members in the water users association, only four variables were highly significantly correlated, and for conflict among members six independent variables were highly significant.

Except for three relationships — satisfaction with the WUA officers' performance as related to cooperation and to conflict occurrence and the rating of the irrigation service as related to the occurrence of conflict — all the other significantly related variables were positively correlated with the level of participation in operation and maintenance, in cooperation, and in conflict over water.

The variables with common highly correlated relationship to participation were education, training experience, perceived benefit from ditch cleaning, family gross income, occurrence of irrigation agent approaching farmers and farmers asking the irrigation agent for assistance, and discussions with the irrigation personnel. The relationships involving communication with the irrigation agents have strong implications for use in influencing farmer participation in operations and maintenance of the tank irrigation systems.

Economics of tank irrigation investments. A study was conducted to estimate the costs and benefits of the three tanks in the RID-IRRI sample. A general description of the three tanks is in Table 20.

Direct benefits to irrigated farming were measured using the *with versus without* basis. Farm production data in the three tanks were collected by field survey of 95 farmers with irrigation and 38 farmers without irrigation. The costs of construction, maintenance, and repairs for the tank projects

Table 20. Data on irrigable area for three Thailand sites, 1980.

Category	Huai Sathot	Huai Aeng	Huai Kaeng
Construction period	1967-69	1963-64	1966-76
Storage capacity (million m^3)	12	22	37
Planned wet season irrigable area (ha)	1280	2880	2400
Actual wet season irrigable area (ha)	1500	3640	1640
Actual wet season irrigated area (ha)	755	2860	910
Percentage actual irrigated to planned irrigable area	59	99	38

were taken from government records. The alternative crop used for the rainfed farmers who could not grow rice was cassava. The price used was the 5-year average. The internal rate of return for actual irrigated area was 7.4 for Huai Sathot, 10.7 for Huai Aeng, and zero for Huai Kaeng. Internal rate of return for planned irrigable area was 13.5 for Huai Sathot, 18.9 for Huai Aeng, and 6.7 for Huai Kaeng.

Economic analysis of intensity of irrigation facility investments. An analysis was made of the Nam Phong-Nong Wai Irrigation Project in northeastern Thailand, which serves 48,400 ha, to determine the optimal investment mix for a fixed budget and the level of maximum net returns. Data from government sources, interviews with local officials, and surveys among farmers in the already operating pilot areas were used. Linear programming was used to determine the optimum investment conditions.

The analysis indicated that the current government investment limit of $17.3 million should be allocated for land consolidation and intensive improvements on 37% of the area, and extensive improvements on 12%. The remaining 51% should remain unimproved.

The analysis indicated that if the level of investment were increased, the annual return to land and annual net benefits to the investment increase would reach a maximum at the $32 million investment level. At that level, the benefit-cost ratio would be 1.92 with an 18% internal rate of return. At the $32 million level of investment 63% of the project area would have intensive improvement and 37% would have extensive improvement.

Optimal enterprise combinations indicated 100% of the area in rice production for the wet season. For the dry season 82% of the consolidated area would produce rice and 18% would be fallow with 5% of the extensively improved area in rice, 6% in vegetables, and 88% fallow because of water shortages.

Soil and crop management

Soil characterization

Soil Chemistry Department

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The main areas of research were peat soil problems, nitrogen needs of rice, boron toxicity, zinc deficiency, influence of water regime and straw incorporation on soil fertility, soil management effects on zinc, availability of iron and chromium, and land characterization.

PEAT SOIL PROBLEMS

The first known instance of a rice response to zinc on a peat soil was observed on a Histosol (pH: 5.4; organic C: 27%; available zinc: 0.3 mg/kg) in Laguna province, Philippines.

In a test of 27 rices in a farmer's field, dipping the roots of seedlings in a 4% suspension of zinc oxide in water before transplanting increased grain yield by an average of 0.4 t/ha. The significant responses are shown in Figure 1. In a similar test with 10 rices on another Histosol in Rizal province, 8 entries had yield increases of 0.4-0.8 t/ha when zinc was applied.

The results indicate that one growth-limiting factor on about 30 million ha of peat lands in South and Southeast Asia can be removed by applying zinc.

NITROGEN FERTILIZER NEEDS OF RICE

The nitrogen-supplying capacity of tropical wetland rice soils may range from 50 to 1,000 kg/ha per season and crop yields may vary from 2 to 8 t/ha, but those factors are often ignored in fertilizer recommendations for rice.

A model to tailor nitrogen recommendations to soil and crop needs was proposed:

$$F_N = 40\ Y - 1000\ S_N,$$

where F_N = fertilizer N need in kg/ha
Y = yield target in t/ha
S_N = total soil nitrogen in percent

The model is based on these assumptions:

- 5% of total soil nitrogen is mineralized per season;
- efficiency of soil and fertilizer nitrogen is 50%;
- mass of soil in the top 15 cm of a 1-ha puddled field is 2×10^6 kg; and
- most rice roots are in the top 15 cm of soil.

The model was tested with data from 3 rice varieties grown at 2 levels of nitrogen on a soil containing 0.2% N at IRRI in the 1974-77 dry seasons. The results were:

Fertilizer N (kg/ha)	Mean yield (t/ha)	
	Actual	Calculated by model
0	4.7	5.0
140	7.9	8.5

Experiments in 1980 showed that the model worked satisfactorily for IRRI soils with nitrogen contents ranging from 0.104 to 0.237% (Fig. 2).

BORON TOXICITY

Soil test for boron. In 1980 tests, 0.05 *M* HCl, which is used to determine available zinc and copper in rice soils (1979 annual report), was tested as an extractant for available boron. The 0.05 *M* HCl extraction is a simple, reliable, rapid, and inexpensive method requiring no reflux equipment and barium chloride addition.

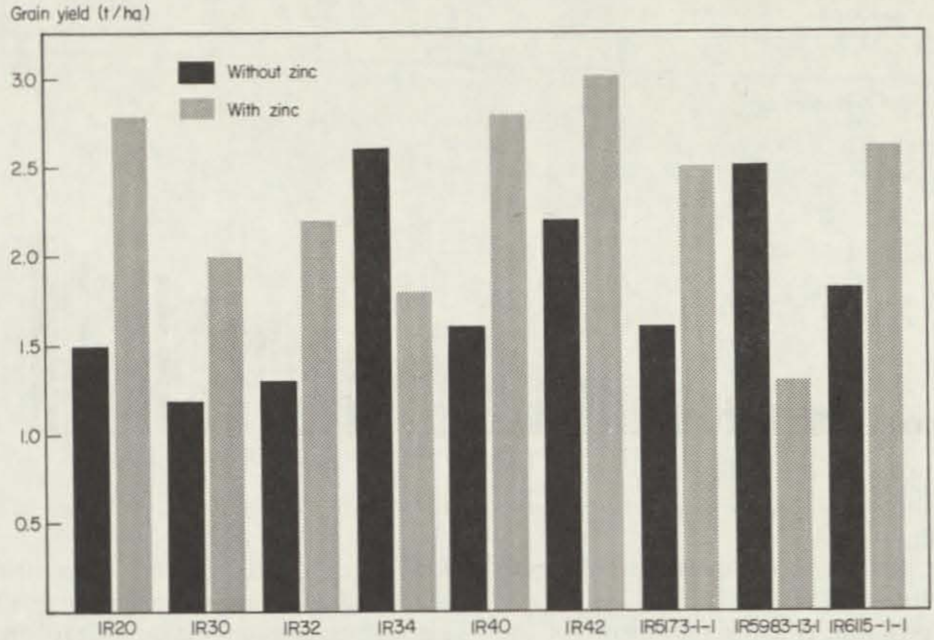
In 53 soils selected to give a range of available boron concentrations, pH ranged from 3.5 to 8.0, organic carbon content from 0.1 to 14%, and the available boron content from 0.2 to 24 mg/kg. Available boron was extracted and measured by the current procedure (reflux extraction with boiling barium chloride solution) and by the 0.05 *M* HCl method. Plant uptake of boron was measured by analyzing the plants grown on 53 soils in the greenhouse.

The 0.05 *M* HCl values for available boron correlated highly (r = 0.96**) with the reflux values, and plant boron concentration correlated better with the 0.05 *M* HCl method (r = 0.91**) than with the reflux method (r = 0.84**).

On 18 of the 53 soils, rice showed boron toxicity symptoms. All 18 soils contained >4.2 mg available boron/kg by the 0.05 *M* HCl method, and 13 gave >35 mg plant boron/kg, the toxic limit for rice.

Critical limits. Greenhouse and field experiments allowed the establishment of the following critical toxicity limits:

Culture solution	2.5 mg/liter
Soil	5 mg/kg (reflux)
	4 mg/kg (0.05 *M* HCl)
Soil solution	2 mg/liter
Plant (10 weeks old)	35 mg/kg

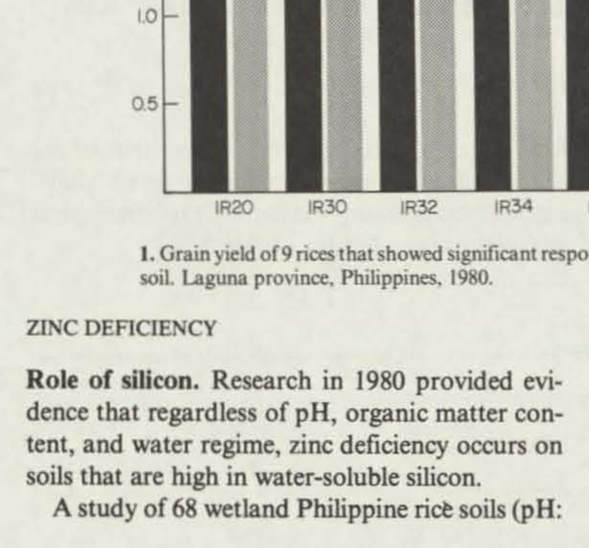


1. Grain yield of 9 rices that showed significant responses among 27 rices tested for zinc application on a peat soil. Laguna province, Philippines, 1980.

ZINC DEFICIENCY

Role of silicon. Research in 1980 provided evidence that regardless of pH, organic matter content, and water regime, zinc deficiency occurs on soils that are high in water-soluble silicon.

A study of 68 wetland Philippine rice soils (pH: 3.8 to 7.9; organic C: 0.8 to 22%; available Zn: 0.2 to 25 mg/kg) revealed that 34 were zinc-deficient (<1 mg available zinc/kg soil). All but three of the soils contained >100 mg water-soluble silicon/kg soil (Fig. 3). The mean silicon content was 164 mg/kg for the deficient soils and 80 mg/kg for the zinc-sufficient soils. Silicon apparently was tying up zinc as insoluble complexes or adsorption products.



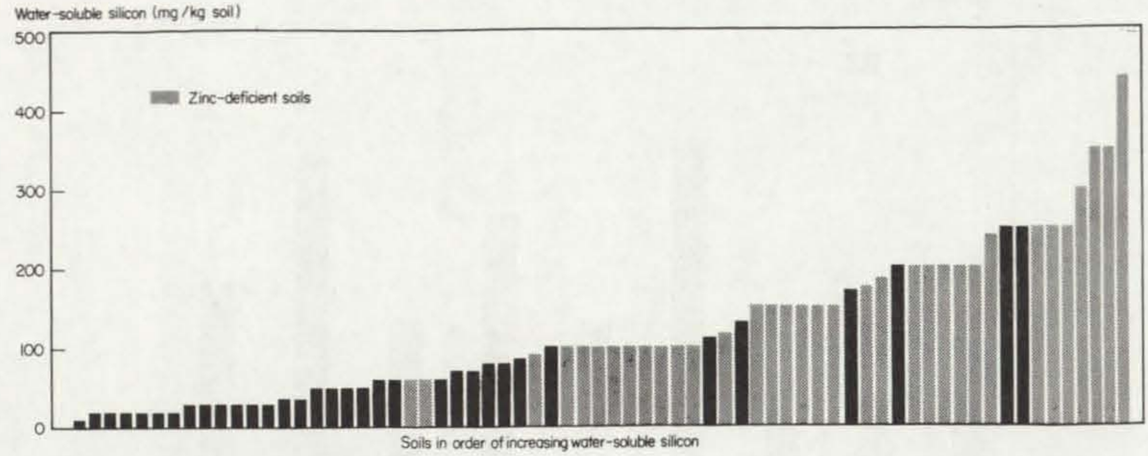
2. Relationship between grain yield on 6 soils of varying nitrogen content and the value of the expression ($1000\ S_N + F_N$), where Y = yield target in t/ha, N = total soil N in percentage, and F_N = fertilizer need in kg/ha. IRRI, 1980.

Heavy metal interactions. Some zinc-deficient rice soils have a high chromium and nickel content. To ascertain the role of these metals and copper on zinc deficiency, the effects of zinc and nickel at 10 mg/kg and copper and chromium at 5 mg/kg on rice growth were studied factorially on a zinc-deficient soil in a greenhouse experiment.

Zinc increased yield except when combined with chromium and copper. Copper, chromium, and nickel in combination depressed yield severely when zinc was absent, suggesting that those heavy metals may depress zinc availability.

WATER REGIME

Drum studies. The results of the 13th cropping experiment without fertilizers on 3 soils confirmed the benefits of flood fallowing on rice yield, nitro-



3. Correlation between water-soluble silicon and zinc deficiency. IRRI, 1980.

gen uptake, and the organic matter and nitrogen content of the soil (Table 1).

Field experiment. A long-term experiment on the influence of water regime with and without straw incorporation on the yield of rice and soil fertility continued. The 16th experiment in the series confirmed earlier findings that flood fallowing and straw incorporation increase grain yield and improve soil fertility (Table 2).

Table 1. Effects of 3 water regimes, without fertilizers, averaged for 3 soils on rice yield, nitrogen uptake, and soil nutrient status after the 13th crop in the 200-liter drums. IRRI, 1980.[a]

Water regime	Yield (g/drum)		Nitrogen uptake (g)	Organic carbon (%)	Total nitrogen (%)
	Straw	Grain			
Flood fallow	104 a	127 a	2.11 a	1.75 a	0.169 a
Flood fallow with MSD[b]	94 a	105 a	1.63 b	1.75 a	0.172 a
Dry fallow	66 b	72 c	1.12 c	1.24 b	0.123 b
Dry fallow with MSD	66 b	75 c	1.14 c	1.16 b	0.117 b

[a]Separation of means in each column by Duncan's multiple range test at the 5% level. [b]Midseason soil drying.

Table 2. Influence of water regime and incorporation of straw from preceding crop on rice yield and fertility status of Maahas clay after the 16th crop. IRRI, 1980.

Treatment[a]		Grain yield (t/ha)	Organic carbon (%)	Total nitrogen (%)	Olsen phosphorus (mg/kg)
Water	Straw incorporation				
Dry fallow	No	2.9	1.68	0.172	8.0
	Yes	3.4	2.02	0.207	10.3
Difference		0.5**	0.34**	0.035**	2.3**
Dry fallow with MSD	No	3.5	1.84	0.192	8.3
	Yes	4.1	1.98	0.208	8.5
Difference		0.6**	0.14**	0.016ns	0.2ns
Flood fallow with MSD	No	4.5	1.80	0.181	6.0
	Yes	5.0	2.00	0.205	7.5
Difference		0.5**	0.20**	0.024*	1.5*

[a]MSD = midseason soil drying.

Table 3 Effects of straw incorporation every season, without fertilizer, on rice yield, nitrogen uptake, and soil nutrient status averaged for 3 soils after the 11th crop. IRRI, 1980.

Straw incorporation	Yield (g/drum)		Nitrogen uptake (g)	Organic carbon (%)	Total nitrogen (%)	Olsen phosphorus (mg/kg)	Exchangeable potassium (mmol/kg)
	Straw	Grain					
No	68	77	1.19	1.38	0.130	8.4	3 2
Yes	89	112	1.53	1.62	0.157	9.8	6 3
Difference	21**	45**	0 34**	0.24**	0.027**	1.4*	3.1**

Table 4. Effects of 4 straw treatments on rice yield and the nutrient status of Maahas clay after the 16th crop. IRRI, 1980.[a]

Straw treatment	Grain yield (t/ha)	Organic carbon (%)	Total nitrogen (%)	Olsen phosphorus (ppm)
Removed	3.2 b	1.56 b	0.167 c	9 b
Burned	3.4 b	1 67 b	0.173 bc	12 b
Incorporated	4.1 a	1.82 a	0.182 b	12 b
Composted and added	4 2 a	1.89 a	0 203 a	27 a

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

STRAW MANAGEMENT

Drum studies. Adding straw at 5 t/ha each season, without fertilizer, significantly increased rice yield and nitrogen uptake, and improved the nutrient status of the soil. Data for the 11th crop are in Table 3.

Field experiments. The results of a long-term experiment in IRRI fields confirmed earlier findings that straw incorporation each season, without fertilizer, increases yield and improves the nutrient status of the soil (Table 4).

SOIL MANAGEMENT EFFECTS ON UPTAKE OF ZINC, IRON, AND CHROMIUM

Zinc. In dry season experiments in a field and in drums with a neutral, noncalcareous, very poorly drained zinc-deficient soil in the Philippines, low-cost methods were tested to minimize zinc deficiency in wetland rice. One treatment comprised land ridging and planting the seedlings along the base of the ridges to improve aeration and zinc availability in part of the root zone. The practice reduced deficiency symptoms and improved growth and total dry matter production. However, it proved less effective than application of zinc oxide, either broadcast and incorporated or as a root dip before transplanting.

In a wet season experiment, the ridging method was compared with methods of treating seedlings with zinc for different periods before transplanting. Seedling treatments were in a seedbed outside the deficient area without added zinc, and at the zinc-deficient site with low zinc oxide applications in the seedbed.

The ridging treatments were less effective than other methods because of a greater weed problem and lack of control of water levels. The two highest yielding treatments were root dipping of 20-day-old seedlings in 4% ZnO suspension and transplanting 40-day-old seedlings grown in a seedbed outside the zinc-deficient soil area. Thus there appears to be an alternative to zinc application in zinc-deficient, perennially wet soils.

Iron and chromium. The uptake and transport of iron and chromium in plants grown in soils ranging from well-drained to very poorly drained were reviewed and studied.

In wetland rice growing on poorly drained neutral soils, iron concentrations ranged from about 100 to several thousand mg/kg dry matter in shoots 8 weeks after transplanting as well as in straw at maturity, without causing iron toxicity symptoms. There was no clear relation with plant zinc contents, which were generally above 15 mg/kg. In a treatment on a drained soil, iron concentrations were significantly lower, about 200 mg/kg, at zinc contents no higher than in the other treatments.

Chromium normally has a low mobility in plants. Chromium concentrations generally range from 0.1 to 5 mg/kg in above ground parts, and from less than 0.01 to about 0.1 mg/kg in grain. In a drum experiment in which a neutral, zinc-deficient soil material was kept wet throughout the growing season, chromium contents of the rice plants were about 5 mg/kg 4 and 8 weeks after transplanting and more than 10 mg/kg at maturity. Total chromium contents in rice grain were in the same range. Chromium seems to be more mobile and to accumulate to higher concentrations in rice plants on very poorly drained, reduced soils than in plants on well-drained soil.

LAND CHARACTERIZATION

A guide was developed to enable researchers with different backgrounds to do land characterization and soil sampling for experiments on wetland rice. The guide was tested in part of the INSFFER network.

Land characterization centers on the hydrology, landform, and soil of the site where an experiment is conducted, and uses terms understood by a wide range of persons. Combined with a limited set of analytical data on the soil samples, the guide allows:

- diagnosis of conditions limiting yield or response at the site;
- comparison between sites, sorting of the results from many sites into groups, and explanation of yield differences by observed features;
- prediction of results and formulation of advice in farmers' fields with similar conditions.

Soil and crop management

Biological nitrogen fixation

Soil Microbiology Department

Effect of nitrogen fertilizer on heterotrophic N_2 fixation in long-term fertility trials. Surveys of heterotrophic nitrogen fixation activities associated with rice and in the soil in long-term fertility plots at Maligaya, Nueva Ecija province, and at Luisiana, Laguna province, showed that heterotrophic N_2 fixation was not significantly affected by nitrogen fertilizers. Field acetylene reduction assays (ARA) were made to determine N_2 fixation in association with the rice plant (IR42) and in the soil among plant hills. At Maligaya, no-fertilizer (0-0-0) and NPK fertilizer (70-60-60 kg/ha) plots were compared; at Luisiana PK fertilizer (0-40-40 kg/ha) and NPK fertilizer (60-40-40 kg/ha) were compared. ARA were made four times during one rice crop.

Plant and soil ARA activities were much lower in acid (pH 5.2) Luisiana soil than in neutral (pH 6.8) Maligaya soil. Soil and plant ARA activities in both soils did not statistically differ in response to fertilizer application.

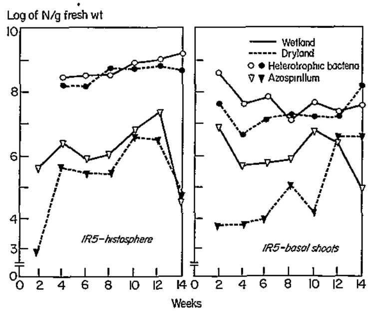
Differences in N_2-fixing population and activities between dryland and wetland rice. IR5 and OS4 were grown as wetland and dryland crops. Acetylene reduction activities were measured in situ and in water culture, and aerobic N_2-fixing bacteria in the histosphere and lower portion of shoots were counted. ARA values associated with dryland rice were less than 3 μmol C_2H_4/hill per day (in situ assay) or less than 0.4 μmol C_2H_4/hill per 5 hours (water culture assay), and were much lower than those of wetland rice.

The population of Azospirillum in or on the root was much lower in dryland rice than in wetland rice, despite little difference in the number of heterotrophic bacteria (Fig. 1). The difference in Azospirillum was greatest in or on the basal shoots. The contribution of the lower portion of the shoot to N_2 fixation associated with rice is, therefore, likely to be characteristic of wetland rice plants.

Incidence of nitrogenase positive bacteria among the heterotrophic bacteria in the histosphere ranged from 9% to 61% in wetland rice, and 1% to 34% in dryland rice. Among the heterotrophic bacteria isolated from the dryland rice histosphere and basal shoots, none was N_2-fixing, Pseudomonas-like bacteria. The results clearly showed that wetland soil is favorable for the establishment of aerobic N_2-fixing bacteria in rice plants.

Incorporation of $^{15}N_2$ gas into rice plants. Rice plants growing in pots of flooded soil were exposed to $^{15}N_2$-enriched atmosphere for 3-13 days in a gastight chamber. The soil surface was covered with black cloth to reduce the activity of phototrophic N_2-fixing microorganisms. Direct evidence for heterotrophic nitrogen fixation associated with rice roots was obtained in four experiments. After 3 or 7 days exposure to $^{15}N_2$ gas, no enrichment of ^{15}N in the shoot above the black cloth was detected despite enrichment in the root and soil. Higher or equal enrichment of the subsurface root as compared with the surface root could not be explained by phototrophic N_2 fixation at the surface of flooded soil.

The apparent rate of nitrogen fixation in rice roots was much higher at the heading stage than at tillering stage. To examine the translocation of the newly fixed nitrogen to the plant shoot, rice plants exposed to $^{15}N_2$ gas during heading were kept in ambient air until maturity. The incorporation of ^{15}N during exposure to $^{15}N_2$ was confirmed by analysis of ^{15}N content in one tiller just after exposure. The ^{15}N enrichment in the shoot increased with time, and at plant maturity the shoots contained more of total ^{15}N than the roots (Table 1). Panicles that matured later were more enriched than the early-maturing panicles. The pattern of increasing enrichment with time is compatible with the concept that the newly fixed N_2 becomes avail-



1. Microbial populations of wetland and dryland rices. IRRI, 1980.

Table 1. ^{15}N enrichment in single tillers harvested immediately after exposure (12.8 days) at the tillering stage and at harvest (43 days after exposure to $^{15}N_2$). IRRI, 1980.

Plant part and soil	Total nitrogen (mg)	Atom N excess (%)	^{15}N Mg	^{15}N % of total
Immediately after exposure[a]				
Panicle	0.79	0.07		
Dead flag leaf	3.18	0.05		
2d leaf	7.11	0.03		
3d leaf	2 11	0.01		
Dead lower leaves	1 13	0.01		
Outer leaf sheath	0.47	0 04		
Inner leaf sheath	0.77	0.09		
At maturity				
Early harvested panicle	54.7	0.28	0 16	3 5
Panicle	99 5	0.34	0.43	9.5
Shoot	65 1	0 14	0.092	2.0
Lower shoot	5.8	0 27	0.016	0.4
Basal node	4.2	0.50	0.021	0 5
Surface root	0 8	0.44	0 004	0.1
Subsurface root	10.9	0.90	0.097	2 1
Surface soil	108.0	0.12	0 130	2.9
Subsurface soil	3240.0	0.11	3 570	79.0

[a]Analysis to 2 decimal places because of small sample size

able to the plant after it is incorporated in bacterial cells and subsequently mineralized. Most of the ^{15}N fixed remained in the soil.

Loss of nitrogen during nitrogen balance studies. In nitrogen balance studies in flooded pots, labeled ammonia at 2 rates (10 kg N/ha and 160 kg N/ha) was applied to pots and mixed thoroughly with soil. After three crops of flooded rice, the balance of total nitrogen and the applied ^{15}N was determined. The addition of the small amount of mineral nitrogen did not decrease the positive nitrogen gain (100-120 mg N/pot per crop), but the larger amount depressed N_2 fixation almost completely. The recovery of $^{15}N_2$ was 92% or more. It was concluded that loss of soil nitrogen was negligible and that net positive gain of nitrogen in planted pots almost equaled biological N_2 fixation.

Inoculation of N_2-fixing bacteria on a sterile rice plant. Three types of aerobic N_2-fixing bacteria were isolated from the roots and basal shoots of wetland rice grown in an IRRI field — Azospirillum (*A. lipoferum*), Enterobacteriaceae (mostly *Klebsiella pneumoniae* and some *Enterobacter cloecae*), and Pseudomonas-type (formerly Achromobacter-type). N_2 fixation of the bacteria in association with rice was tested.

IR26 was grown in 500-ml bottles in a sterile

Table 2. The population of N_2-fixing bacteria inoculated into the rice plant and their activity. IRRI, 1980

Treatment	Most probable no /g fresh root	Acetylene reduction activity in 20 h[a] (nmol C_2H_4/plant)
1. Noninoculated	0	200 ± 40
2. Pseudomonas-like	1 × 10⁷	250 ± 70
3. Enterobacteriaceae	1 9 × 10⁶	560 ± 250
4. Azospirillum[b]	4 × 10⁵	1500 ± 470
5 Mixture of 2, 3, 4	9 × 10⁶	1900 ± 370

[a]Average and standard error of 3 replications [b]On malate medium.

vermiculite mixture. One bottle contained 18 mg nitrogen as ^{15}N-labeled ammonium sulfate. A bacterial suspension was added just after the sterile rice seedling was transferred and the rice was grown for 9 weeks under flooding. Acetylene reduction activity was measured, roots were subjected to microbial analysis and shoots to ^{15}N analysis. Acetylene reduction activity was highest when Azospirillum was inoculated, despite the lower MPN (most probable number) count of Azospirillum (Table 2). The activity was more than 10% lower than the activity in the field grown to wetland rice. Interaction with other non-N_2-fixing microflora may be involved in N_2-fixation associated with wetland rice in the field.

AUTOTROPHIC N_2 FIXATION

Fate of algal nitrogen in soil. To clarify the fate of nitrogen that is biologically fixed by blue-green algae, experiments were initiated with a ^{15}N-labeled algal mass. Nostoc was grown in the laboratory and labeled with ^{15}N by nitrate. The cells were collected and used for experiments. In one pot, fresh Nostoc cells were buried at 5-cm depth; in two pots, Nostoc cells were spread on the surface and mollusks were added to one of the pots. Rice seedlings were transplanted into the pots. At 14 days after transplanting and at harvest, soil cores were taken to analyze soil nitrogen and its ^{15}N content.

In the pot with mollusks, algal cells were quickly digested and mollusk excreta accumulated on the surface. Without mollusks, blue-green alga cells equally decomposed.

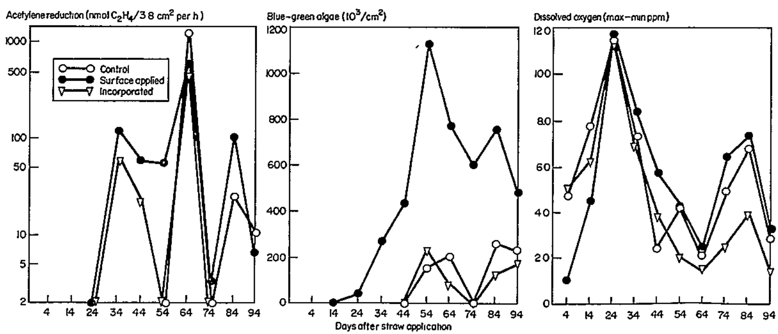
At harvest, rice grain and straw had 12% of the surface-applied algal ^{15}N, regardless of mollusk addition, and 38% of the incorporated algal nitrogen. Digestion of algae by mollusks did not change the pattern of ^{15}N distribution in soil and plants. Recovery of ^{15}N from soil and rice was almost 100% in all 3 treatments. At harvest, more ^{15}N was found in the 1- to 6-cm layer than at the top or 1-cm, even when alga was surface applied.

Nitrogen enrichment at the surface of flooded soil. In preliminary greenhouse experiments, covering pots with black cloth eliminated surface accumulation of nitrogen. In the field, 1-m^2 frames were placed in plots and 3 treatments (without black cloth cover and insecticide, without black cloth but with insecticide, and with insecticide and black cloth) were compared. The plots that received insecticide and were exposed to light had a statistically significant (7 kg N/ha) increase of total nitrogen content of the surface 3 mm of soil. This accumulation represented the residue of newly fixed nitrogen, which had not moved down or had not been taken up by plants or undergone loss.

Algae-predator relation in the paddy. The addition of insecticides to a paddy induces algal development, a phenomenon explained by the elimination of predator pressure by insecticides. Data collected from outside and within IRRI identified two important groups of predators — gastropods and ostracods — with the potential to prevent or limit algal growth and N_2 fixation. The biomass of snails (mainly *Lymnaea* sp.) at IRRI ranged from a few kilograms to 1.5 t fresh weight/ha. A greenhouse experiment demonstrated an immense reduction in acetylene reduction activity when established algal biomass was grazed by an average population of snails. After 2 days, the activity decreased to 25% of that of the control.

Field densities of ostracods (subclass Crustaceae) in IRRI plots where experiments on surface accumulation of nitrogen were conducted were consistently high, ranging from a few hundred to 10,000/m^2. The densities of ostracods in 250-ml water samples were 115 in the treatment with insecticide, 4 with insecticide plus black cloth, 6 with no insecticide, and 253 with insecticide plus straw. Insecticide encouraged the population of ostracods. The population of the snail (*Lymnaea viridis* and *L. requetti*) was slightly depressed by insecticide but not completely eliminated. The results suggest that repeated application of insecticide (mainly Furadan) established the tolerant microfauna.

Effect of straw on soil surface on algal growth. The experiments described immediately above suggested enhancement of blue-green algae growth in plots that received rice straw on the soil surface. To demonstrate the effect on phototrophic N_2 fixation, tests were made in 60- × 60-cm plots with transplanted rice. Treatments without straw, with surface-applied straw, and with incorporated straw were compared. Figure 2 shows the change in light-dependent, aerobic, acetylene reduction activity and the number of cyanobacter propagules in surface cores. The stimulation of blue-green algae by



2. N_2-fixation rate, counts of blue-green algae, and photosynthetic rate as affected by straw application. IRRI, 1980

surface-applied straw was remarkable.

In control and straw-incorporated plots, phototrophic acetylene reduction activity showed sporadically high values, but in the surface-straw plot, higher phototrophic activity was maintained from 34 days to 64 days after the application (Fig. 2).

Respiratory activity of floodwater, estimated by dissolved oxygen content and pH at night, was highest in the plots with surface straw throughout the experiment. But the differences among plots became smaller 34 days after application. Photosynthetic activity of floodwater, approximated by the difference between dissolved oxygen content at night and in the daytime in the surface-straw plots surpassed that in the other plots 34 days after application. During this period, algal N_2 fixation was also stimulated.

AZOLLA-ANABAENA SYMBIOSIS

Dual culture of rice and azolla by wide row spacing. By wide double-row spacing of the rice plants (53-cm-wide row was alternated with 13.3-cm-wide row), several crops of azolla were grown during one crop of rice. Nitrogen accumulated by azolla amounted to about 70 kg N/ha. Three treatments — no nitrogen and no azolla, chemical nitrogen only, and azolla dual culture — were compared on the same plots in continuous cropping. From the fourth crop, the field was changed and one crop of azolla was grown before transplanting. The summary for five crops of rice is in Table 3. The incorporation of azolla increased rice yield by 1 t/ha and was comparable to 70-100 kg N/ha as chemical nitrogen fertilizer.

Temperature response of azolla collection. More than 30 strains of azolla, including *A. pinnata, A. mexicana, A. filiculoides, A. caroliniana,* were maintained at IRRI in flasks containing mineral nutrient solution. To screen azolla strains for tolerance for high temperature, they were grown in culture solution at 3 day/night temperature levels: 37°/29° C (av 33° C), 33°/25° C (av 29° C), and 26°/18° C (av 22° C). Tests for 27 strains covered three collections of *A. filiculoides,* one collection each from *A. caroliniana* and *A. mexicana*, and the rest were *A. pinnata*. The description of the azolla collection is in Table 4.

For most strains (except *A. filiculoides*) maximum relative growth rate, which in most collections occurred during the first week, was higher at 33° C than at 22° C. As the ferns grew, growth slowed down more severely at higher temperature.

At 22° C, the period for attaining the maximum biomass was 30-50 days and the highest value was 14 g N/m^2 or 320 g dry weight/m^2 produced by *A. caroliniana. A filiculoides,* a German strain, had 12 g N/m^2 or 290 g dry weight/m^2.

Table 3. Effects of soil incorporation of azolla on rice yield IRRI, 1978-80.

Crop	Cropping duration and variety (from transplanting to harvest)	Chemical N applied (kg/ha)	Azolla crops incorporated (no.) and N content	Grain yield[a] (t/ha)		
				No N	Chemical N	Azolla
First	Dec 1978-Apr 1979 121 days IR26	107	6 crops 105 kg N/ha	6.3 a	8.3 a	6.7 a
Second	May-Aug 1979 124 days IR42	60	4 crops 70 kg N/ha	3.7 b	4 5 b	5.7 a
Third	Nov 1979-Mar 1980 104 days IR43	100	4 crops 70 kg/ha	2.7 b	2.2 b	3 6 a
Fourth[b]	Feb-Jun 1980 121 days IR42	60	4 crops 70 kg N/ha	5.2 b	6 2 a	6.2 a
Fifth	Jul-Nov 1980 106 days IR42	60	4 crops[c] 60 kg	3 3 b	4.7 a	5.0 a

[a]Separation of values in a row by Duncan's multiple range test at the 5% level. [b]Field used different from that from previous crop. One crop of azolla was grown before transplanting Plant density was half of the previous one [c]One crop of azolla was grown before transplanting

Table 4. Azolla collections. IRRI, 1980.

Species	Number	Designation	Collection site	Country	Year of collection
A pinnata R. Brown	1	Bicol I	Santo Domingo, Albay	Philippines	1975
	2	Malaysia	Bumbong Lima, Butterworth	Malaysia	1977
	3	Bogor	Bogor	Indonesia	1977
	4	Banaue	Banaue, Ifugao	Philippines	1977
	5	Bangkok	Bangkok	Thailand	1977
	6	DAT 15		Thailand	1978
	7	DAT 16		Thailand	1978
	8	DAT 17		Thailand	1978
	9	Cheng Mai	Sampatong, Cheng Mai	Thailand	1978
	10	Sri Nagor	Sri Nagor, Dacca	Bangladesh	1978
	11	Tangail	Tangail	Bangladesh	1978
	12	Bharatpur	Bharatpur	Nepal	1978
	13	Khumaltar	Khumaltar, Lapitpur	Nepal	1978
	14	Bicol II	Santo Domingo, Albay	Philippines	1978
	15	Apalit	Apalit, Pampanga	Philippines	1978
	16	Floridablanca	Floridablanca, Pampanga	Philippines	1978
	17	Vietnam Green 1	Hanoi	Vietnam	1978
	18	Vietnam Green 2	Hanoi	Vietnam	1979
	19	Vietnam Purple	Hanoi	Vietnam	1978
	20	Vietnam Wild	LaVan, Thai Vinh	Vietnam	1979
	21	Putian Zhu	Fujieng	China	1978
	22	Tanchang	Tanchang, Shandong	China	1979
	23	Cuttack	Cuttack, Orissa	India	1978
A. filiculoides Lamark	101	East German		German Democratic Republic	1979
	102	Hawaii	Hawaii	USA	1976
	103	California	Tisdale, California	USA	1978
A. mexicana Presl.	201	California	Graylodge, California	USA	1978
A. caroliniana Wild	301	Ohio	Ohio	USA	1978

At 29° C, the maximum biomass was attained in 20-35 days. The highest value was 6.3 g N/m^2 or 150 g dry weight/m^2 by *A. caroliniana.* At 33° C, most azolla yielded less than 4 g N/m^2.

Most strains gave the maximum biomass after 13-23 days, while some strains could grow up to 30 days, resulting in higher maximum biomass. The highest maximum biomass at 33° C was 5.5 g N/m^2 or 140 g dry weight/m^2 by *A. pinnata* from Cheng Mai, Thailand.

The formation of ammonia in the medium was examined. Ammonia formation occurred mostly under crowded growth. At 33° C some collections of *A. pinnata* and *A. mexicana* released or formed 0.3-0.8 ppm ammonia during their initial exponential growth stage.

Growth of azolla collection in the field. Azolla collections — *Azolla pinnata,* Bangkok, Cuttack, Vietnam Green, Khumaltar, DAT 15, Pampanga, Tangail, and *Azolla caroliniana* Ohio — were grown in an IRRI field with phosphorus fertilizer at 3.75 and 7.5 kg P_2O_5 as superphosphate/ha applied every 3 days for 2 weeks. Azolla was grown four times a year. The effect of phosphorus on the maximum biomass was statistically significant only in the hot dry season (April-May).

The sum of the maximum biomass (fresh weight) for four seasons did not differ significantly among collections. *Azolla caroliniana* grew well in Los Baños. Among the collections this fern showed maximum growth in controlled temperatures — 33° day/25° C night. Thus, *A. caroliniana* is considered suitable for the tropics.

Factors affecting sporulation of azolla. At IRRI, only a few azolla collections formed sporocarps — *A. pinnata* Tancheng, *A. filiculoides* from eastern Germany, and *A. mexicana.* Those collections produced sporocarps to such an extent that the material would be useful for the sporulation experiments. The germination rate of zygotes in experiments was always low.

The effects of several environmental factors on the sporulation of *A. mexicana* were observed. Low temperature stimulated sporulation or its development (Table 5). As sporulation was stimulated, the ratio of microsporocarps to megasporo-

Table 5. Effect of temperature on the sporulation of *A. mexicana* in a natural-light growth chamber at IRRI (70% relative humidity), 18 Jan to 4 Feb 1980.

Temp (°C) at 12 h day/12 h night	Mic: meg[a] (%)	Mic (no./g fresh wt of azolla)
36°/27°	6.5 ± 2.4	9.7 ± 3.5
29°/21°	31 2 ± 3.2	65.0 ± 4.1
26°/18°	50.0 ± 2.0	82.1 ± 3.0
20°/15°	35.7 ± 2 9	67.6 ± 5.4

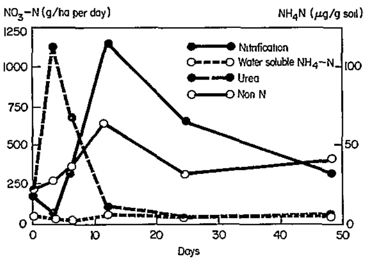
[a]Ratio of microsporocarps (mic) to megasporocarps (meg).

carps increased.

In the greenhouse where temperature was always higher than 25° day/20° C night, these combinations of photoperiod — 12 hours day/12 hours night, 15 hours/9 hours, and 8 hours/16 hours — did not produce sporocarps, but in temperature controlled at 25° C (12-hour day)/20° C (12-hour night) sporocarps were formed. It is unlikely that photoperiod is a main factor in sporulation. Phosphorus deficiency stimulated sporulation, whereas iron deficiency and the addition of ammonium sulfate (5 ppm N) depressed sporulation.

The addition of soil water where *A. mexicana* has long been grown or the presence of decomposing *A. mexicana* stimulated sporulation, suggesting the presence of antheridogens (antheridium-forming factors) in the plant itself. The supernatant of azolla water extract (low molecular compound) stimulated sporulation at 0.2% in culture solution. The active substance or substances were not identified.

Phosphorus nutrition of azolla. Phosphorus is one of the governing factors in the growth of azolla in the field. By using continuous flow culture, a



3. Nitrification activity of surface soil and ammonium nitrogen content of water after surface application of urea IRRI, 1980.

minimum level of phosphorus in the nutrient solution was determined. *A. pinnata* Bangkok showed phosphorus deficiency symptoms at 0.03 ppm P, but not at 0.06 ppm.

Various strains of azolla were grown in continuous flow 0.03 ppm P culture in the greenhouse.

The ability to grow at the 0.03 ppm P level was highly varied. Growth of species other than *A. pinnata* during 11 days was 30-10% of the check strain *A. pinnata* Bangkok. Among *A. pinnata*, the strain from Cuttack grew poorly in 0.03 ppm P and was characterized by fragmented fronds and deformed roots.

NITROGEN TRANSFORMATION

Nitrification in the paddy. An in situ assay method of nitrification in the paddy was developed. ^{15}N-labeled nitrate was added to undisturbed soil cores and from the dilution of ^{15}N in nitrate, nitrification rate was determined. The rate of nitrate consumption was determined simultaneously.

The changes of nitrification activity were monitored after the surface application of urea (60 kg N/ha). Ammonium content in floodwater reached the peak 3 days after the application, followed by a decrease (Fig. 3). Nitrification reached its peak 12 days after the application, following which the rate in the fertilized plots dropped to the level of unfertilized plots. Because the paddy soil was puddled before transplanting, the oxidized and reduced layers were mixed. The delay in the development of nitrification activity may be explained by the differentiation of the layers, which occurred after initial rapid oxygen uptake.

Nitrification during dry season. Various ways of conserving moisture in dry season maize after wet season rice were examined. Included were mulching and various tillage practices. The changes of in vitro nitrification activities were monitored. Four treatments — combination mulching (no mulch vs mulch) and tillage (no tillage vs one rototillage) — were compared. Soil (0-15 cm) was sampled periodically and 3 cores from one plot were mixed. Without adding water, urea was added to the sampled soil at 100 µg N/dry soil before soil incubation at 30° C for 10 and 20 days. Nitrate content was determined.

As moisture decreased, nitrification rate also decreased. The rate was minimum at 95 days after

Table 6. ^{15}N-N ratio in deepwater rice in shallow and deepwater at IRRI and 3 Thailand sites, 1980.

Site	Water depth	Light exposure[a]	Total N (mg/pot)	^{15}N (mg/pot)	^{15}N-N ratio (%)
Bangkhen	Shallow	+	718	111	15.4
Huntra	Semideep	+	979	86	8 8
Ongkarak	Deep	+	952	98	10.2
IRRI	Shallow	+	502	194	38.6
	Shallow	–	504	230	45.6
	Deep	–	737	201	27.2
	Deep	–	530	114	21.5

[a]+ = with light exposure, – = no light.

tillage when the moisture content was minimum. At that time, differences in nitrification rate among the treatments were statistically significant. The mulch treatment increased the moisture content of 0-15 cm layer and favorably affected the nitrification rate. The population of ammonium oxidizers was almost constant (3,000/g) during the dry season.

Nitrogen nutrition of deepwater rice — role of epiphytic blue-green algae. Little is known about sources of nitrogen for deepwater rice. To study nitrogen source a ^{15}N-dilution technique was used. Pots containing soil with ^{15}N ammonium salt were placed in shallow water (5 cm) and deepwater fields.

In Thailand, pots in shallow water were studied at the Department of Agriculture, Bangkhen. At Huntra and Ongkarak, pots were placed in a deepwater rice field (at Huntra water was not deeper than 50 cm).

At IRRI, deepwater rice DW6255 was grown in pots with ^{15}N-ammonium salt and submerged in a deepwater field tank. For shallow water tests, some pots were placed on an elevated platform in the deepwater tank.

The surface of some pots in shallow water was covered with black cloth to prevent algal growth on the soil surface. In deep water, the submerged portion of some plants was covered with black cloth to prevent epiphytic algal growth on the rice plant. Total N and ^{15}N uptake in the aboveground portion is shown in Table 6.

The total plant ^{15}N contents were lower in deep water than in shallow water (Table 6). This suggests that nitrogen in deepwater rice may come either from water or atmospheric nitrogen or from both. In exposed plants, the aquatic roots and the submerged leaf sheaths, where growth of epiphytic blue-green algae was abundant, had lower ^{15}N content than they had in shaded plants. This suggests that nitrogen was fixed by blue-green algae in those tissues.

Role of subsoil in wetland rice growth. About 4 t yield/ha, or more, is obtained at IRRI without nitrogen fertilizer. The depth of the organic-matter-rich layer is greater than 20 cm in most fields. To see if nitrogen and other elements come from the soil below the plow pan, rice was grown in plots with a plastic sheet at 17- to 20-cm depth. The soil profile is characterized in Table 7. The growth of rice was poorer in plots with plastic bottom than in control plots. Grain yield and nitrogen uptake of rice were 4,300 kg/ha and 80 kg N/ha in the control plots and 2,700 kg/ha and 40 kg N/ha in plastic-bottomed plots.

Ammonia and nitrous oxide loss from the field. Ammonia volatilization from applications of ammonium sulfate to a wet season crop of flooded rice at IRRI was measured directly by a micrometeorological technique. Before transplanting, ammonium sulfate (80 kg N/ha) was broadcast on the flooded soil and incorporated by harrowing. At panicle initiation, 40 kg N/ha was broadcast. The pH of the floodwater varied from 7.5 to 9.5 during the experiment.

Loss of ammonia was detected immediately after application of ammonium sulfate and continued for about 7 days. Ammonia volatilization rates were highest in the middle of the day and declined each evening, following the diurnal varia-

Table 7. Characteristics of the soil profile IRRI, 1980.

Depth (cm)	Profile	Bulk density (g/g)	pH	Total nitrogen (%)	Mineralized nitrogen (µg/g)	Bacteria counts (10^6/g) Viable cells	Bacteria counts (10^6/g) Spores
0-20	Ap	0.772	7.1	0 153	29.6	16	1.5
20-35	A	0.944	6.7	0.074	17.6	3	0.8
35-55	A	0.957	7.0	0.055	15.5	4	0.5
55-70	B	0.916	7.2	0.047	15.8	0.4	0.04

tions in water temperature and wind speed.

More ammonia was lost from the fertilizer applied at panicle initiation (10.6%) than from the preplanting application (5.1%). The overall measured loss of ammonia was small and amounted to about 7% (8.4 kg N/ha) of the total applied.

Nitrous oxide losses, measured with a chamber system, amounted to only 0.1% of the nitrogen applied as ammonium sulfate, and occurred a few days after broadcast of ammonium salt.

MICROBIOLOGY OF DRYLAND RICE AFFECTED BY SOIL SICKNESS

A higher incidence of *Fusarium moniliforme* occurs in the roots of continuously cropped dryland rice than in the roots of a dryland rice crop in a rotation. This was confirmed in 1980 wet season tests. The difference in Fusarium composition was also found in soil dilution plate counts. Root residues taken 4 weeks after the previous crop harvest were preferentially colonized by *F. moniliforme*, indicating the survival of the fusaria on root residues. The pathogenicity of *F. moniliforme* to dryland rice was examined. *F. moniliforme* culture was inoculated into a healthy crop-rotated soil, but rice growth was not retarded.

Soil and crop management

Soil fertility and fertilizer management

Agronomy and Soil Chemistry Departments

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NITROGEN FERTILIZER EFFICIENCY

Agronomy Department

Irrigated rice. Field experiments at IRRI evaluated sulfur-coated urea (SCU) broadcast and incorporated, point placement of urea supergranule, prilled urea applied in split doses (two-thirds basal and incorporated and one-third topdressed 5-7 days before panicle initiation), and prilled urea, applied basally and incorporated. The test varieties were early-maturing IR36 and IR50, and medium-maturing IR46 and IR48. The experiments were part of the fourth trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER).

In the dry season, the mean yield of IR46 was higher than that of IR36 and the response to nitrogen was significantly higher than that of IR36 at higher nitrogen rates (Table 1). For each increment of applied nitrogen, the SCU treatment gave the highest yield, followed by supergranule placement. Split application of prilled urea was not better than broadcasting and incorporating all at planting at rates of 54 kg N/ha and 108 kg N/ha. The yields of both varieties with SCU and urea supergranules at 27 kg N/ha were similar to those with prilled urea at 54 kg N/ha, which confirmed the advantage of SCU and urea supergranules in increasing nitrogen fertilizer efficiency.

In the wet season, the superiority of SCU and urea SG to prilled urea application was pronounced at 27 kg N/ha for both IR50 and IR48 (Table 2). At higher nitrogen rates, yields of IR50 did not improve further with SCU and supergra-

Table 1. Yields of IR36 and IR46 as affected by sources of urea, rates, and methods of application. Fourth Trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (wetland). IRRI, 1980 dry season.

Sources of urea	Rate (kg N/ha)	Method of application	Yield (t/ha)		
			IR36[a]	IR46[a]	Av
Unfertilized control	0	—	3.1 g	3.6 h	3.4
Prilled	27	Split application	4 5 f	4.7 g	4.6
Sulfur-coated	27	Broadcast and incorporated	5 2 de	6.1 cd	5.6
Supergranule	27	Placement	4 8 ef	5 3 f	5.0
Prilled	54	Broadcast and incorporated	4 6 f	5 8 de	5.2
Prilled	54	Split application	4.8 ef	5.4 ef	5.1
Sulfur-coated	54	Broadcast and incorporated	5.6 bcd	6 7 b	6.2
Supergranule	54	Placement	5.4 cd	6 5 bc	6.0
Prilled	108	Broadcast and incorporated	5.6 bcd	6 7 b	6.1
Prilled	108	Split application	5.8 bc	6.7 b	6.2
Sulfur-coated	108	Broadcast and incorporated	6.3 a	7.7 a	7.0
Supergranule	108	Placement	6.0 ab	7.3 a	6.6

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level

Table 2. Yields of IR50 and IR48 as affected by sources of urea, rates, and methods of application. Fourth Trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (wetland). IRRI, 1980 wet season.

Sources of urea	Rate (kg N/ha)	Method of application	Yield[a] (t/ha)	
			IR50	IR48
Unfertilized control	0	—	3.6 h	4 2 g
Prilled	27	Split application	4.9 g	4.7 f
Sulfur-coated	27	Broadcast and incorporated	5.3 de	5.2 cde
Supergranule	27	Placement	5.2 ef	5 2 cde
Prilled	54	Broadcast and incorporated	5.0 fg	5.1 de
Prilled	54	Split application	5.7 b	5.0 e
Sulfur-coated	54	Broadcast and incorporated	5.5 bcd	5.3 cd
Supergranule	54	Placement	5 4 cde	5 4 bc
Prilled	87	Broadcast and incorporated	5.6 bc	5.1 de
Prilled	87	Split application	5.9 a	5.3 cd
Sulfur-coated	87	Broadcast and incorporated	5 3 de	5 6 ab
Supergranule	87	Placement	5 4 cde	5.7 a

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level

Table 3. Yields of IR36 and IR42 as affected by sources of urea and rates and methods of application. Second Trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (rainfed). IRRI, 1980 wet season.

Sources of urea	Rate (kg N/ha)	Method of application	Yield (t/ha)	
			IR36[a]	IR42[a]
Unfertilized control	0	—	3 8 b	4.4 d
Prilled	29	Broadcast and incorporated	5.4 a	4.5 d
Sulfur-coated	29	Broadcast and incorporated	5.5 a	4.9 c
Supergranule	29	Placement	5 4 a	4.9 c
Prilled	58	Broadcast and incorporated	5.4 a	5 0 bc
Sulfur-coated	58	Broadcast and incorporated	5 6 a	5.4 a
Supergranule	58	Placement	5.6 a	5.4 a
Prilled	87	Broadcast and incorporated	5 5 a	5.4 a
Sulfur-coated	87	Broadcast and incorporated	5.7 a	5.3 ab
Supergranule	87	Placement	5.7 a	5 5 a

[a]Av of 4 replications Separation of means in a column by Duncan's multiple range test at the 5% level.

nule because of lodging. At all rates, split application of prilled urea performed better than incorporating all at planting.

Rainfed rice. The second INSFFER trial for rainfed rice during the wet season at IRRI evaluated SCU broadcast and incorporated, point placement of supergranule, and prilled urea basal and incorporated in wetland soils. Test cultivars were early-maturing IR36 and medium-maturing IR42.

With IR36, all the treatments with nitrogen fertilizer performed similarly and yields were significantly higher than those of the unfertilized control (Table 3). Treatment differences were pronounced with IR42. At 29 and 58 kg N/ha, yields of IR42 were significantly higher with SCU and urea supergranule than with urea basal and incorporated; but at 87 kg N/ha the 3 methods were similar. Drought damage at about tillering affected final yield.

SOURCES AND METHODS OF NITROGEN APPLICATION

Agronomy Department

INSFFER trainees carried out the fourth INSFFER trial at IRRI during the 1980 dry season. Results with IR50 indicated that yields with SCU and urea supergranules applied at 27 kg N/ha and yields with urea applied at 54 and 108 kg N/ha were comparable (Table 4). At 27 kg N/ha, SCU and urea supergranules gave significantly higher yields than split-applied urea. Except for SCU, which gave a significantly higher yield than urea broadcast and incorporated at 54 kg N/ha, yields among the various sources and methods of application of urea were not significantly different at the higher nitrogen rates. Compared with prilled urea, SCU and urea supergranule placement, however, gave generally high yields.

Table 4. Effect of sources and methods of application of urea on grain yield of IR50 rice Fourth trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice. IRRI, 1980 dry season.

Sources of urea	Rate (kg N/ha)	Method of application	Yield[a] (t/ha)
Unfertilized control	0	—	2.8 f
Prilled	27	Split application	3.8 e
Sulfur-coated	27	Broadcast and incorporated	5 2 bcd
Supergranule	27	Placement	5.1 cd
Prilled	54	Split application	5 2 bcd
Prilled	54	Broadcast and incorporated	5.0 d
Sulfur-coated	54	Broadcast and incorporated	6.2 ab
Supergranule	54	Placement	5.9 abcd
Prilled	108	Split application	6.0 abcd
Prilled	108	Broadcast and incorporated	6.1 abc
Sulfur-coated	108	Broadcast and incorporated	6 3 a
Supergranule	108	Placement	6.1 abc

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level.

INSFFER TRIAL ON NITROGEN FERTILIZER EFFICIENCY

Agronomy Department

The fourth series of INSFFER trials on nitrogen fertilizer efficiency in irrigated rice, and the second in rainfed rice were planted during 1980.

Irrigated. The dry-season trial was in a clay soil (Vertisol) in Teresa, Rizal province, and the wet-season trial was in two soil types: a silty clay (Vertisol) in Santa Rosa, Laguna province, and a silty loam (Ultisol) in Lucban, Quezon province. Soil analysis before the trials is given in Table 5.

In all soils the application of urea fertilizers at all rates of nitrogen significantly increased grain yield over that of the unfertilized control (Table 6).

The dry season crop in Binangonan clay gave a highest nitrogen response of 2.9 t/ha from SCU

Table 5 Characteristics of soils in farmers' fields in the trial on nitrogen fertilizer efficiency in irrigated and rainfed rice, Philippines, 1980.

Characteristic	Irrigated			Rainfed (Tanay, Rizal)
	Teresa (Rizal)	Lucban (Quezon)	Santa Rosa (Laguna)	
pH (1:1)	6.9	6.2	6.6	5 9
Cation exchange capacity (meq/100 g)	35	42	42	27
Total nitrogen (%)	0 11	0 42	0.34	0 16
Organic matter (%)	2.1	6 0	5.6	2.8
Available phosphorus (ppm) (Bray No 2)	4	92	35	10
Exchangeable potassium (meq/100 g)	0.59	1.03	1 51	0.16
Particle size (%)				
Sand	5	37	8	15
Silt	37	56	38	37
Clay	58	7	55	48
Texture	Clay	Silty loam	Silty clay	Silty clay
Soil series	Binangonan	Luisiana	Guadalupe	Antipolo
Soil order	Vertisol	Ultisol	Vertisol	Ultisol

Table 6. Effects of sources and methods of nitrogen application on grain yield of IR36. Fourth trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (irrigated) in farmers' fields, Philippines, 1980.

Treatment	Grain yield[a] (t/ha)		
	Dry season	Wet season	
	Binangonan clay	Luisiana silty loam	Guadalupe silty clay
No fertilizer nitrogen	3.3 d	4 8 d	3.6 c
		27 kg N/ha	
Urea, split application[b]	4.1 c	5.5 c	4 6 b
Sulfur-coated urea	4.3 c	5.9 abc	5.0 ab
Supergranule placement	4.3 c	5.9 abc	5.1 a
		54 kg N/ha	
Urea, split application[b]	4 4 c	5 7 bc	5 4 a
Urea, basal	4.4 c	6 1 abc	5.2 a
Sulfur-coated urea	5.3 b	5.9 abc	5.4 a
Supergranule placement	5 3 b	6.4 a	5 2 a
	108 kg N/ha	*87 kg N/ha*	
Urea, split application[b]	5 2 b	5 8 abc	5.4 a
Urea, basal	5 3 b	5 8 abc	5 0 ab
Sulfur-coated urea	6.2 a	5.6 c	5.2 a
Supergranule placement	6 2 a	6 2 ab	5.5 a

[a]Av of 4 replications Separation of means in a column and under each N rate by Duncan's multiple range test at the 5% level
[b]Two-thirds basal plus one-third 5-7 days before panicle initiation.

and supergranule at 108 kg N/ha. At 27 kg N/ha, SCU and urea supergranules were comparable to split application of prilled urea, but at 54 or 108 kg N/ha, they proved superior to split application or basal incorporation of urea.

In the wet season, response to nitrogen varied with soils. Supergranule placement of urea at 54 kg N/ha and 87 kg N/ha produced the highest nitrogen response in Luisiana silty loam (1.6 t/ha) and Guadalupe silty clay (1.9 t/ha). Deep placement of urea supergranule gave significantly higher yield than split application at 54 kg N/ha in Luisiana silty loam and at 27 kg N/ha in Guadalupe silty clay, whereas at higher rates, split application was comparable to SCU and urea supergranule.

Although Guadalupe silty clay and Luisiana silty loam soils both had high initial nitrogen status, significant yield differences among treatments were still observed. Textural differences in soils largely determined the differences in the results obtained.

Rainfed. One trial was in a rainfed farmer's field on Antipolo silty clay soil in Tanay, Rizal province. Soil analysis before the trial is given in Table 5 and yields in Table 7. The highest nitrogen response (0.8 t/ha) was obtained with basal application of urea and SCU at 54 kg N/ha. At the same nitrogen rate, urea applied as a basal dose was comparable with SCU and urea supergranule. At 87 kg N/ha, SCU was inferior to urea as a basal dose.

Table 7. Effects of sources and methods of nitrogen application on grain yield of IR36. Second trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (rainfed wetland) IRRI, 1980 wet season.

Treatment	Grain yield[a] (t/ha)
No fertilizer nitrogen	3 3 de
27 kg N/ha	
Urea, basal	3.5 cd
Sulfur-coated urea	3 8 abc
Supergranule placement	4.0 ab
54 kg N/ha	
Urea, basal	4 1 a
Sulfur-coated urea	4 1 a
Supergranule placement	4 0 ab
87 kg N/ha	
Urea, basal	3.9 abc
Sulfur-coated urea	3.0 e
Supergranule placement	3.6 bcd

[a]Av of 4 replications Separation of means by Duncan's multiple range test at the 5% level

Table 8. Effect of sources of urea at the rate of 87 kg N/ha applied by various methods on the grain yield of IR50. IRRI, 1980 dry season

Treatment	Grain yield[a] (t/ha)
No fertilizer nitrogen	4.2 c
Silica-polymer-coated urea (forestry grade), broadcast and incorporated	6 9 a
Sulfur-coated urea (forestry grade), broadcast and incorporated	6.4 ab
Sulfur-coated urea supergranules, placement at 10-12 cm deep	6 2 ab
Prilled urea, plowsole method	6 2 ab
Prilled urea, split application[b]	5.8 b

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level [b]Two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation

All treatments except the unfertilized control lodged during a typhoon. The effect of lodging was greatest at the highest rate of nitrogen. Low yields with deep-placed urea supergranules and SCU broadcast and incorporated were caused by lodging due to higher nitrogen efficiency.

MODIFIED SOURCES OF UREA AND APPLICATION METHODS FOR TRANSPLANTED WETLAND RICE

Agronomy and Soil Chemistry Departments

Use of modified sources of urea (SCU, urea supergranule, SCU supergranule, and silica-polymer-coated urea) for increasing fertilizer nitrogen efficiency in transplanted wetland rice was tested at IRRI during 1980. The tests were part of collaborative experiments between International Fertilizer Development Center and IRRI.

Dry season. Application of silica-polymer-coated urea (forstry grade) at 87 kg N/ha to early-maturing IR50 increased yield by more than 1 t/ha over split application of prilled urea (Table 8). The controlled-release fertilizer (forestry grade SCU) as broadcast and incorporated, deep-placed SCU supergranules, and prilled urea by the plowsole method gave higher yields than the split application but the difference was not significant.

In another trial at IRRI the highest grain yield (7.8 t/ha with IR44 rice) was obtained with the two controlled-release fertilizers (SCU and silica-polymer-coated urea) broadcast and incorporated at 87 kg

Table 9 Effect of sources of urea and their application methods on grain yield of IR44 rice. IRRI, 1980 dry season.

Treatment[a]	Yield[b] (t/ha) 27 kg N/ha	54 kg N/ha	87 kg N/ha	Mean[c]
No fertilizer nitrogen	—	—	—	3.5 d
Split application of urea[d]	4.2	4.7	5.7	4.9 c
SCU (forestry grade), broadcast and incorporated	5.1	6 2	7 8	6.4 ab
SPCU (forestry grade), broadcast and incorporated	5.8	6.7	7 8	6.8 a
Placement as urea supergranules	5 2	6.8	7.6	6.5 a
Placement as conditioned SCU supergranules	5 2	6.3	6.6	6.0 b
Mean[c]	5 1 c	6.1 b	7.1 a	

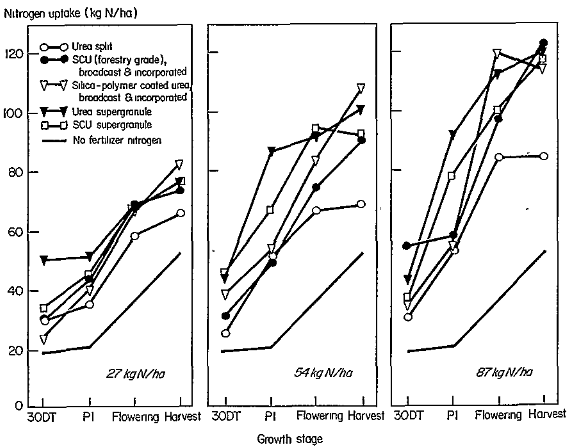
[a]SCU = sulfur-coated urea, SPCU = silica-polymer-coated urea. [b]Av of 4 replications [c]Separation of means in the column or row by Duncan's multiple range test at the 5% level [d]Two-thirds basal and incorporated and one-third topdressed 5-7 days before panicle initiation.

N/ha. When the yields for 3 rates of nitrogen application (27, 54, and 87 kg N/ha) were averaged, the controlled-release and deep-placed nitrogen fertilizers did not differ significantly (Table 9). Both the controlled-release and the deep-placed nitrogen fertilizers gave significantly higher yield than split application. However, SCU supergranules seem to reduce yields markedly at higher rates of application (54 and 87 kg N/ha) when compared with the uncoated urea supergranules. At the lower rate of application (27 kg N/ha), they gave similar yields.

Figure 1 shows the nitrogen uptake of IR44 at various growth stages as influenced by modified sources of urea applied at different rates. The total nitrogen uptake data at harvest showed higher nitrogen utilization from the controlled-release and deep-placed fertilizers than from split (researchers') application.

Results of the dry season trials indicated that fertilizer nitrogen efficiency in wetland rice can be increased markedly by the use of controlled-release and deep-placed nitrogen fertilizer.

Wet season. Tests at the IRRI irrigated and



1. Effect of sources of urea fertilizer at different rates on nitrogen uptake at growth stages of IR44 rice IRRI, 1980 dry season. DT = days after transplanting, PI = panicle initiation.

Table 10. Effect of sources of urea fertilizer at the rate of 54 kg N/ha applied by various methods on the grain yield of irrigated and rainfed IR36 rice. IRRI, 1980 wet season.

Treatment	Grain yield[a] (t/ha)	
	Irrigated	Rainfed
No fertilizer nitrogen	4.4 b	2.5 b
SPCU[b], broadcast and incorporated	5 2 a	4 5 a
SCU[c], broadcast and incorporated	5.2 a	4.7 a
Urea/Didin[d], broadcast and incorporated	5.4 a	4.9 a
SCU[c] supergranules, placement at 10-12 cm deep	5 0 a	4.7 a
Urea by plowsole method	5 3 a	4.8 a
Urea split[e]	5.2 a	4.9 a
Mean	5 1	4.4

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Forestry-grade silica-polymer-coated urea. [c]Forestry-grade sulfur-coated urea [d]Urea with nitrification inhibitor Didin; active ingredient is dicyandiamide. [e]Two-thirds basal and incorporated and one-third topdressed 5-7 days before panicle initiation

rainfed sites during the wet season failed to show significant differences in yield of IR36 rice among fertilizer treatments (Table 10). Lodging reduced the grain yield differences at the irrigated site and soil moisture stress after transplanting affected the yield at the rainfed site. A new fertilizer material, urea/Didin (dicyandiamide), included in the trial for the first time, performed satisfactorily under both water regimes.

METHODS OF APPLICATION OF DIFFERENT SOURCES OF UREA

Agronomy Department

In an IRRI experiment on increasing efficiency of nitrogen fertilizer, deep placement and slow release were compared with the researchers' split application of nitrogen, and also with the farmers' split application.

Dry season. Early-maturing IR50 was used to test different sources of urea at 54 and 108 kg N/ha. Nitrogen at 150 kg/ha was further tested as researchers' split application.

The first 54 kg N of slow-release urea (ordinary SCU), urea supergranules deep-placed, and prilled urea applied by plowsole applicator increased grain yield by 3.0 t/ha; the researchers' split increased yield by 2.3 t/ha (Table 11). Except for the farmers' split, increasing nitrogen fertilizer level to 108 kg N/ha did not significantly increase yield further. The slight lodging when nitrogen was

Table 11. Effect of methods of application of different urea sources on grain yield of IR50. IRRI, 1980 dry season

Treatment	Yield[a] (t/ha)
No fertilizer nitrogen	3.0 e
54 kg N/ha	
Plowsole[b]	6 3 a
Researchers' split[c]	5 3 c
Farmers' split[d]	4 6 d
Supergranule placement[e]	5.9 abc
Sulfur-coated urea[f]	6.2 ab
108 kg N/ha	
Plowsole[b]	6 0 abc
Researchers' split[c]	6.0 abc
Farmers' split[d]	5 4 bc
Supergranule placement[e]	5.9 abc
Sulfur-coated urea[f]	6 3 a
150 kg N/ha	
Researchers' split[c]	6 3 a

[a]Av of 3 replications Separation of means by Duncan's multiple range test at the 5% level [b]Applied during primary tillage [c]Two-thirds basal and one-third 5-7 days before panicle initiation. [d]One-half 10 days after transplanting and one-half 10 days after panicle initiation. [e]Point placed at 10-12 cm soil depth [f]Broadcast and incorporated during land preparation.

deep-placed with a plowsole applicator explains the lower yield with that treatment. Results from the study indicate that plowsole application of nitrogen and use of slow-release fertilizer such as SCU are two potential treatments for generating high yield during the dry season, even at a low nitrogen rate (54 kg N/ha).

Wet season. The wet-season rates of nitrogen fertilizer were 29 and 58 kg N/ha. Prilled urea at the rate of 75 kg N/ha was further evaluated as researchers' split application. IR36 replaced IR50.

At the first 29 kg N/ha, the yields from slow-release fertilizer and deep placement of urea supergranules were a ton more than that of the unfertilized control; however, they were not different from that from researchers' split. Yields from plowsole application of urea nitrogen were as good as those from farmers' split. Increasing nitrogen rate to 75 kg N/ha as researchers' split did not give any significant yield increase (Table 12).

The researchers' split at the low nitrogen rate was as efficient as slow-release urea or deep-placed urea supergranules.

RESPONSE OF RICE SELECTIONS TO METHODS AND RATES OF NITROGEN APPLICATION

Agronomy Department

The response of 4 rice varieties and 10 early-maturing IRRI lines to rates and methods of nitro-

Table 12. Effect of methods of application of different urea sources on grain yield of IR36. IRRI, 1980 wet season.

Treatment	Yield[a] (t/ha)
No fertilizer nitrogen	4.0 d
29 kg N/ha	
Plowsole	4 8 c
Researchers' split	5.4 abc
Farmers' split	4.7 c
Supergranule placement	5 2 abc
Sulfur-coated urea	5 3 abc
58 kg N/ha	
Plowsole	5 9 a
Researchers' split	5.7 ab
Farmers' split	4.9 bc
Supergranule placement	5.1 abc
Sulfur-coated urea	5.2 abc
75 kg N/ha	
Researchers' split	5 3 abc

[a]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level.

gen application was evaluated at IRRI during both seasons.

During the dry season, all rices showed significant grain yield response to nitrogen application (Table 13). IR8 had the lowest average yield. SCU and deep-placed urea supergranules gave no yield increase over the urea split. Lodging reduced the grain yield differences between the methods of nitrogen aplication.

In the wet season, 8 of the 10 lines tested gave average yields similar to those of IR36 (Table 14). Severe lodging at the early milk stage and sheath blight incidence after lodging significantly reduced the yield of IR50. Interactions between variety and fertilizer suggest that different selections had different responses to fertilizer application. Nitrogen application resulted in yield increase in some selections, but many others had yield decrease because of severe lodging. Most affected by lodging were plots fertilized by deep-placed or by controlled-release nitrogen fertilizer (at 58 kg N/ha) and urea split at a high rate of application (85 kg N/ha). The coefficient of variation on grain yield was much greater in the wet season than in the dry season probably because of a more severe lodging problem during the wet season.

Increasing protein content with basal nitrogen fertilizers. Protein content in rice grains is primarily determined by a genetic factor. Earlier results suggest that applying nitrogen, particularly in split doses, increases protein content by at least one percentage point over the no-fertilizer control. Tests at IRRI during the dry season confirmed that. Current results suggest, however, that with slow-release nitrogen fertilizers, such as SCU, one dose as a basal application during the final harrowing significantly increases protein content in the early-maturing IR9729-67-3 rice by an additional percentage point while maintaining high grain yield (Table 15).

Table 13. Effect of fertilizer nitrogen application on field duration and yield of 4 varieties and 10 early-maturing IR rices. IRRI, 1980 dry season.

Entry	Field duration (days)	Grain yield[a] (t/ha)					Av yield	
		0 N	108 kg N/ha			150 kg N/ha		
			Urea split	SCU	Urea SG	Urea split	t/ha	kg/ha per day[b]
IR8	101	2 7 b	3.5 a	3 5 a	3 6 a	3.4 a	3 3	33
IR36	84	4.3 b	5 8 a	5.8 a	6.0 a	6.0 a	5 6	66
IR42	108	5.3 b	6.7 a	5.8 b	6 5 a	6.9 a	6.2	58
IR50	83	4 2 b	6.4 a	6 2 a	6 4 a	6.6 a	6 0	72
IR9708-51-1-2	76	3.8 b	5 8 a	5 8 a	6 0 a	6.1 a	5.5	72
IR9729-67-3	83	4 6 b	6.9 a	7 0 a	7 1 a	7 3 a	6 6	79
IR9752-71-3-2	81	3 7 b	6 3 a	6 6 a	6 6 a	6.7 a	6 0	74
IR10179-2-3-1	76	3.5 b	5 4 a	5 5 a	5 6 a	5.6 a	5 1	68
IR13204-3-3-3	76	3 5 b	5 8 a	5 8 a	6 1 a	6 1 a	5 5	72
IR19728-9-3-2	77	3.4 b	5 7 a	5 7 a	5.8 a	5 9 a	5 3	69
IR19743-25-2-2	77	4.8 b	6 0 a	5 9 a	5.9 a	6 2 a	5 8	75
IR19746-28-2-2	76	3.8 c	5.6 b	6 2 ab	6.1 ab	6.4 a	5.6	74
IR19795-17-3-2	77	4.6 b	6 3 a	6.0 a	6.5 a	6 4 a	6 0	77
IR19819-31-2-3	77	3 6 b	5 5 a	5 6 a	6.0 a	5 8 a	5 3	69

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level SCU = sulfur-coated urea, SG = supergranule [b]Does not include 20 days in the seedbed

Table 14. Effect of fertilizer nitrogen application on field duration and yield of 4 varieties and 10 early maturing IR lines. IRRI, 1980 wet season

Entry	Field duration (days)	Grain yield[a] (t/ha)					Av yield	
		0 N	58 kg N/ha			85 kg N/ha		
			Urea split	SCU	Urea SG	Urea split	t/ha	kg/ha per day[b]
IR8	103	3 3 a	3.9 a	3.7 a	4.0 a	4.0 a	3.8	37
IR36	94	4.7 a	4 2 ab	3.7 b	4.0 ab	4.0 ab	4.1	44
IR42	110	5 1 a	5.5 a	5 2 a	5.8 a	5.3 a	5 4	49
IR50	87	5.0 a	3.5 b	3 0 b	3.2 b	2 9 b	3.5	41
IR9708-51-1-2	84	4.2 a	3.8 a	3 8 a	3.9 a	4.1 a	4.0	45
IR9729-67-3	87	5.1 a	4.8 ab	4.2 bc	3 8 c	4.6 ab	4.5	52
IR9752-71-3-2	83	4 3 b	4.9 ab	5 4 a	5.2 a	5.0 ab	5 0	60
IR10179-2-3-1	77	3.1 a	3.9 a	3.6 a	4.0 a	3.8 a	3.7	48
IR13204-3-3-3	84	4.5 a	4.9 a	4 3 a	4.6 a	5 0 a	4.7	56
IR19728-9-3-2	82	3 6 a	4.1 a	3.8 a	3.9 a	4.0 a	3.9	47
IR19743-25-2-2	87	4.7 a	3 8 ab	4.0 ab	4 1 ab	3.7 b	4.1	47
IR19746-28-2-2	82	4 8 a	4.5 ab	3.9 ab	4 2 ab	3.8 b	4.2	52
IR19795-17-3-2	80	4.5 a	5 2 a	5.3 a	4 9 a	5.0 a	5 0	62
IR19819-31-2-3	80	4 3 a	4 5 a	4.4 a	4 6 a	4.7 a	4.5	56

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level. SCU = sulfur-coated urea, SG = supergranule. [b]Does not include 16 days in the seedbed

Table 15. Effect of sources of nitrogen fertilizer and method of application on the brown rice protein of the early-maturing line IR9729-67-3. IRRI, 1980 dry season.[a]

Treatment	Brown rice protein (%)	Grain yield (t/ha)
No fertilizer nitrogen	8.4 c	4 6 b
108 kg N/ha		
Urea split[b]	9.5 b	6.9 a
SCU[c], broadcast and incorporated	10.6 a	7.0 a
Urea supergranule, placement at 10-12 cm deep	10 5 ab	7.1 a
150 kg N/ha		
Urea split[b]	9.8 ab	7.3 a

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]Two-thirds basal and incorporated, and one-third topdressed 5-7 days before panicle initiation. [c]Ordinary sulfur-coated urea.

SEEDLING AGE AND FERTILIZER MANAGEMENT PRACTICES FOR INCREASING FERTILIZER NITROGEN EFFICIENCY IN TRANSPLANTED RICE

Agronomy Department

During both seasons, fertilizer nitrogen efficiency was further evaluated at IRRI for two seedling ages (20 and 40 days) of two varieties (early-maturing IR36 and intermediate-maturing IR42). Sowing of seeds for the seedling age treatments was staggered so that transplanting was at the same time.

During the dry season, both varieties showed significant yield response to nitrogen regardless of the age of seedlings (Table 16).

The wet season results are seen in Table 17.

During both seasons, a significant yield reduc-

Table 16. Effect of fertilizer management practices on the grain yield of IR36 and IR42 transplanted as 20- and 40-day-old seedlings at 4-6 seedlings/hill. IRRI, 1980 dry season

Treatment	Grain yield[a] (t/ha)					
	IR36			IR42		
	20 d	40 d	Difference	20 d	40 d	Difference
No fertilizer nitrogen	3.9 b	3 6 c	0 3	4.4 c	4.0 b	0.4*
87 kg N/ha						
Split application of urea[b]	6 4 a	4.9 b	1.5**	6.4 b	6 5 a	−0.1
Topdressing 15 and 40 DT[c]	6 4 a	4.8 b	1.6**	6.6 b	6.6 a	0 0
Ordinary SCU,[d] broadcast and incorporated	6.7 a	5.0 b	1.7**	7 0 a	6.6 a	0.4*
150 kg N/ha						
Split application of urea[b]	6.7 a	5.6 a	1.1**	7.0 a	6.8 a	0.2

[a]Av of 4 replications Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Two-thirds basal and incorporated, and one-third topdressed 5 to 7 days before panicle initiation. [c]Days after transplanting. [d]Sulfur-coated urea.

Table 17. Effect of fertilizer management practices on the grain yield of IR36 and IR42 transplanted as 20-day-old seedlings at 2 to 3 seedlings/hill and as 40-day-old seedlings at 8 to 9 seedlings/hill. IRRI, 1980 wet season.

Treatment	Grain yield[a] (t/ha)					
	IR36			IR42		
	20 d	40 d	Difference	20 d	40 d	Difference
No fertilizer nitrogen	3 8 b	2.6 b	1.2**	4 1 c	4.3 c	−0.2
54 kg N/ha						
Split application of urea[b]	4.6 a	3.4 a	1.2**	4.9 ab	5.2 b	−0.3
Topdressing 15 and 40 DT[c]	4.6 a	2 8 b	1.8**	4.8 b	5.3 b	−0.5*
Ordinary SCU[d], broadcast and incorporated	4 8 a	3.4 a	1.4**	4 8 b	5.1 b	−0 3
75 kg N/ha						
Split application of urea[b]	4 9 a	3 6 a	1.3**	5 2 a	6.0 a	−0 8**

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Two-thirds basal and incorporated, and one-third topdressed 5 to 7 days before panicle initiation [c]Days after transplanting. [d]Sulfur-coated urea.

tion was pronounced in the older seedlings of IR36, but the difference in IR42 was not significant.

MOVEMENT AND DISTRIBUTION OF NH_4^+-N AS AFFECTED BY DEPTH OF PLACEMENT

Agronomy Department

Experiments at IRRI in both seasons traced the movement and distribution of ammonium nitrogen (NH_4^+-N) following deep placement of supergranule at soil depths of 5.0, 7.5, 10, and 15 cm. The early-maturing IR50 and medium-maturing IR48 were used to evaluate the effect of deep placement of nitrogen fertilizer on rices with different growth durations. ^{15}N-depleted ammonium sulfate was used to monitor the patterns of nitrogen absorption and translocation when fertilizer was placed at various soil depths.

In both seasons, application of nitrogen gave both varieties significantly higher yields than the yield of the unfertilized control (Table 18). With placement of urea supergranules at various soil depths, the grain yields of both varieties were similar, indicating that placement at 5.0 cm or deeper can increase the grain yield of varieties with different growth durations.

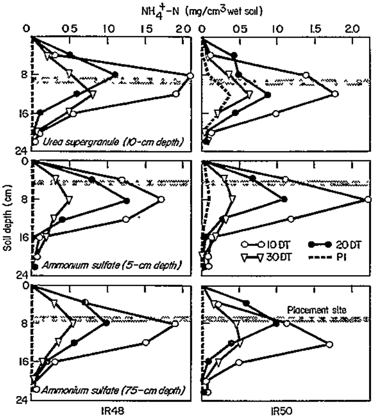
The movement of NH_4^+-N in the soil was traced for various depths. Downward movement was prevalent in the dry season; fertilizer placed at 5-7.5 cm produced a peak NH_4^+-N concentration at 8- to 12-cm soil depths (Fig. 2). Fertilizer placed at 10-cm soil depth tended to be stable and the peak of NH_4^+-N concentration was at 8-12 cm soil depth, regardless of whether urea or ammonium sulfate supergranules were deep placed. Placement of fertilizer at 15-cm soil depth tended to move NH_4^+-N downward to 12- to 20-cm soil depth (Fig. 3).

NH_4^+-N concentration in soil 10 days after transplanting (DT) ranged from 1.5 to 2.3 mg

Table 18. Effect of depth of placement of supergranule on the yields of IR50 and IR48. IRRI, 1980 dry and wet seasons.

Treatment	Depth of placement (cm)	Yield[a] (t/ha)					
		Dry season[b]			Wet season[b]		
		IR50	IR48	Mean	IR50	IR48	Mean
No fertilizer nitrogen	—	4 4 c	4.5 c	4.5	4.0 c	4.1 c	4.0
Urea supergranule	10	7.7 ab	7.8 a	7.8	5.6 a	5 2 a	5.4
Ammonium sulfate supergranule	5	8.0 a	7 5 ab	7.8	5.6 a	5.1 a	5.4
Ammonium sulfate supergranule	7.5	7.7 ab	7 6 ab	7.7	5.6 a	5.2 a	5.4
Ammonium sulfate supergranule	10	8.1 a	7.8 a	7.9	5.6 a	5 2 a	5.4
Ammonium sulfate supergranule	15	8 0 a	7.8 a	7.9	5.7 a	5.3 a	5.5
Split application of ammonium sulfate[c]	—	7.3 b	7.2 b	7.2	5.1 b	4 9 b	5.0

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level [b]Nitrogen levels were 100 kg/ha in the dry season and 50 kg/ha in the wet. [c]Two-thirds basal, and one-third 5-7 days before panicle initiation.



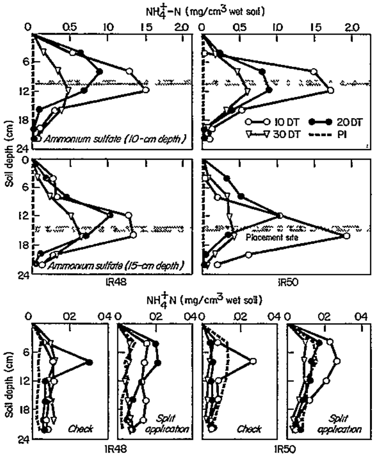
2. Distribution curves of ammonium nitrogen (NH_4^+-N) after supergranule placement at various depths of soil planted to IR50 and IR48. IRRI, 1980 dry season. DT = days after transplanting, PI = panicle initiation.

N/cm^3 on wet soil basis regardless of rice variety. With time, NH_4^+-N decreased to 0.9-1.3 mg/cm^3 at 20 DT, and to 0.3-0.8 mg/cm^3 at 30 DT. At panicle initiation, all NH_4^+-N in the soil was consumed or taken up by the rice plants. The patterns of movement of NH_4^+N were similar, regardless of rice variety.

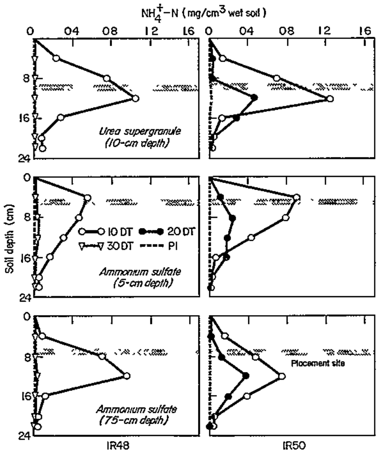
Split application of fertilizer produced a uniform NH_4^+-N concentration of 0.02-0.03 mg/cm^3 from the topsoil to about 12-cm soil depth (Fig. 3).

In the wet season, the deep-placed nitrogen fertilizer at various soil depths was fairly stable and the downward movement in the soil was minimal. Deep-placed fertilizer tended to move upward in some instances. The range of NH_4^+-N concentration in soil at 10 DT was 0.7-1.2 mg/cm^3 (wet soil basis). At 20 DT, the NH_4^+-N concentration (wet soil basis) decreased to 0.3-0.5 mg/cm^3. At 30 DT, all NH_4^+-N was consumed or taken up by the rice plant and no NH_4^+-N remained in the floodwater (Fig. 4 and 5).

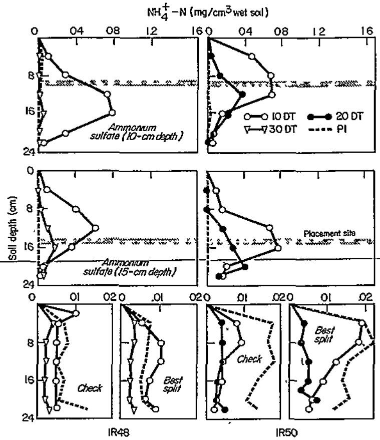
Losses of nitrogen from split application were shown by the presence of 78-98 μg N/ml in the



3. Distribution curves of ammonium nitrogen (NH_4^+-N) after supergranule placement at various depths of soil planted to IR50 and IR48. IRRI, 1980 dry season. DT = days after transplanting, PI = panicle initiation.



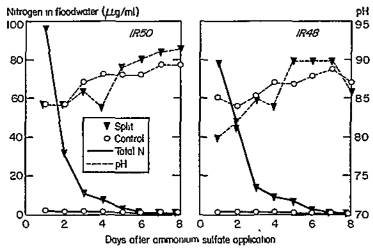
4. Distribution curves of ammonium nitrogen (NH_4^+-N) after supergranule placement at various depths of soil planted to IR50 and IR48. IRRI, 1980 wet season. DT = days after transplanting, PI = panicle initiation.



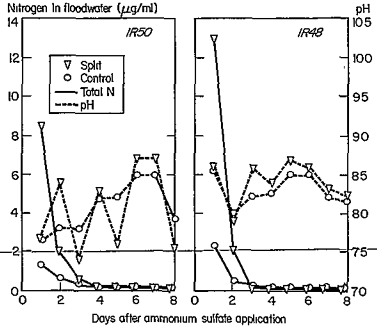
5. Distribution curves of ammonium nitrogen (NH_4^+-N) after supergranule placement at various depths of soil planted to IR50 and IR48. IRRI, 1980 wet season. DT = days after transplanting, PI = panicle initiation.

floodwater after fertilizer application in the dry season. Although pH values of floodwater with and without ammonium sulfate treatments were similar, NH_4^+-N concentration in floodwater was greater with ammonium sulfate treatment than in the unfertilized control (Fig. 6).

The concentration of nitrogen in floodwater was low (8.5-13 μg N/ml) in the wet season because of the low rate of nitrogen applied and the dilution



6. Changes in pH and total nitrogen concentration of floodwater as affected by nitrogen fertilizer application. IRRI, 1980 dry season



7. Changes in pH and total nitrogen concentration of floodwater as affected by nitrogen fertilizer application. IRRI, 1980 wet season

caused by continuous rain after fertilizer application (Fig. 7). The trend of pH changes was similar to that in the dry season experiment but with lower values.

Another field experiment was conducted simultaneously to compare the movement and distribution of NH_4^+-N from ammonium sulfate (^{15}N depleted) with urea applied at different soil depths. Varieties and treatments were similar to those in the first experiment.

In the dry season, both varieties with application of 100 kg N/ha produced 3-4 t/ha more than the control.

In the wet season, yields of IR50 and IR48 were comparable. Urea placement at various soil depths gave similar yields that were significantly higher than those for split application of urea fertilizer (Table 19).

PHOSPHORUS SOURCE TRIALS ON TWO PHILIPPINE SOILS

Agronomy Department

During the 1980 crop year, the evaluation of the residual effects of three sources of phosphorus fertilizers on two soils continued. The residual effects were determined after application of the phosphorus fertilizers for five consecutive croppings. In the 1980 dry season, no application of phosphorus was made; in the wet season 60 kg

Table 19. Effect of depth of placement of urea supergranule on the grain yield of IR50 and IR48. IRRI, 1980 dry and wet seasons.

Treatment	Depth of placement (cm)	Yield[a] (t/ha)					
		Dry season[b]			Wet season[b]		
		IR50	IR48	Mean	IR50	IR48	Mean
No fertilizer nitrogen	—	3 2 d	3.4 d	3 3	4.0 c	3.8 c	3 9
Urea supergranule	5	7.3 b	6.9 bc	7.1	5.2 a	5.2 a	5.2
Urea supergranule	7.5	7.7 ab	7.1 ab	7.4	5 3 a	5.3 a	5 3
Urea supergranule	10	7.8 a	6 8 bc	7.3	5.3 a	5.3 a	5 3
Urea supergranule	15	7.9 a	7.5 a	7.7	5 3 a	5 3 a	5.3
Split application[c]	—	6.8 c	6 7 c	6.7	4.9 b	4.8 b	4 8

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Nitrogen levels were 100 kg/ha in the dry season and 50 kg/ha in the wet. [c]Two-thirds basal, and one-third 5-7 days before panicle initiation.

P_2O_5/ha as ordinary superphosphate (OSP) was applied to both soils.

Dry season. Rice yields varied with soil and among phosphorus treatments (Table 20). Without any phosphorus, yields were lower in Luisiana silty clay than in Binangonan clay. The highest yield difference between treated plants and control was on Luisiana silty clay (3.6 t/ha).

The response to residual phosphorus was generally higher with an increased rate of phosphorus applications in both soils. Among the sources, OSP at 60 kg P_2O_5/ha produced the highest grain yield response.

Wet season. Grain yields in all treatments with phosphorus were lower in the wet season (Table 20). In both soils, marked yield differences among the previously treated plants were observed, especially with fresh application of OSP.

LONG-TERM FERTILITY EXPERIMENTS

Agronomy Department

Long-term fertility trials continued at IRRI, at Philippine research stations, and in farmers' fields.

IRRI. The 32d and 33d crops in long-term fertility experiments were grown in 1980 with IR8, IR36, and IR42 as test varieties. In the dry season, all three varieties had significant increase in yield in treatments with 140 kg N/ha over those without it (Table 21). Except for IR8, there was a significant increase in grain yield with nitrogen and phosphorus treatments over nitrógen treatment alone. That

Table 20. Grain yield of IR36 as affected by residual phosphorus from various phosphorus treatments on Binangonan clay (Teresa, Rizal), and Luisiana silty clay (Lucban, Quezon), Philippines, 1980.

Previous treatment (source and kg P_2O_5/ha)	Grain yield[a] (t/ha)			
	Binangonan clay		Luisiana silty clay	
	Dry season	Wet season	Dry season	Wet season
No phosphorus (control)	3.3 d	3.6 cd	2.6 e	3 3 e
Ordinary superphosphate				
20	4.5 c	4.2 ab	3.8 d	3.4 de
40	5.3 abc	4.4 a	5.3 bc	3 9 bcd
60[b]	6.0 a	3.4 d	6 2 a	4.4 a
Rock phosphate[c]				
20	4.5 c	4.2 ab	3.8 d	3 4 de
40	5 0 bc	4.5 a	4.7 c	4.3 ab
60	5.5 ab	4.2 ab	5.4 abc	3.6 cde
Guano				
40	5.4 ab	4.6 a	4 7 c	4.0 abc
80	5.3 abc	3.9 bc	5.7 ab	4.4 a
120	5.6 ab	3.7 cd	5.7 ab	4.5 a

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Fresh application was made in the wet season planting in both soils. [c]Phospal for Binangonan clay and phosmak for Luisiana silty clay

Table 21. Effects of nitrogen-phosphorus-potassium fertilizers on the grain yields of IR8, IR36, and IR42 in the 32d (dry season) and 33d (wet season) consecutive crops. IRRI, 1980

Fertilizer (kg/ha)			Yield[a] (t/ha)		
N	P_2O_5	K_2O	IR8	IR36	IR42
Dry season					
0	0	0	2.5 c	2.7 c	2.8 c
140	0	0	5.8 b	4.9 b	6.6 b
0	30	0	2 8 c	2 6 c	3.1 c
0	0	30	2.5 c	2.4 c	2.7 c
140	30	0	6 2 ab	5.7 a	7 4 a
140	0	30	6.5 a	5.8 a	6.8 b
140	30	30	6.4 a	6.2 a	6.6 b
140	30	30	6.0 ab	6 0 a	7 1 ab
Wet season					
0	0	0	1.8 bc	3.0 d	3.0 d
60	0	0	2 1 abc	3.8 bc	4 4 ab
0	30	0	1.7 c	2.7 d	3 4 c
0	˙0	30	2.2 abc	3 2 cd	3 7 bc
60	30	0	2 5 ab	4 2 ab	4.7 a
60	0	30	2.7 a	4.2 ab	4.8 a
60	30	30	2.1 abc	4 6 a	4.8 a
60	30	30	2 3 abc	4 0 a	4.9 a

[a]Av of 4 replications. Separation of means in a column and in each season by Duncan's multiple range test at the 5% level.

trend, however, was not seen with the complete fertilizer treatments.

In the wet season, the response to application of fertilizer nitrogen in all three varieties was similar. IR42 outyielded IR8 and IR36 in all fertilizer treatments in the wet season. Phosphorus and potassium treatments did not result in significant increase in wet season grain yields, which confirmed earlier results.

BPI stations. The 25th and 26th crops in long-term fertility experiments were grown at three BPI stations with IR8, IR36, and IR42 rices as test varieties. During the dry season, an increase in yield was obtained at all stations in all three varieties with complete fertilizer treatments (NPK) and with nitrogen and P_2O_5 combinations (Table 22). Treatments with nitrogen alone or nitrogen with K_2O had yields higher than those of the control plots. Similar response patterns were observed during the wet season (Table 23).

Table 22. Effect of nitrogen-phosphorus-potassium fertilizers on grain yield of IR8, IR36, and IR42 in the 25th crop (dry season) in the long-term fertility experiments at Maligaya Rice Research and Training Center, Bicol Rice and Corn Experiment Station, and Visayas Rice Experiment Station, Philippines. 1980 dry season.

Fertilizer (kg/ha)			Grain yield[a] (t/ha)								
			Maligaya			Bicol			Visayas		
N	P_2O_5	K_2O	IR8	IR36	IR42	IR8	IR36	IR42	IR8	IR36	IR42
0	0	0	2.0 e	2.4 e	2.2 e	2 4 f	3.2 ef	2 7 f	1.3 d	1.2 d	1.4 d
140	0	0	3.4 d	3 3 d	3 5 d	3.2 ef	4.2 de	3.2 ef	1 3 d	1.7 d	1.8 d
140	60	0	6.6 ab	6.7 ab	5 0 c	4 0 de	5.7 abc	5.4 abcd	3.4 bc	4.1 ab	3.7 bc
140	0	60	3.4' d	3.9 d	3.1 d	4.6 cd	4.4 de	4.5 cde	1.2 d	1 6 d	1.8 d
140	60	60	6 1 b	6.9 ab	6 8 ab	5 1 bcd	6 2 ab	6.5 a	4.0 abc	4.1 ab	4.1 ab
140	60	60 + 30	6 8 ab	7.2 a	7.2 a	4 8 cd	6.3 ab	6.6 a	3.6 bc	4 6 a	4.1 ab

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 23. Effect of nitrogen-phosphorus-potassium fertilizers on grain yield of IR8, IR36, and IR42 rices in the 26th crop (wet season) in the long-term fertility experiments at Maligaya Rice Research and Training Center, Bicol Rice and Corn Experiment Station, and Visayas Rice Experiment Station, Philippines. 1980 wet season.

Fertilizer (kg/ha)			Grain yield[a] (t/ha)								
			Maligaya			Bicol			Visayas		
N	P_2O_5	K_2O	IR8	IR36	IR42	IR8	IR36	IR42	IR8	IR36	IR42
0	0	0	2.0 c	2 8 b	2.6 c	2.2 b	2.8 b	3.2 d	1.0 b	1 3 b	1 3 b
70	0	0	2.6 bc	3.3 b	3.9 b	1.8 b	4 6 a	3 6 cd	1.8 b	1.6 b	1.2 b
70	60	0	2.4 bc	4 8 a	5.1 a	3.6 a	3.2 b	3.9 bcd	4.4 a	3.9 a	3.3 a
70	0	60	3.1 ab	3.4 b	3.8 b	3.7 a	4.8 a	4 3 abc	1.5 b	1.5 b	1.4 b
70	60	60	3 3 ab	4.7 a	5.0 a	3.8 a	4 8 a	5 0 ab	4 1 a	4.3 a	4 1 a
70	60	60 + 30	3.8 a	5.2 a	5 8 a	4.2 a	5.1 a	5.1 a	4.1 a	4.1 a	3.8 a

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 24. Effects of nitrogen, phosphorus, and potassium fertilizers on grain yield of IR36 and IR42 rices in the 8th (dry season) and 9th (wet season) consecutive crops. Luisiana clay, Laguna province, Philippines, 1980.

Fertilizer treatment[a]	Yield[b] (t/ha)			
	Dry season		Wet season	
	IR36	IR42	IR36	IR42
Control	3.6 e	3.3 e	2.1 cd	2.9 cd
Nitrogen	4.2 cd	4.0 d	3.6 a	3.7 a
Phosphorus	3.5 e	2.9 e	1.9 d	2.6 d
Potassium	4.0 de	2.9 e	2.4 bc	3.2 bc
Nitrogen + phosphorus	5 3 b	6 0 b	3 4 a	3 6 ab
Phosphorus + potassium	3 7 e	3.1 e	2 0 cd	2 8 cd
Nitrogen + potassium	4.7 bc	5.0 c	2.7 b	3.6 ab
Nitrogen + phosphorus + potassium	6.2 a	6 9 a	3.6 a	3.9 a

[a]Nitrogen at 120 kg/ha for dry season, and 60 kg/ha for wet season; P_2O_5 and K_2O each at 40 kg/ha in both seasons. [b]Av of 4 replications Separation of means by Duncan's multiple range test at the 5% level.

Table 25. Effects of nitrogen, phosphorus, and potassium fertilizers on grain yield of IR36 and IR42 in the 7th (dry season) and 8th (wet season) consecutive crops. Bay clay, Tanay, Rizal, Philippines, 1980.

Fertilizer treatment[a]	Yield[b] (t/ha)			
	Dry season		Wet season	
	IR36	IR42	IR36	IR42
Control	3 1 b	2.8 d	2.4 c	3.5 bc
Nitrogen	4.7 a	4 8 b	3.8 b	3 9 abc
Phosphorus	3.5 b	3.6 c	2.8 c	3.5 bc
Potassium	2 9 b	3.1 cd	3 7 b	3.3 c
Nitrogen + phosphorus	5.3 a	4.7 b	3.7 b	4 0 ab
Phosphorus + potassium	3 5 b	3 2 cd	3.4 b	3.6 bc
Nitrogen + potassium	4.7 a	4.9 ab	4.5 a	3 3 c
Nitrogen + phosphorus + potassium	5.2 a	5 5 a	4 8 a	4 2 a

[a]Nitrogen at 120 kg/ha for dry season, and 60 kg/ha for wet season; P_2O_5 and K_2O each at 40 kg/ha in both seasons. [b]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Farmers' fields. The eighth and ninth crops in Luisiana silty clay and the seventh and eighth crops in Bay clay were grown in Laguna and Rizal provinces.

On Luisiana silty clay, nitrogen responses were significant in both seasons (Table 24). Although added phosphorus alone did not increase grain yield significantly, its presence enhanced nitrogen response. Phosphorus response (NPK vs NK) was observed on IR36 in both seasons and on IR42 in the dry season. A response to potassium (NPK vs NP) was observed in both varieties in the dry season.

On Bay clay, the response to nitrogen alone was observed in both varieties in the dry season and only on IR36 during the wet (Table 25). However, in combination with other fertilizer elements, nitrogen response was noted in both varieties and seasons. On IR42 response to phosphorus was observed, whereas that to potassium was inconsistent.

Soil and crop management

Rice culture

Agronomy Department

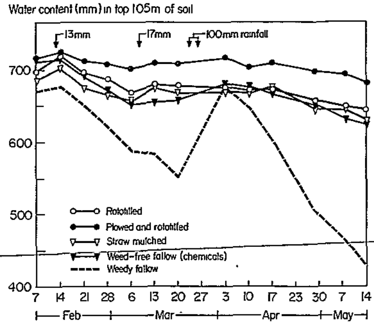
EFFECT OF DRY SEASON LAND MANAGEMENT ON SOIL MOISTURE STORAGE DURING FALLOW

Five land management practices were tested during the dry season on a clay soil at IRRI for their contribution to soil moisture conservation: soil mulch by shallow rototillage, soil mulch by plowing and rototillage, straw mulch, chemical weed control, and weedy fallow.

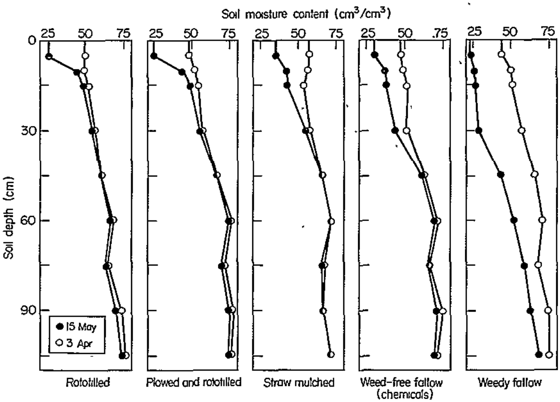
Moisture storage in soil profile. Seasonal soil moisture contents in the soil to a depth of 1.05 m are shown in Figure 1. Weedy fallow plots, which represent the conventional farmer's practice, lost highly significant amounts of soil moisture. The remaining four treatments did not differ significantly; however, a combination of plowing and rototillage maintained the most soil moisture in the profile. The data indicate that keeping land free of weeds during the dry season (through tillage or chemicals) allows significant conservation of soil moisture.

Depth of soil moisture depletion. A typical soil moisture depletion pattern is shown in Figure 2. Significant depletion of soil moisture was limited to the surface 15 cm in the soil mulch plots, but considerable depletion occurred to as deep as 30 cm, 45 cm, and 105 cm under the straw mulch, chemical weed control, and weedy fallow treatments. Moisture depletion was high in the weedy fallow as a result of evapotranspiration by the weedy vegetation; in the remaining weed-free treatments, surface evaporation acted as the primary cause of moisture loss. The groundwater table during the measurement period remained below the 1.5-m depth.

Soil moisture depletion and recharge. The data on soil moisture depletion and recharge from the



1. Water storage in soil profile to the 1.05-m depth under various dry season land management practices. IRRI, 1980



2. Soil moisture depletion during a 6-week dry period under various fallow season land management systems IRRI, 1980.

Table 1. Soil moisture depletion and recharge to 1.05-m depth under various dry season fallow land management systems. IRRI, 1980.

Calendar period	Rainfall (mm)	Pan evaporation (mm)	Water depletion (mm) in soil profile[a]				
			Rototilled (703 mm)	Plowed and rototilled (718 mm)	Straw mulched (686 mm)	Weed-free fallow (chemical) (713 mm)	Weedy fallow (672 mm)
7-14 Feb	12.5	25.5	−14 6	−7.1	−15 6	−3 2	−7.0
14 Feb-6 Mar	0.0	113.3	47.7	21.4	47 3	62.9	90.2
6-13 Mar	17.3	40 8	−10.6	−5 5	−21 3	−4 0	6.1
13-20 Mar	0.0	39.6	3.0	1.1	6 9	−0.6	30.1
20 Mar-3 Apr	108 0	61 2	2.1	−2.7	−2.0	−21 3	−125.9
3-17 Apr	7.4	80.8	1 6	5.6	−4 9	12 6	73.4
17 Apr-8 May	0 0	125.9	24.4	15 7	30.1	32 4	141 3
8-15 May	6.9	38.1	4.9	13.5	14 7	7.0	39.8
Season's total	152.1	525.2	58 5	42.0	55.2	85 8	248.0
Seasonal average (mm/day)	1 53	5 30	0.59	0 42	0.56	0 86	2 5

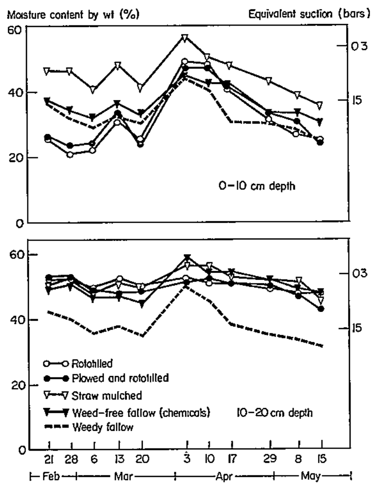
[a]Numbers in parentheses indicate initial soil moisture. Negative values indicate moisture accretion from rainfall.

rainfall during the dry season of February to May 1980 are summarized in Table 1. The initial soil moisture at the start of the dry season was the same for all treatments, but by the end of the season, large differences were apparent. Tillage and straw mulch plots maintained soil moisture in the profile at their maximum retention capacity. That is exemplified by the data of 20 March through 3 April, when these treatments showed essentially no recharge from a low pressure rainstorm with 108 mm of rainfall.

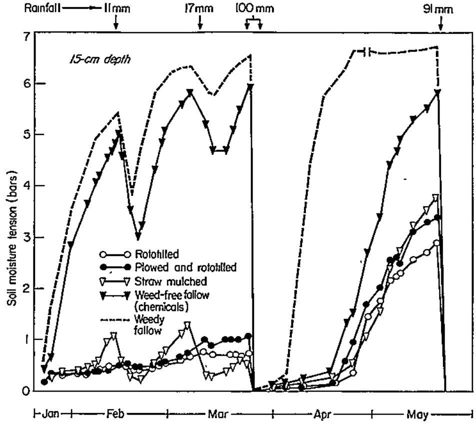
Seedbed zone soil moisture. Soil moisture level in the plow layer at the end of the dry season determines the amount of rainfall needed for land preparation and dry seeding of rice. Figure 3 depicts the gravimetric soil moisture contents throughout the dry season. At shallow soil depths of 0-10 cm, straw mulch always maintained the highest moisture content, but tillage performed to create the soil mulch resulted in the lowest moisture level. At 10-20 cm depth all treatments except weedy fallow showed minor differences. Weedy fallow plots lost distinctly greater amounts of soil moisture, with equivalent soil moisture tensions exceeding 15 bars.

Soil moisture tension. Soil moisture tension (SMT) at 15- and 30-cm depth under various land management systems is shown in Figures 4 and 5. At 15-cm depth, the SMT under soil mulch and straw mulch remained below 1 bar during most of the dry season except May when severe drying raised it to 2-4 bars. On the other hand, SMT under the chemical weed control and weedy fallow treatments reached 6 bars or more during the season.

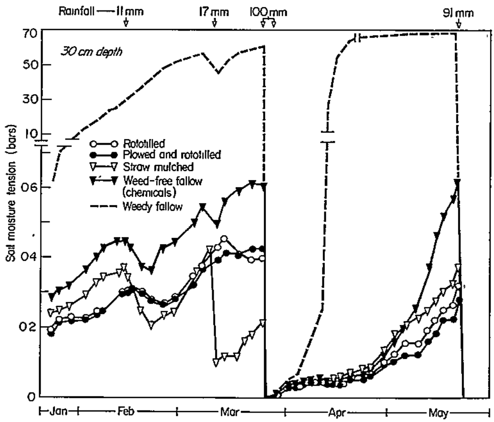
At 30-cm depth, the SMT remained below 0.6 bar under the soil mulch, straw mulch, and chemical weed control treatments but under weedy fallow SMT exceeded 6 bars during April-May. The



3. Gravimetric soil moisture content in the 0-10 and 10-20 cm depths under various dry season land management practices. IRRI, 1980



4. Effect of dry season land management practices on soil moisture tension (SMT) at 15-cm depth, IRRI, 1980. A break in the curve for weedy fallow indicates SMT exceeded 6 bars.



5. Effect of dry season land management practices on soil moisture tension (SMT) at 30-cm depth IRRI, 1980. Note the difference in scale above the 0 7 bar A break in the curve for weedy fallow indicates SMT exceeded 6 bars.

residual soil moisture contents at the end of the dry season indicate that relatively small amount of rainfall moisture (20-50 mm rainfall) will be required at the onset of monsoons to establish dry-seeded rice in fields where land is kept free of weeds.

EFFECT OF DRY SEASON FALLOW LAND MANAGEMENT AND SEEDBED PREPARATORY TILLAGE ON DRY-SEEDED RAINFED BUNDED RICE

In an experiment on a clay soil at IRRI, dry-seeded rice was established by minimum tillage (one rototilling) and no tillage in plots that were previously tilled or left untilled the previous dry season. The dry season treatments were:

- herbicide weed control;
- herbicide weed control + rice straw mulch at 3.75 t/ha;
- 3 rototillings in January + 1 rototilling in April to keep plots weed free; and
- 1 plowing and 2 rototillings in January + 1 rototilling in April to keep plots weed free.

In May, IR36 and IR50 were dry-seeded in 25-cm rows. Following one rototilling, seeds were dropped in furrows made with an indigenous harrow (*lithao*). For no tillage, seed was dropped in 4- to 6-cm-deep furrows made with an animal-drawn plow. Plots were fertilized with 80 kg N, 30 kg P_2O_5, and 30 kg K_2O/ha. Yields of the two varieties did not differ significantly; therefore, the data in Table 2 are means for both varieties. No differences in grain yield, tiller number, panicle number, and weed weight were found among the four land management systems. Grain yield showed no response to use of tillage for seedbed preparation in May when the land was tilled at the end of the previous wet season. However, minimum tillage improved yields over no tillage where the land was kept untilled before planting.

The results suggest that minimum and no tillage can be practiced for dry-seeded rice establishment if weed growth is controlled during the fallow season.

EFFECT OF LAND PREPARATION METHOD AND NITROGEN FERTILIZER SOURCE ON WET SEASON TRANSPLANTED RAINFED RICE

In an experiment on a clay soil at IRRI five tillage intensities for land preparation before transplanting were used (Table 3) in a split-split-plot design. Tillage treatments were main plots, two rice varieties were subplots, and three nitrogen fertilizer sources were sub-subplots. Fertilizer was applied at 58 kg N/ha. The experimental area had a crop of maize during the previous dry season. The field was disk plowed once after maize harvest and remained fallow until wetland preparation. Irrigation provided water for land preparation, but the crop depended on rainfall after transplanting.

Increase in tillage intensity did not significantly affect grain yield, weed weight, and the weeding labor requirements (Table 3). The soil physical properties also remained similar (Table 4). How-

Table 2. Effect of dry season fallow land management and seedbed preparatory tillage[a] on grain yield, tiller number, panicle number, and weed weight in dry-seeded rainfed rice. IRRI, 1980.

Dry season fallow land management treatment	Grain yield (t/ha)		Tillers (no./m²)		Panicles (no./m²)		Weed wt[b] (t/ha)	
	Minimum	No till	Minimum	No till	Minimum	No till	Minimum	No till
Dry season untilled								
Herbicide weed control	6.40 a	5.51 a	1002 a	690 a	426 a	274 a	1.64 a	1.51 a
Herbicide weed control + rice straw mulch	6.07 a	5.52 a	1062 a	692 a	408 a	332 a	1.36 a	1.36 a
Dry season tilled								
3 rototillings in Jan + 1 rototilling in Apr	5.98 a	5.88 a	1041 a	728 a	412 a	336 a	1.63 a	1.95 a
1 plowing + 2 rototillings in Jan + 1 rototilling in Apr	5.50 a	5.64 a	1008 a	698 a	438 a	390 a	1.74 a	1.42 a
LSD .05 (minimum vs no till)	0.68*		ns		ns		ns	

[a]Minimum = one rototilling before seeding; no till = no seedbed preparation. Means of 3 replications and 2 rice varieties (IR36 and IR50). Separation of means in a column by Duncan's multiple range test at the 5% level. [b]First weeding 3 wk after emergence

Table 3. Effect of tillage intensity for wetland preparation on grain yield, weed weight, and weeding labor.[a] IRRI, 1980 wet season.

Land preparation technique	Grain yield[b] (t/ha)		Weed wt (kg/ha)			Weeding labor (h/ha)	
	IR36	IR52	1st weeding	2d weeding	3d weeding	2d weeding	3d weeding
1 plowing + 1 harrowing	3.17 a	2.73 a	409 a	400 a	310 a	195 a	293 a
1 plowing + 3 harrowings	2.57 a	2 57 a	416 a	400 a	278 a	311 a	420 a
1 plowing + 1 harrowing + 1 rototilling	2.66 a	2.78 a	406 a	382 a	285 a	234 a	360 a
1 plowing + 2 harrowings + 2 rototillings	2.65 a	2 47 a	444 a	467 a	341 a	183 a	270 a
2 plowings + 2 harrowings	3.10 a	2.75 a	429 a	393 a	296 a	179 a	407 a

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Means of 3 nitrogen fertilizer sources.

Table 4. Effect of tillage intensity for wetland preparation on soil physical parameters.[a] IRRI, 1980 wet season.

Land preparation technique	Apparent specific volume (cm^3/g)	Bulk density (g/cm^3)	Total porosity (%)	Void ratio
		Before land preparation		
	0 90 ± 0 02[b]	1.03 ± 0.03	60.4 ± 1.2	1.52 ± .03
		After land preparation		
1 plowing + 1 harrowing	0.88 a	1.06 a	59.3 a	1.45 a
1 plowing + 3 harrowings	0 83 a	1.11 a	57.5 a	1.35 a
1 plowing + 1 harrowing + 1 rototilling	0 87 a	1.07 a	58 8 a	1.43 a
1 plowing + 2 harrowings + 2 rototillings	0.92 a	1.02 a	60.7 a	1.54 a
2 plowings + 2 harrowings	0.90 a	1.03 a	60.2 a	1 52 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level [b]Standard deviation

Table 5. Effect of tillage intensity for wetland preparation on labor and fuel requirements IRRI, 1980 wet season.

Land preparation technique	Labor requirements[a]			Fuel used (liters/ha)
	Man-h/ha	Animal-h/ha	Machine-h/ha[b]	
1 plowing + 1 harrowing	114	114	0.0	0.0
1 plowing + 3 harrowings	214	214	0 0	0 0
1 plowing + 1 harrowing + 1 rototilling	127	114	13	18.2
1 plowing + 2 harrowings + 2 rototillings	190	164	25	35.0
2 plowings + 2 harrowings	228	228		

[a]Carabao and operator hours are based on an 8-h work day. [b]Rototillage was with a two-wheel landmaster tractor.

ever, as the tillage intensity increased, manpower and animal power use increased substantially (Table 5). The data demonstrate the usefulness of minimum tillage for wetland preparation of soils where no favorable changes in soil properties and grain yields are obtained from additional tillage.

The data in Table 6 show that grain yield was significantly affected by the source of nitrogen fertilizer. Supergranule urea (SGU) proved superior to sulfur-coated urea (SCU) and regular urea on the clay soil. Both SGU and SCU, however, gave significantly higher grain yield than the commonly practiced split application of regular urea.

Table 6. Effect of nitrogen fertilizer source[a] on grain yields of rainfed rice varieties IR36 and IR52. IRRI, 1980 wet season.

Nitrogen source	Grain yield[b] (t/ha)		
	IR36	IR52	Difference
Regular urea	2.35 a	2.23 a	0.12 ns
Sulfur-coated urea (SCU)	3.02 b	2.71 b	0.31 ns
Supergranule urea (SGU)	3.12 b	3.03 c	0.09 ns

[a]Two-thirds regular urea and all SCU as basal application; one-third regular urea broadcast 3 days before panicle initiation; SGU applied 2 days after transplanting. [b]Means of 5 land preparation techniques and 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. ns = not significant.

EFFECT OF TILLAGE AND MULCHING PRACTICES ON SOIL PHYSICAL PROPERTIES AND RAINFED MAIZE FOLLOWING TRANSPLANTED IRRIGATED RICE

To evaluate soil and crop management practices that can improve dryland crop performance on a previously puddled and flooded soil, maize was grown after different tillage and mulching practices (Table 7). The test field had grown puddled-flooded rice for several years. Phil. DMR#2 maize was seeded 15 December in 75-cm rows. Fertilizer was applied as 66 kg N, 50 kg P_2O_5, and 50 kg K_2O/ha with half of the nitrogen and all phosphorus and potassium applied basally and the remaining half of nitrogen topdressed 3 weeks after seeding. One hand weeding was done 4 weeks after seeding. Maize was harvested during the last week of March. The crop period had about 90 mm rain, of which nearly 50 mm occurred 1 week after emergence.

Table 7. Summary of tillage and mulching treatments for maize following transplanted-irrigated rice. IRRI, 1980

Treatment	Primary tillage	Secondary tillage
Tillage treatment	No tillage	None
	1 moldboard plowing (15-cm depth)	2 disk harrowings (7-cm depth)
	1 shallow chisel plowing (15-cm depth)	2 rototillings (7-cm depth)
	1 deep chisel plowing (25-cm depth)	2 disk harrowings (7-cm depth)
	1 rototilling (10-cm depth)	2 rototillings (7-cm depth)
Mulch treatment	No mulch	
	Rice straw mulch at 5 t/ha	

Seedbed soil moisture. The soil moisture content during primary tillage and seeding are shown in Table 8. Secondary tillage for seedbed preparation reduced soil moisture contents. Although no-tillage maintained the highest moisture content, the moisture level was not enough to induce germination of maize and a sprinkler irrigation of about 3 cm was given to encourage crop establishment.

Soil aeration. Table 9 gives the data on air-filled porosity 3 weeks after seeding. The no-tillage treatment showed the least air-filled porosities in the shallow depths. Crop growth was adversely affected at air-filled porosity less than 10%. Values considerably less than 10% of air-filled porosity in the 15-25 cm depths indicate that previous puddling of soil resulted in less-than-optimum soil aeration. A significant linear relationship was observed (Fig. 6) between the air-filled porosity and maize yields.

Soil strength. The data on resistance to soil penetration, bulk density, and moisture content are given in Table 10. Resistance to soil penetration was highest in no-tillage at the shallow depth only; no differences were found at 20-25 cm depths. Bulk density and moisture contents were nearly the same in all tillage treatments.

Soil tilth. Soil tilth was characterized by the soil's aggregate size distribution. Distinct initial differences in soil tilth following secondary tillage

Table 8. Soil moisture content during primary tillage and at seeding as influenced by tillage operations IRRI, 1980

Tillage treatment		Soil moisture[a] (% by wt)	
Primary tillage	Secondary tillage	At primary tillage (0-15 cm depth)	At seeding time (3-8 cm depth)
No tillage	None	43.1 a	35.5 a
1 moldboard plowing	2 disk harrowings	46.1 a	28.7 b
1 chisel plowing, shallow	2 rototillings	41 2 a	31 3 ab
1 chisel plowing, deep	2 disk harrowings	44.4 a	30.5 ab
1 rototilling	2 rototillings	43.8 a	27.1 b

[a]Av of 4 replications Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 9. Air-filled porosity at field moisture content as affected by various tillage treatments 3 weeks after seeding of maize. IRRI, 1980.

Tillage treatment		Air-filled porosity[a] (%)		
Primary tillage	Secondary tillage	5-10 cm depth	15-20 cm depth	20-25 cm depth
No tillage	None	8.1 b	3 6 a	7 7 a
1 moldboard plowing	2 disk harrowings	12.7 ab	4 2 a	6.7 a
1 chisel plowing, shallow	2 rototillings	17 6 a	7 1 a	7.9 a
1 chisel plowing, deep	2 disk harrowings	11 4 ab	3 9 a	5.0 a
1 rototilling	2 rototillings	15 0 ab	4.7 a	7.5 a

[a]Means of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

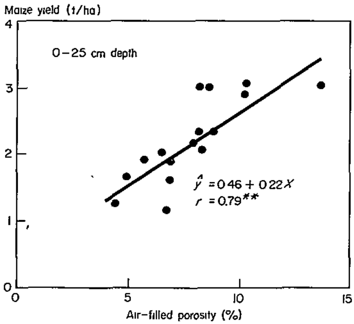
Table 10. Some indices of soil strength[a] at various soil depths 3 weeks after seeding of maize, as influenced by tillage treatments. IRRI, 1980.

Tillage treatment	Penetration resistance (kg/cm^2)		Soil moisture by wt (%)		Bulk density (g/cm^3)		
	5-10 cm	20-25 cm	5-10 cm	20-25 cm	5-10 cm	15-20 cm	25-30 cm
No tillage	5 28 a	9.48 a	47.6 a	48.0 a	1.07 a	1.18 a	1 07 a
Moldboard plowing	4.91 ab	9 62 a	45 8 a	48.7 a	1 04 a	1.14 a	1.07 a
Chisel plowing, shallow	3.69 b	8 44 a	45 7 a	45 5 a	0.99 a	1.13 a	1.11 a
Chisel plowing, deep	4 44 ab	7 96 a	45 8 a	46 7 a	1.06 a	1 15 a	1.12 a
Rototilling	4.38 ab	9.79 a	45.9 a	48.7 a	1.01 a	1.14 a	1.06 a

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

showed rototilled plots with a finer tilth than the disk-harrowed plots. The differences disappeared, however, after the heavy rains in late December. The physical impact of rainfall destroyed the cloddy structure of disk-harrowed plots and resulted in nearly the same geometric mean diameter of aggregates as in the rototilled plots (Fig. 7).

Soil water extraction by maize. Table 11 shows the soil water depletion and water use efficiency of

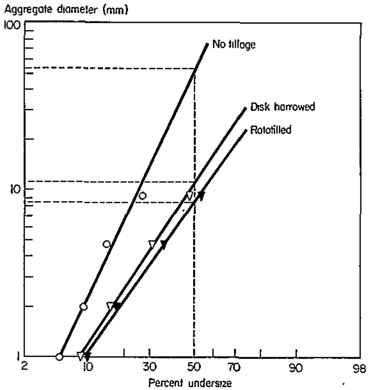


6. Relationship between soil air-filled porosity and maize yields IRRI, 1980.

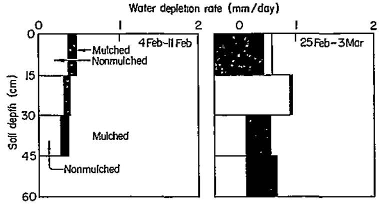
maize grown with different tillage and mulch treatments. Water use efficiency did not differ among tillage treatments but mulching with straw increased it over the no-mulch treatments. Mulching favored better root distribution and deeper root extension, which resulted in higher soil water extraction (Fig. 8). The leaf water status measured midday on 27 February showed leaf water potentials in the range of -16 to -19 bars, indicating maize suffered from water stress during later growth stages.

Crop stand and yield. Maize stand and grain and stalk yields did not differ among tillage treatments (Table 12). Shallow chisel plowing (the treatment that provided the most favorable physical environment) gave the highest grain yield of 2.82 t/ha with mulch and 2.20 t/ha without mulch. Mulching produced significantly more yields than no-mulch, giving an average increase of 0.51 t grains/ha and 0.47 t maize stalks/ha.

Nutrient content and uptake in maize. Table 13 shows nitrogen, phosphorus, and potassium concentration in maize ear leaves at silking. The nutrient uptake in grains and stalks at maturity is given



7. Aggregate size distribution in the seedbed 3 weeks following secondary tillage. Dotted lines indicate the geometric mean diameter of aggregates IRRI, 1980



8. Soil water depletion rates during 2 rainless periods in mulched and nonmulched maize plots. Data are average of 5 tillage treatments. IRRI, 1980.

in Table 14. Tillage treatments did not significantly affect nitrogen, phosphorus, and potassium nutrition of maize, but mulching usually resulted in higher nitrogen uptake. Mulching also increased phosphorus uptake in no-tillage plots; potassium uptake was not affected.

Table 11. Effect of tillage and mulch treatments on soil moisture depletion to 45-cm depth and water use efficiency of rainfed maize for the period 4 weeks after germination to maturity. IRRI, 1980.

Tillage treatment	Soil moisture depletion (mm)		Crop water use[a] (mm)		Water use efficiency (kg/ha per mm daily)	
	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch
No tillage	55	51	90	86	0.49	0.37
Moldboard plowing	53	50	88	85	0.48	0 38
Chisel plowing, shallow	63	67	98	102	0.49	0 37
Chisel plowing, deep	50	52	85	87	0 46	0.41
Rototilling	60	58	95	93	0.43	0 36

[a]Estimated from summation of soil water depletion and rainfall (35 mm) during the 58-day sampling period.

Table 12. Maize germination, plant population, grain yield, and stalk yields as influenced by tillage and mulch treatments.[a] IRRI, 1980.

Mulch treatment	No tillage	Moldboard plowing	Chisel plowing, shallow	Chisel plowing, deep	Rototilling
	Germinated seedlings (no./20 m²) before thinning				
None	146 a	136 a	152 a	173 a	146 a
	Plants (no./20 m²) at harvest				
Straw mulch (M1)	91 a	86 a	81 a	82 a	85 a
No mulch (M0)	80 a	78 a	85 a	86 a	86 a
Difference	11 ns	8 ns	−4 ns	−4 ns	−1 ns
	Grain yield (t/ha) at 14% moisture				
Straw mulch (M1)	2.54 a	2.49 a	2.82 a	2 28 a	2 42 a
No mulch (M0)	1.87 a	1.86 a	2 20 a	2.07 a	1.99 a
Difference	0 67**	0.63**	0 62**	0.21 ns	0 43*
	Stalk yield (t/ha)				
Straw mulch (M1)	3.09 a	3.75 a	3.91 a	3 30 a	3 83 a
No mulch (M0)	2 41 b	3.06 ab	3.42 ab	2 98 ab	3.64 a
Difference	0.68*	0.69*	0.49 ns	0.32 ns	0.19 ns

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level.

Table 13. Nitrogen, phosphorus, and potassium content of maize ear leaves at silking as influenced by tillage and mulch treatments.[a] IRRI, 1980.

Mulch treatment	No tillage	Moldboard plowing	Chisel plowing, shallow	Chisel plowing, deep	Rototilling
		Nitrogen content (%)			
Straw mulch (M1)	2.57 a	2.53 a	2.71 a	2 29 a	2 47 a
No mulch (M0)	2.27 a	2.16 a	2.15 a	2.16 a	2.17 a
Difference	0.30 ns	0.37*	0.56**	0.13 ns	0.30 ns
		Phosphorus content (%)			
Straw mulch (M1)	0.31 a	0.28 a	0.30 a	0.28 a	0 27 a
No mulch (M0)	0.24 b	0.27 ab	0 28 ab	0.30 a	0.26 ab
Difference	0.07**	0 01 ns	0.02 ns	−0.02 ns	0.01 ns
		Potassium content (%)			
Straw mulch (M1)	2.12 a	2.12 a	2.10 a	2.10 a	2.13 a
No mulch (M0)	2.12 ab	2.06 b	2.27 a	2.03 b	2.15 ab
Difference	0.00 ns	0.06 ns	−0.17*	0.07 ns	−0 02 ns

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level. ns = not significant.

Table 14 Nitrogen, phosphorus, and potassium uptake of maize (grains + stalk) as influenced by tillage and mulch treatments IRRI, 1980.

Mulch treatment	No tillage	Moldboard plowing	Chisel plowing, shallow	Chisel plowing, deep	Rototilling
		Nitrogen uptake (kg/ha)			
Straw mulch (M1)	56 46 a	59.10 a	65.52 a	52.79 a	55.03 a
No mulch (M0)	41.20 a	42.98 a	50.77 a	43.65 a	49.72 a
Difference	15.26*	16.12*	14.75*	9.14 ns	5.31 ns
		Phosphorus uptake (kg/ha)			
Straw mulch (M1)	10.14 a	11.19 a	11.59 a	8.93 a	10 60 a
No mulch (M0)	7.65 a	8.39 a	9.84 a	8.37 a	9.86 a
Difference	2.49*	2 80**	1.75 ns	0.56 ns	0.74 ns
		Potassium uptake (kg/ha)			
Straw mulch (M1)	49.66 a	62.86 a	76 75 a	58 91 a	75.95 a
No mulch (M0)	41.52 a	53 25 a	63 73 a	44 86 a	71.74 a
Difference	8.14 ns	9.61 ns	13.02 ns	14 05 ns	4 21 ns

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level. ns = not significant

Environment and its influence

Plant Physiology Department

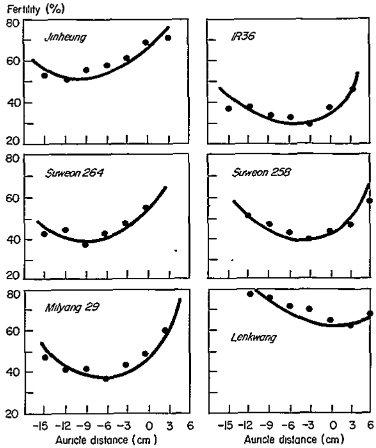
CLIMATIC ADAPTABILITY OF INDICA-JAPONICA RICES

Indica-japonica rices are highly adapted to a wide climatic region — 37°N to 14°N — primarily because of their growth duration (1979 annual report). In 1980 the low temperature tolerance of indica-japonica rices at two critical stages — reduction division and ripening — was studied in the IRRI phytotron.

Low temperature injury at reduction division stage. Rice is sensitive to low temperature. Two kinds of low temperature injury occur to the rice plant at the reduction division stage: degeneration of spikelets and spikelet sterility. To test varietal differences in tolerance for low temperature at the reduction division stage, potted plants were subjected to 15°/15°C for 4 and 7 days. Distance between the auricle of the flag leaf and that of the penultimate leaf was used as a measure of pollen development stage. The auricle distance for the most critical stage (tetrad stage identified under a microscope) varied from +1 cm for Lenkwang to −12 cm for Jinheung.

When the plants were subjected to low temperature for 4 days, percentages of spikelet degeneration ranged from 2% for Lenkwang to 13% for IR36. In the 7-day treatment, the percentages increased considerably, ranging from 3% for Lenkwang to 26% for Suweon 258 (Table 1). Three indica-japonica rices and IR36 had much higher percentages of spikelet degeneration than the cold-tolerant Lenkwang and Jinheung.

A similar trend was observed for spikelet sterility. Lenkwang is the most tolerant of low temperature and Jinheung is the second most tolerant; IR36 is most susceptible (Fig. 1). The low temperature tolerance of three indica-japonica rices was higher than that of IR36 but much lower than that of the traditional cold-tolerant japonica variety, Jinheung.



1. Relationship between fertility of the upper spikelets and auricle distance when the plants were subjected to low temperature (15°/15°C) for 4 days. IRRI, 1980.

Effect of temperature on grain filling. Effects of temperature on grain filling were studied for 6 temperature regimes from 32°/24°C to 17°/9°C. Varietal differences in percentage of filled spikelets as affected by low temperature were clear (Table 2). At 17°/9°C, Jinheung and Lenkwang had more than 50% filled spikelets; IR36 and 3 indica-japonica rices died at the early stages of grain filling. At 20°/12°C, only IR36 died, and the other varieties had more than 70% filled spikelets. The 23°/15°C regime appeared to be the minimum

Table 1. Effect of low temperature for 4 and 7 days at reduction division stage on degeneration of spikelets. IRRI, 1980.

Variety	Spikelets (no./panicle)			Degeneration (%)	
	Control	4 days	7 days	4 days	7 days
Jinheung	54	51	50	6	8
IR36	101	88	76	13	25
Suweon 264	98	92	74	8	25
Suweon 258	154	145	114	6	26
Milyang 29	146	136	115	10	21
Lenkwang	134	133	131	2	3

Table 2. Effects of temperature on the percentage of filled spikelets. IRRI, 1980.

Day/night temp (°C)	Filled spikelets[a] (%)					
	IR36	Jinheung	Suweon 264	Suweon 258	Milyang 29	Lenkwang
17/9	—	52 6	—	—	—	58 3
20/12	—	79.5	73.1	71 6	70 5	77.3
23/15	76 8	84 9	80 4	78.5	78.7	86.7
26/18	82 8	85 7	82 3	81.2	81.1	87.6
29/21	78.9	89 8	81 8	79.6	80.4	88.1
32/24	81.0	88 6	81.7	80 3	76 4	86 8

[a]Dash indicates plants died.

Table 3. Effects of temperature on grain weight IRRI, 1980.

Day/night temp (°C)	Grain weight[a] (mg/grain)					
	IR36	Jinheung	Suweon 264	Suweon 258	Milyang 29	Lenkwang
17/9	—	23 3	—	—	—	20.5
20/12	—	25 3	19.7	21.4	22 8	22.2
23/15	20.1	25 2	20 6	22.1	24 1	23.3
26/18	22.2	25.7	20.3	22 5	25.1	23 3
29/21	21 6	24 1	20 5	22.6	23 8	23.1
32/24	21.4	23 8	19.4	21.7	23 8	22 8

[a]Dash indicates plants died.

temperature for normal grain growth in all varieties tested.

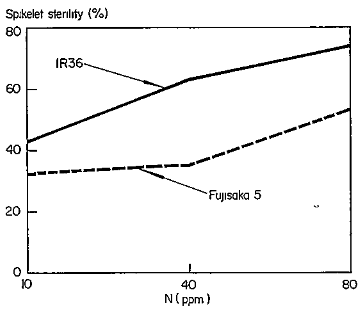
Optimum temperature range for maximum grain weight varied with variety (Table 3). Below and above the optimum temperature range, grain weight was slightly lower in all varieties. These results indicated that low temperature tolerance of indica-japonica rices was clearly lower than that of a traditional japonica (Jinheung) and a tolerant indica (Lenkwang).

WEATHER-NUTRIENT INTERACTIONS

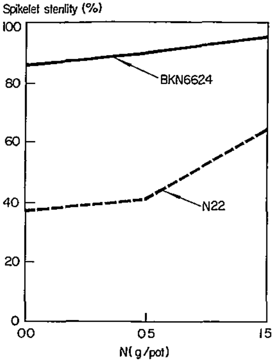
A variety's tolerance for environmental stresses may be greatly affected by levels of plant nutrition, which, in turn, are influenced by soil fertility and fertilizer practices. The effects of nitrogen and potassium nutrition on the variety's tolerance for low and high temperature stresses were studied in the IRRI phytotron. Plants were subjected to low temperature at the reduction division stage or to high temperature at anthesis.

Nitrogen. The cold tolerance of Fujisaka 5 was higher than that of IR36 and more stable with respect to nitrogen nutrition. The percentages of spikelet sterility due to low temperature in IR36 increased from 43% at 10 ppm N to 65% at 40 ppm, and to 74% at 80 ppm N in solution culture (Fig. 2). In the cold-tolerant japonica variety Fujisaka 5, however, spikelet sterility was fairly low — 32-35% at 10 and 40 ppm N, and 56% at 80 ppm N.

BKN 6624 tolerance for high temperature was not much affected by nitrogen nutrition (Fig. 3); spikelet sterility was already high (86%) even at the lowest level of nitrogen. On the other hand, the



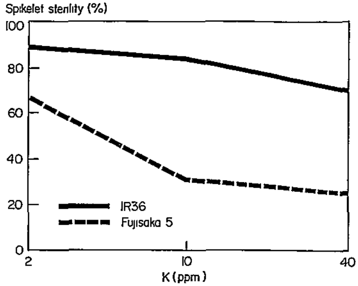
2. Effect of nitrogen (N) on spikelet sterility induced by low temperature (15° C) at reduction division of plants in solution culture. IRRI, 1980.



3. Effect of nitrogen (N) on spikelet sterility induced by high temperature (35° C) at heading of plants in soil culture. IRRI, 1980.

spikelet sterility of N22 increased from 40% at 0.5 g N/pot to 64% at 1.5 g N/pot.

Potassium. Potassium deficiency induces high percentages of spikelet sterility even at normal temperature. In Fujisaka 5, spikelet sterility was 15% at 2 ppm K, 4% at 10 ppm K, and 2% at 40 ppm K. When the variety was subjected to low temperature, potassium deficiency increased spikelet sterility significantly (Fig. 4 and 5). Given 40 ppm K, Fujisaka 5 was not affected at all by low temperature for 3 days. A similar trend was

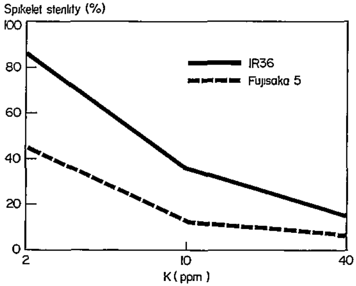


5. Effect of potassium (K) on spikelet sterility induced by low temperature (15° / 15° C) for 5 days at reduction division stage. IRRI, 1980.

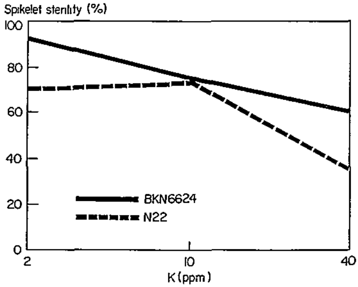
observed in IR36. With low temperature for 5 days, spikelet sterility at 40 ppm K increased to 70% for IR36 but was only 24% for Fujisaka 5. Increased supply of potassium significantly decreased spikelet sterility due to high temperature (Fig. 6). Thus, an adequate supply of potassium along with use of cold-tolerant varieties appears to be an efficient means of overcoming cold damage at the reduction division stage. Potassium also appears to counteract adverse nitrogen effects on spikelet sterility at both low and high temperatures.

TOLERANCE FOR ANAEROBIC SOIL CONDITIONS

Studies with anaerobic soils examined the inter-



4. Effect of potassium (K) on spikelet sterility induced by low temperature (15° / 15° C) for 3 days at reduction division stage IRRI, 1980.

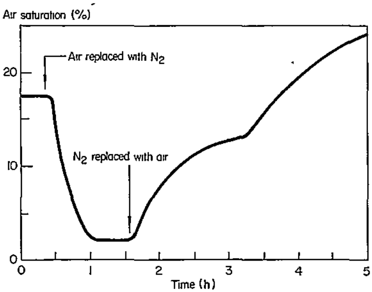


6. Effect of potassium (K) on spikelet sterility induced by high temperature (35° /27° C) at heading IRRI, 1980

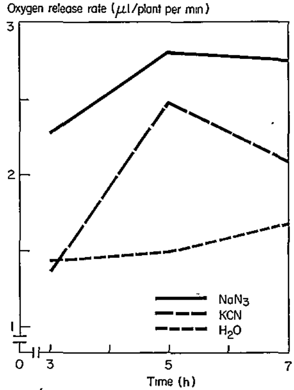
relationship between oxygen release and oxidizing power, investigated the physiological mechanism of the tolerance of the whole plant for anaerobic soil conditions, and attempted to identify donors of physiologically well-defined tolerance.

Release of molecular oxygen from rice roots. Release of molecular oxygen from rice roots into the rhizosphere is a possible means of counteracting adverse anaerobic soil conditions. When rice roots were placed in water void of oxygen, the oxygen concentration of water increased with time and reached a maximum value of 20 to 40% of air saturation. When the atmosphere surrounding the shoots were changed from air to nitrogen gas, the oxygen concentration of the rooting water rapidly decreased within 10 minutes. When the nitrogen gas was again replaced by air, a rapid increase in oxygen concentration of the rooting water occurred (Fig. 7). The results indicated that movement of air from shoot to root was rapid and responded to changes in oxygen content of the atmosphere surrounding the plants. The results also support the idea that air moves in a pipe-like structure, with the shoot being the source and the root the sink.

Effect of respiratory inhibitors on oxygen release rate and α-NA oxidizing power. To determine if a biochemical pathway is responsible for oxygen release from rice roots, roots were treated with metabolic inhibitors. As shown in Figure 8, the oxygen release rate was increased when the roots were treated with sodium azide or potassium



7. Effect of atmospheric oxygen concentration on oxygen release from rice roots IRRI, 1980.



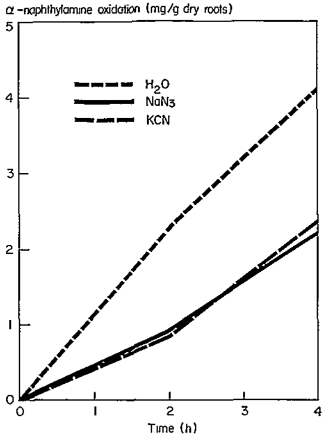
8. Effects of metabolic inhibitors on the rates of oxygen release of rice roots. IRRI, 1980.

cyanide. The metabolic inhibitors, however, reduced the roots' ability to oxidize α-naphthylamine (NA) (Fig. 9). This was expected because oxidation of α-NA by roots is enzymatic.

Effect of temperature on oxygen release rate and α-NA oxidizing power. The rice roots' ability to oxidize α-naphthylamine is due to peroxidase. The α-NA oxidizing power is well correlated with the roots' respiration rate and ferrous iron oxidizing power at pH 4.0.

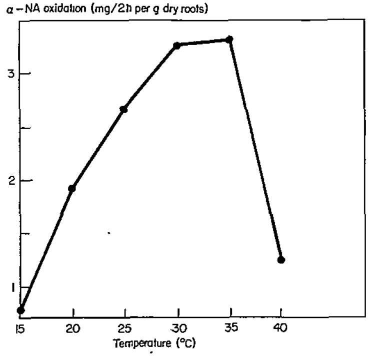
Temperature affects oxygen release rate and α-NA oxidizing power in opposite directions (Fig. 10 and 11). Oxygen release rate decreased with increasing temperature. At 35° C, oxygen release rate became almost nil. On the other hand, the α-NA oxidizing power of roots increased with increasing temperature up to 30° C, stayed the same up to 35° C, but declined sharply beyond it. Thus, at 30-35° C in the rhizosphere, a temperature common in the tropics, rice roots have low oxygen release rates but high α-NA oxidizing power.

Fate of oxygen transported from shoot to root. When oxygen is transported from shoot to root, a large portion is used for root respiration. Because the enzymatic oxidation of α-NA consumes a very small portion of the oxygen, the amount of oxygen released from the roots is almost equal to the



9. Effects of metabolic inhibitors on α-naphthylamine oxidation by rice roots. IRRI, 1980.

difference between the amount transported and that consumed in respiration (Fig. 12). About 70% of the oxygen transported to the root is used for the respiration of root tissues at 25°C. At 35°C, almost all the transported oxygen is used for root respiration. Thus, the primary function of oxygen transport from shoot to root is to maintain respira-

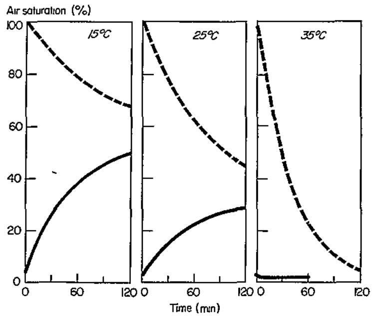


11. Effect of temperature on α-naphthylamine oxidation by rice plants. IRRI, 1980

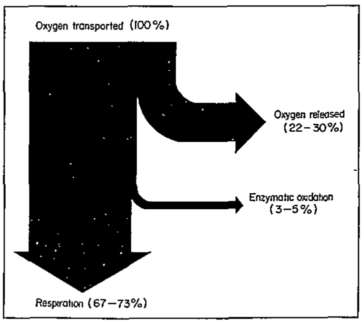
tion of roots growing in anaerobic environments. Oxygen release occurs only when there is surplus oxygen.

Effect of external supply of oxygen on root growth. Rice can grow well in anaerobic soils and also in culture solution without aeration. However, an external supply of air appears to favor elongation of rice roots in culture solution (Fig. 13). Dry weights of shoots and roots were also increased by aeration.

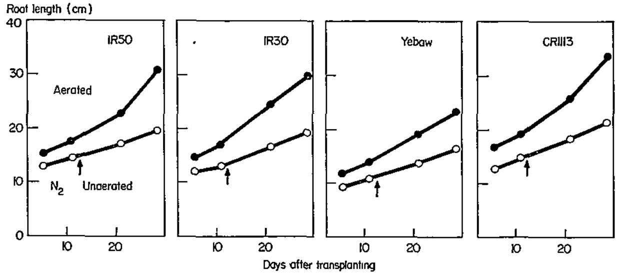
Effect of mineral nutrition on root growth and



10. Effect of temperature on oxygen release by rice roots. Solid lines indicate rates of oxygen release and dotted lines, rates of oxygen consumption. IRRI, 1980



12. Distribution of oxygen in IR36 roots at 25°C. IRRI, 1980.



13. Effect of aeration on root growth. Aerated: 97% of air saturation, N_2: 38% of air saturation for 12 days; unaerated; 54% of air saturation. IRRI, 1980.

root oxidizing power. Two-week-old IR36 seedlings grown in complete culture solution were transferred to culture solutions deficient in individual nutrients and grown for 1 week. Deficiency symptoms of nitrogen, calcium, and magnesium were clear; those of potassium and phosphorus were moderate. In the nitrogen-deficient plants, shoot growth was markedly decreased but root growth, both in length and weight, increased significantly (Table 4). As a consequence, the root-shoot ratio of the nitrogen-deficient plants was more than two times that of control plants. Calcium deficiency, however, decreased shoot and root growth to a similar degree. The oxygen release rates were also lower in the nitrogen- and calcium-deficient plants. The roots' ability to oxidize α-NA was significantly reduced only in the nitrogen-deficient plants.

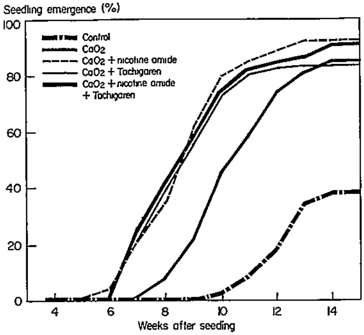
CHEMICAL CONTROL OF SEEDLING EMERGENCE FROM FLOODED SOILS

Effect of calcium peroxide, nicotine amide, and Tachigaren on seedling emergence. Coating rice seeds with calcium peroxide improves seedling emergence from flooded soils (1979 annual report). In 1980, a pot experiment was used to examine the effect of nicotine amide and Tachigaren on seedling emergence at high temperatures that prevail in the tropics. Seeds were soaked in 1,000 ppm nicotine amide solution for 24 hours and then coated with calcium peroxide. Tachigaren was added to calcium peroxide at a rate of 3%. Seedling emergence was faster when the seeds were treated with either nicotine amide or Tachigaren along with calcium peroxide than with calcium peroxide coating alone. There was, however, less than 10% difference in seedling emergence among the treatments 13 weeks after seeding (Fig. 14).

Comparison of methods of seedling establishment. Four methods of seedling establishment were compared to study the effectiveness of calcium peroxide coating in wetland direct seeding (Table 5). In machine seeding, coated or uncoated seeds were sown by a wet paddy seeder. In broadcast flooded seeding, coated or uncoated seeds were broadcast on flooded puddled soil before soil particles were fully settled. In broadcast drained seeding, only uncoated seeds were broadcast on

Table 4. Effects of mineral nutrition on growth and oxidizing power of IR36 plants. IRRI, 1980.

Culture solution	Dry wt (mg/plant) Shoot	Dry wt (mg/plant) Root	Root-shoot ratio	Oxygen release rate (μl O_2/plant per min)	α-NA oxidizing power (mg/g dry root per h)
Complete	308	61	0.20	0.87	1.11
−N	184	93	0.50	0 39	0.80
−P	237	64	0.27	0 66	1 39
−K	245	45	0.19	1.02	1.27
−Ca	187	32	0.17	0.27	1.35
−Mg	286	65	0.23	0 93	1.09



14. Effect of various chemicals on rice seedling emergence from flooded soil. IRRI screenhouse, 1980.

the soil surface after the field was drained. For the fourth treatment 20-day-old seedlings were transplanted at 20- × 20-cm spacing.

Coating with calcium peroxide ensured that sufficient seedlings emerged from flooded puddled soil. As a consequence, grain yields of wetland direct-seeded crops were comparable to those of the broadcast-drained and the transplanted plots. When uncoated seeds were placed in flooded puddled soil, however, percentages of seedling emergence were extremely low and uneven, resulting in low yields.

Effect of seedling density on grain yield of wetland direct-seeded crop. Because the calcium peroxide required is proportional to the amount of rice seeds, three seeding rates — 30, 50, and 70 kg/ha — were used to examine whether seeding rate and calcium peroxide cost can be reduced (Table 6).

Table 5. Effectiveness of calcium peroxide seed coating used in different planting methods IRRI, 1980[a].

Method of planting	Calcium peroxide coating	Emerged seedlings (no./m²)	Grain yield (t/ha)
Machine seeded[b]	With	174	5.5
	Without	8	0 6
Broadcast, flooded	With	216	5.4
	Without	30	2.7
Broadcast, drained	Without	259	5.6
Transplanted[c]	—		5.4

[a]Variety IR36, at seeding rate of 50 kg/ha [b]Row spacing of 30 cm. [c]20- × 20-cm spacing

Table 6. Effect of seeding density on grain yield of IR36 in wetland direct seeding. IRRI, 1980.

Seeding rate (kg/ha)	Emerged seedlings (no./m²)	Grain yield (t/ha)
30	157	4 20
50	223	3.94
70	273	4 24

The experiment indicated that by coating rice seeds with calcium peroxide, seeding rate can be reduced to one-third or one-fourth of the current practice. Seedling emergence ranged from 157 plants/m^2 at 30 kg seeds/ha to 273 plants/m^2 at 70 kg seeds/ha. Because the seedlings that emerged were evenly distributed in the field and IR36 is a high tillering variety, the difference in initial plant density did not affect grain yields among three seeding rates. In traditional direct-seeding practice, seeding rates of 100 to 120 kg/ha are common.

Constraints on rice yields

Agricultural Economics and Agronomy Departments

CONSTRAINTS TO HIGH RICE YIELDS IN FARMERS' FIELDS

Agricultural Economics Department

Constraints research in economics for 1981 focused on technical and economic relationships between rice yields and input use in the individual paddy, and analysis of economic and institutional factors influencing the farmer's use of technology. Economic efficiency is partitioned into two components:

- the individual's ability and desire to maximize profits — referred to as price or allocative efficiency — and
- the farmer's capacity to obtain the greatest possible output for a given set of inputs — referred to as technical efficiency.

Price responsiveness of Laguna (Philippines) rice farmers. A sample of 81 rice farmers was drawn from the Economics Department's long-term loop survey of Laguna province. Most of the farmers were leaseholders, double-cropping about 2.2 ha of irrigated rice. One-third of the sample owned a carabao and 41% owned hand tractors at the time of the survey (early 1979). The farmers grew modern rice varieties and used high levels of inputs. Wet season yields averaged 3.9 t/ha, which was twice the national average (Table 1).

The output function of the rice production process was specified as:

$$Y = A\ F^{\alpha 1}\ M^{\alpha 2}\ P^{\alpha 3}\ C^{\alpha 4}\ E^{\alpha 5}\ W^{\alpha 6}\ Z_1^{\delta 1}\ Z_2^{\delta 2} \exp(\rho_1 D_1 + \rho_2 D_2) \quad (1)$$

where

Y is rice output, in kilograms;
A is a constant;
F is the quantity of fertilizer applied, in kilograms;
M is the number of mechanical (hand tractor) power days for land preparation;
P is the quantity of pesticide applied (a composite of insecticide and herbicide);
C is the number of carabao days for land preparation;
E is the number of days of labor to transplant the rice crop;
W is the number of days of labor used for crop maintenance, mainly weeding;
Z_1 is the rice area, in hectares;
Z_2 is capital inputs, in pesos,
D_1 is an irrigation index (1 = low, 5 = high quality); and
D_2 is a soil quality index (1 = clay, 5 = light-textured soil).

Table 1. Typical rice production systems in Laguna, Philippines, 1978 wet season.[a]

	Physical unit/ha	Value[b] ($/ha)
Output		
Rough rice	3 9 t	489 80
Inputs		
Fertilizer	250 kg	112.10
Pesticides	1 kg a i.	31 70
Carabao	28 h	12.10
Power tiller	32 h	142 59
Labor — preharvest	58 d	103.40
— harvest-postharvest	28 d	55 37
— total	86 d	172 38

[a]Sample size = 81 [b]In the 1979 dry season US$1 = ₱7 35

$F, M, P, C, E,$ and W are the variable factors of production; Z_1, Z_2, D_1, and D_2 are fixed factors. Because profit functions explicitly include prices in the analytical models, profit function is a useful way to study allocative efficiency. The normalized restricted profit function derived from (1) is given by:

$$\ln \pi^* = \ln A^* + \sum_{i=1}^{6} \beta_i^* \ln P_i + \sum_{j=1}^{2} \gamma_j \ln Z_j + \sum_{k=1}^{2} \delta_k D_k + u \quad (2)$$

where

π^* is restricted profit (current revenue less current variable costs) per farm, normalized by the output price of rice;
A^* is a constant (technical efficiency parameters);
P_1 is the money price of fertilizer, per kilogram, normalized by the price of output;
P_2 is the money price of mechanical input per day, normalized by the price of output;
P_3 is the money price of pesticides per kilogram (insecticides and herbicides), normalized by the price of output;
P_4 is the money price of animal output per day, normalized by the price of output;
P_5 is the money wage per day for crop establishment normalized by the price of output;
P_6 is the money wage per day for crop maintenance (mainly weeding), normalized by the price of output; and
Z_1 to D_2 are as defined in equation 1.

The restricted profit function defined by equation 2 is in terms of exogenous variables: normalized (or real prices) and fixed factors of production. As such the associated levels of variable inputs X_i, which will maximize expected profits, cannot be estimated directly from equation 2.

The optimal levels of variable inputs are estimated from the input demand function as:

$$\frac{-X_i P_i}{\pi^*} = \beta_i^* + \nu_i \tag{3}$$

where $i = F, M, P, C, E, W.$

$F, M, P, C, E,$ and W are the variable production inputs defined in equation 1; and

ν_i are error terms representing divergence between expected and realized price of each variable input.

The logarithmic normalized profit function (equation 2) and variable factor demand functions (equation 3) are jointly estimated to obtain the unknown parameters A^*, β_i^*, γ_i, and δ_k. Restricted Aitken's estimation techniques provide asymptotically efficient estimates of these parameters.

Profit-maximizing assumption. An argument inherent in the profit function approach is that farmers are price efficient. The acceptability of the assumption that farmers attempt to maximize short-term profits can be judged by testing whether the elasticities of the variable inputs are similar when derived from the normalized profit function and from the corresponding variable factor demand equations.

Table 2. Tests of restrictions on ß-parameters of restricted profit function and factor demand functions. IRRI, 1980.

Restrictions	Lagrange multipliers λ^a	Lagrange multipliers t^b	X^2-test statistic
$\beta_1^{\pi^*} = \beta_1^{*F}$	1.51 (1.99)	0.76	9 56
$\beta_2^{\pi^*} = \beta_2^{*M}$	6.08 (4.50)	1 35	
$\beta_3^{\pi^*} = \beta_3^{*P}$	5.11 (4 69)	1 09	
$\beta_4^{\pi^*} = \beta_4^{*C}$	1 83 (3.64)	0.50	
$\beta_5^{\pi^*} = \beta_5^{*E}$	3 97 (2.18)	1 82	
$\beta_6^{\pi^*} = \beta_6^{*W}$	3.84 (2.56)	1.50	

[a]Figures in parentheses are standard errors of estimates (n = 81). [b]Student t-values to assess whether λ_i was significantly different from zero

The Lagrange multipliers (λ_i) used to restrict the estimates of the β_i's when derived from the profit function and variable factor demand equations were not significantly different from zero (Table 2). The X^2 test, which tested the validity of the restrictions as a whole, also was not significant. Thus, the assumption that Laguna rice farmers seek to maximize current profits did not appear to be unduly restrictive. Of the variable inputs, however, two categories of labor — in particular labor for crop establishment — came closest to violating the profit-maximizing assumption. One reason for that result may be that the hired labor wage was a poor proxy for the imputed opportunity cost of family labor; another reason was the difficulty of obtaining precise labor inputs based on single-recall interviews.

Table 3. Restricted normalized profit function and factor demand functions, 1979 wet season, Laguna, Philippines.

Variable[a]		Restricted profit function[b]	Factor demand function[b]
A^*	constant	8 07 (1.11)	
β_1^*	N fertilizer price	−0.16 (0 05)	−0 16 (0 05)
β_2^*	N mechanical power price	−0 26 (0.05)	−0 26 (0 05)
β_3^*	N price of pesticides	−0 05 (0 02)	−0 05 (0.02)
β_4^*	N price of animal power	−0 09 (0 04)	−0 09 (0.04)
β_5^*	N labor, establishment	−0.14 (0 26)	−0.14 (0.26)
β_6^*	N labor, maintenance	−0 27 (0.08)	−0 27 (0.08)
γ_1	area	0.74 (0 11)	
γ_2	assets	0 08 (0 04)	
δ_1	irrigation index	−0.09 (0.03)	
δ_2	soil texture index	−0 01 (0 01)	

[a]N implies normalized input prices, i.e., p_i/p_y. [b]Numbers in parentheses are estimates of asymptotic standard errors (n = 81).

Output supply and input demand elasticities. The restricted parameter estimates of the normalized profit function and the factor demand functions are listed in Table 3. The output (supply) elasticity for rice with respect to its own price (0.97) approaches unity; hence, a 1% increase in rice price is expected to induce an almost similar increase in rice supplies. Laguna farmers, therefore, were responsive to changes in rice prices.

The demand for labor for crop maintenance (-0.27) which as mainly weeding, and mechnaical land preparation (-0.26) were sensitive to changes in rice price. However, the demand for pesticides and animal power was not (both less than 0.1), and fertilizer (0.16) was between those. The output supply elasticity of rice exceeded 0.7 for land, but was low (less than 0.1) for capital. Thus, within the range of farm sizes studied, an increase in irrigated area (allowing for adjustments in the levels of variable inputs) would have a substantial impact on output. Improving the quality of irrigation although significant had a small effect on profits. The insensitivity of wet season profits in the Laguna sample to irrigation quality was probably due to less dependence of the monsoon rice crop than of the dry season crop on irrigation water.

Indirect production elasticities. The indirect production elasticities derived from the restricted profit function are listed in Table 4. Diminishing returns to scale prevailed with respect to rice production (0.91). The elasticity coefficients showed that farm size was the most important factor influencing rice output on a per farm basis. The production elasticities for all inputs except crop maintenance and power tillage were low — less than 0.1.

Technical efficiency of Laguna rice farmers. Laguna rice farmers appeared to be allocatively efficient. The above analysis, however, did not allow examination of the comparative *technical* efficiency of this sample of rice farms.

Technical efficiency is a measure of a farm's *success in producing maximum output from a given set of inputs.* A prodution frontier model was used to study the comparataive technical efficiency of the farmers. The function was estimated as the envelope curve of most efficient farmers, and the technical efficiency of individual farms then assessed in relation to the efficient set.

The frontier production function, or maximum technologically possible output (MTPO) curve corresponding to equation 1 is:

$$Y = f(X_i, Z, D) + u + v \qquad (4)$$

where

$Y, X_i, Z,$ and D are as defined in equations 1-3;
u is the difference between the farm's practice and the best practice technique and relates to the firm's technical efficiency — it is either zero or negative; and
v is the statistical error term.

Table 4. Indirect estimates of production function elasticities, 1979 wet season, Laguna, Philippines.

Variable		Production elasticity (indirect estimate)
Fertilizer	α_1	0.08
Mechanical power	α_2	0.13
Pesticides	α_3	0.03
Animal power	α_4	0.04
Labor — establishment	α_5	0.07
— maintenance	α_6	0 13
Area	γ_1	0.38
Assets	γ_2	0.04

It was assumed that v was normally distributed and u was a half normal distribution. Maximum likelihood techniques were used to estimate the parameters in the equation because ordinary least squares techniques were not suitable with two error terms as structured in the equation.

The relative variability of u and v provided a means to statistically estimate the sources of the difference between the farmer's yield and that estimated by MTPO. This was achieved by calculating the variance ratio parameter (γ), which related the variability of u to total variability (σ^2) in the following way:

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \qquad (5)$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $0 \leqslant \gamma \leqslant 1$.

γ has two important characteristics:

- when σ_v^2 tends to zero, then u is the predominant error in equation 4, and $\gamma \rightarrow 1$. This implies that the output of the sample farmers differs from the MTPO mainly because of differences in technical efficiency.
- when σ_u^2 tends to zero, then the symmetric error v is the predominant error in equation 4, so $\gamma \rightarrow 0$.

Thus, based on the value of γ, it is possible to identify whether the difference between a farmer's output and the efficient output is principally due to statistical errors ($\gamma \rightarrow 0$), or to the sample's less than efficient use of technology ($\gamma \rightarrow 1$).

The ordinary least squares (OLS) and maximum likelihood estimates (MLE) of equation 4 are in Table 5. The estimates of the partial regression coefficients in the OLS and MLE models were similar; the main difference was between the intercept terms. When compared to the OLS or *average* model, the MLE function tended to cause a vertical

Table 5. Ordinary least squares (OLS) and maximum likelihood estimates (MLE) for a sample of Laguna (Philippines) rice farmers, 1978 wet season.[a]

Variable		OLS	MLE
Constant	A	504 47	541.01
Fertilizer	F	09**	.08**
Mechanical power	M	.12**	12**
Pesticides	P	.03 ns	.03**
Carabao days	C	0.13**	.12**
Labor, establishment	E	.02 ns	02 ns
Labor, maintenance	W	.14**	.14**
Area	Z_1	.37**	36**
Assets	Z_2	ϕ ns	ϕ ns
Irrigation index	D_1	02 ns	.02
Soil texture index	D_2	ϕ ns	ϕ ns
$\bar{R}^2$		52	—
F ratio		9.65**	—
Log likelihood function		−108 88	−31.27
Variance ratio	γ	—	04+
Total variability	σ^2	—	20**
Farmer variability	σ^2_u	—	.01
Random variability	σ^2_r	—	19
n		81	81

[a]** Implies significant at 1% level, + implies significant at 10% level, ns = not significant, ϕ implies less than 0 01

shift, as opposed to a change in the slope of the production function.

An important result in Table 5 for the MLE model was that the variance ratio parameter, γ, while greater than zero ($P \leqslant 10\%$) was comparatively small (0.04), given the internal within which γ lies. By inference, the variation in an individual farm's output arises mainly from random variability as opposed to marked differences in between-farmer levels of technical efficiency. Therefore, differences in technical efficiency of the sample Laguna farmers were not large — given the technology they now employ to grow their wet season rice crop.

The production elasticities derived directly from the production function (Table 5) and those derived indirectly from the profit function (Table 4) were similar. They demonstrate the robustness of the primal production and the dual profit function.

BIOLOGICAL CONSTRAINTS

Agronomy Department

Fertilizer forms and timing of application. Forms of urea fertilizer, application methods, and timing of application were studied in farmers' fields in three Philippine provinces. Three forms of urea — prilled urea (PU), sulfur-coated urea (SCU), and supergranule urea (SGU) — were used. Treatments and resulting grain yields are summarized in Tables 6-7. Supplemental treatments compared the farmers' and researchers' timing of applying nitrogen. All treatments received a basal application of 30 kg P_2O_5/ha and 30 kg K_2O/ha in a randomized complete block design with 2 replications. Yields are summarized in Table 8. Highlights of the 1980 results are in the following sections.

Nueva Ecija sites. Although the highest dry season grain yield (6.9 t/ha) in Nueva Ecija was obtained with the application of 120 kg N/ha as prilled urea in 3 equal splits, such yield did not differ significantly from that obtained from any of the treatments with 80 kg N/ha except the researchers' 3-split application. The researchers' timing of three equal applications gave an average yield increase of 0.3 t/ha from farmers' timing (8 days and 38 days after transplanting [DT]), but the increase was not significant (Table 6).

In the supplemental experiment, the lower ni-

Table 6. Effect of sources and methods of nitrogen application on the grain yield of rice in farmers' fields in 3 Philippine provinces, 1980 dry season.

Treatment	Grain yield[a] (t/ha)		
	Nueva Ecija	Laguna	Camarines Sur
No fertilizer nitrogen	4 9 d	4 3 c	3.5 c
	Farmers' N level[b]		
Farmers' split[c]	6 1 c	6.5 ab	4 9 b
Researchers' 3 equal split applications[d]	6.4 abc	6 2 b	5.4 ab
	80 kg N/ha		
Plowsole application	6 5 ab	6.0 b	5 1 ab
Supergranule point placement[e]	6 5 ab	7 0 a	5 6 a
Sulfur-coated urea broadcast and incorporated	6.6 ab	6 3 ab	5.5 a
Researchers' 3 equal split applications	6.3 bc	6 3 ab	5.3 ab
Researchers' 2 unequal split applications[f] with incorporation[g]	6.5 ab	6 2 b	5 5 a
Researchers' 2 unequal split applications	6 6 ab	5 8 b	5 3 ab
	120 kg N/ha		
Researchers' 3 equal split applications	6 7 a	7.0 a	5.5 a

[a]Data are averages of 7 farms in Nueva Ecija, 4 in Laguna, and 3 in Camarines Sur. Separation of means in a column by Duncan's multiple range test at the 5% level [b]Average was 86 kg N/ha for Nueva Ecija sites, 90 kg N/ha for Laguna, 85 5 kg N/ha for Camarines Sur. [c]Applied 8 and 38 days after transplanting (DT) in Nueva Ecija; 18 and 53 DT in Laguna, and basal broadcast and incorporated (BI), 30 DT, and 5-7 days before panicle initiation (DBPI) in Camarines Sur [d]BI, 20-30 DT, and 5-7 DBPI. [e]10-12 cm below soil surface [f]Two-thirds BI, and one-third 5-7 DBPI. [g]With rotary weeder or by hand 5-7 DBPI.

Table 7. Effect of sources and methods of nitrogen application on the grain yield of rice in farmers' fields in 3 Philippine provinces, 1980 wet season.

Treatment	Grain yield[a] (t/ha)		
	Nueva Ecija	Laguna	Camarines Sur
No fertilizer nitrogen	4.4 c	4 1 b	3.5 c
Farmers' N level[b]			
Farmers' split[c]	5 7 b	4 8 a	4 5 a
Researchers' 2 equal split applications[d]	6 0 a	4.9 a	4.5 a
29 kg N/ha			
Plowsole application[e]	5 4 b	4 8 a	3 9 b
Supergranule point placement	5 4 b	5 2 a	4.4 a
Sulfur-coated urea broadcast and incorporated	5 3 b	4 9 a	4 5 a
Researchers' 2 equal split applications	5.3 b	4 8 a	4 2 ab
Researchers' 2 unequal split[f] applications with incorporation[g]	5 3 b	5 0 a	4.2 ab
Researchers' 2 unequal split applications	5.4 b	4.7 a	4.3 ab
60 kg N/ha			
Researchers' 2 equal split applications	5 5 b	4 9 a	4.4 a

[a]Data are averages of 8 farms in Nueva Ecija, 5 in Laguna, and 8 in Camarines Sur. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Average was 69 kg N/ha for Nueva Ecija sites, 70 kg N/ha for Laguna, 62 kg N/ha for Camarines Sur [c]Nueva Ecija: 10 days after transplanting (DT) and 5-7 days after panicle initiation; Laguna 18 and 49 DT; Camarines Sur: basal, 20 DT, and 5-7 days before panicle initiation (DBPI). [d]Basal broadcast and incorporated (BI) and 5-7 DBPI. [e]For Laguna and Camarines Sur, average rates of nitrogen applied were 25 and 21 kg/ha. [f]Two-thirds BI and one-third 5-7 DBPI [g]With rotary weeder or by hand 5-7 DBPI.

trogen rate (I-1 = 50 kg N/ha) gave researchers' timing an average 0.6 t/ha yield increase from farmers' timing (Table 8).

In wet season trials, yields from the 29 kg N/ha application techniques were comparable to those from prilled urea at 60 kg N/ha applied in 2 equal split doses. Plots receiving high rates of nitrogen had severe lodging caused by typhoons and substantial yield reduction.

The trial results indicated that the incorporation of topdressed nitrogen at 5-7 days before panicle initiation was not necessary for achieving high yield (Table 7).

In the supplemental experiment researchers' timing yielded significantly higher than farmers' timing at all nitrogen levels (Table 8). These results agreed with an earlier finding in Nueva Ecija that many farmers apply fertilizer nitrogen inefficiently.

Laguna sites. The highest dry season grain yield (7.0 t/ha) in Laguna was obtained with 80 kg N/ha as urea supergranules placed at 12-cm soil depth 4 DT. With 120 kg N/ha as prilled urea applied at 3 equal splits, grain yield was only 7.0 t/ha (Table 6). Farmers' split application (18 and 53 DT) produced yields similar to the researchers' split.

In the supplemental experiment, yield differences were not significant (Table 8).

In the wet season, urea supergranules at 29 kg N/ha placed at 12-cm depth 4 DT produced 5.2

Table 8. Effect on grain yield of farmers' and researchers' timing of application of farmers' level and test levels of fertilizer nitrogen in farmers' fields in 3 Philippine provinces, 1980

Province	Sites (no.)	Time of nitrogen application[a]	Nitrogen applied		Grain yield[c] (t/ha)			
			Rate (kg/ha)	Timing[b]	Farmers' level	I-1	I-2	H
			Dry season					
Nueva Ecija	6	F	112	8,38 DT	6 7 a	6 2 a	6 9 a	7 6 a
Nueva Ecija	6	R	112		6 9 a	6 8 b	7 0 a	7.4 a
Laguna	4	F	84	18,53 DT	6 5 a	5 9 a	6 7 a	6.8 a
Laguna	4	R	84		6.7 a	6 2 a	6.7 a	6 8 a
Camarines Sur	5	F	82	4,45 DT	5 5 a	5 0 a	5 5 a	5.5 a
Camarines Sur	5	R	82		5 2 a	5 2 a	5.5 a	5 2 a
			Wet season					
Nueva Ecija	4	F	62	10,5-7	6 1 a	5 7 a	6 1 a	6 4 a
Nueva Ecija	4	R	62	DAPI	6 7 b	6 4 b	6 4 b	6 7 b
Laguna	6	F	70	18,49 DT	5 2 a	5 0 a	5 1 a	5 0 a
Laguna	6	R	70		5 1 a	4 9 a	5 2 a	4 8 a
Camarines Sur	5	F	66	0,43 DT	5 4 a	5 0 a	5.5 a	5 9 a
Camarines Sur	5	R	66		5 7 a	5 2 a	5 8 a	6 1 a

[a]F = farmers', R = researchers' [b]DT = days after transplanting DAPI = days after panicle initiation Researchers' timing of N application. dry season — 3 equal split applications (basal broadcast and incorporated, 20-30 DT, and 5-7 days before panicle initiation); wet season — 2 equal applications (basal broadcast and incorporated, and 5-7 days before panicle initiation [c]Test rates of nitrogen for dry season· intermediate levels were I-1 = 50 kg N/ha, I-2 = 100 kg N/ha, high level (H) was 150 kg N/ha. For wet season, I-1 = 29 kg N/ha, I-2 = 58 kg N/ha, H = 87 kg N/ha. For each province, separation of means in a column by Duncan's multiple range test at the 5% level.

Table 9. Levels of inputs used in yield response trials in farmers' fields in 3 Philippine provinces, 1980.

Province	Input level[a]	Sites (no.)	Fertilizer[b] (kg/ha)			Insect control[c]	
			N	P_2O_5	K_2O	F	G
			Dry season				
Nueva Ecija	F	2	85	36	36	1.5	0.5
Nueva Ecija	I	2		30	30	1.0	0 5
Nueva Ecija	H	2	120	30	30	3 0	4 0
Laguna	F	2	118	23	23	2.5	0
Laguna	I	2		30	30	1 0	2 0
Laguna	H	2	120	30	30	3.0	4.0
Camarines Sur	F	3	88	24	20	1 0	0
Camarines Sur	I	3		30	30	1 0	0
Camarines Sur	H	3	120	30	30	4 0	3 0
			Wet season				
Nueva Ecija	F	2	82	46	18	2.5	2 0
Nueva Ecija	I	2		30	30	2 5	1 0
Nueva Ecija	H	2	87	30	30	5.5	4.0
Laguna	F	2	70	11	11	2.0	0
Laguna	I	2		30	30	1 0	2.0
Laguna	H	2	87	30	30	3 0	4.0
Camarines Sur	F	3	74	30	30	2 3	0
Camarines Sur	I	3		30	30	2.0	0
Camarines Sur	H	3	87	30	30	3 7	4 0

[a]F = farmers', I = intermediate, H = high [b]Other test rates of nitrogen: dry season — 0, 60, 90, and 150 kg/ha; wet season — 0, 29, 58, and 116 kg/ha. Time of N application. 2 split doses (two-thirds basal broadcast and incorporated, and one-third 5-7 days before panicle initiation) Phosphorus and potassium were applied basally. [c]Data show average number of foliar (F) sprays (monocrotophos, methyl-parathion, azinphos-ethyl) or of granular (G) applications (lindane, carbofuran, diazinon) to paddy water. The main field crops were treated In some cases, seedbeds were also treated.

t/ha, but treatments did not differ significantly (Table 7). The yield from farmers' split application of 70 kg N/ha was similar to that with the researchers' timing of fertilizer application.

In the supplemental experiment, grain yields with farmers' timing were similar to yields with researchers' timing at all nitrogen levels (Table 8). Low yields were due to lodging.

Camarines Sur sites. At Camarines Sur, the average dry season grain yields at 80 kg N/ha were similar for point placement of urea supergranules, basal application of ordinary sulfur-coated urea, and the researchers' split (2 and 3) applications of prilled urea (Table 6). Application of a higher rate (120 kg N/ha as prilled urea) using the researchers' 3-split method gave no additional yield increase. The average yield with plowsole placement of prilled urea was only 5.1 t/ha because of extremely low yield from 1 farm.

In the supplemental experiment, yields with farmers' and researchers' timing at all levels of nitrogen did not differ significantly (Table 8). Bacterial blight and sheath blight caused substantial yield reductions on plots that received high levels (I-2 and H) of nitrogen.

In the wet season, yields with plowsole application were significantly lower than those in other treatments, but the plowsole treatments had only 21 kg N/ha. With plowsole application yields ranged from 2.4 to 5.7 t/ha. Yield variations could be attributed to the length of time nitrogen was applied before transplanting, and variations in nitrogen rates from farm to farm.

In the supplemental experiment, no significant yield differences were seen (Table 8).

Yield response to major farm inputs. A 1980 dry season experiment on irrigated farms in three provinces evaluated the response of transplanted rice to increasing levels of nitrogen. The levels of inputs are shown in Table 9.

Nueva Ecija sites. Dry season grain yields at farmers' and all test levels of nitrogen (except zero level) at Nueva Ecija were not statistically different. Among the fertilizer combinations tested, complete fertilizer (NPK at 120-30-30 kg/ha) produced a grain yield of 7.0 t/ha (Table 10). Without fertilizer nitrogen, the yield decreased substantially (3.6 t/ha) and the omission of phosphorus and potassium in the fertilizer package decreased yield by as much as 1.0-1.4 t/ha. The yield responses to phosphorus and potassium were not significant. As in the results obtained from the main experiment, the

Table 10 Yield response of rice to nitrogen, phosphorus, and potassium in farmers' fields in 3 Philippine provinces, 1980.

Fertilizer application[a]	Grain yield[b] (t/ha)		
	Nueva Ecija	Laguna	Camarines Sur
	Dry season		
PK	3 6 b	5.6 b	4.3 c
NK	6.0 a	6 3 ab	5 4 b
NP	5.6 ab	6.7 a	5 6 ab
NPK	7.0 a	6 5 a	6 5 a
	Wet season		
PK	4 3 b	3.5 b	4.1 a
NK	6 8 a	4 5 ab	4 2 a
NP	6 5 a	4 4 ab	4 2 a
NPK	7 1 a	4 8 ab	4 5 a

[a]Dry season: 120 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha; wet season: 87 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha. [b]Number of test sites for both dry and wet seasons. Nueva Ecija — 2, Laguna — 2, Camarines Sur — 3. Separation of means in a column by Duncan's multiple range test at the 5% level

incorporation of the remaining dose of nitrogen to the soil at 5-7 days before panicle initiation gave no further yield increase (Table 11).

In the wet season, grain yields increased with increasing levels of nitrogen up to 87 kg N/ha, but the yields obtained with 29 kg N/ha, 58 kg N/ha, and the farmers' nitrogen level of 82 kg N/ha were not significantly different.

No additional yield response was obtained with the application of 116 kg N/ha. Complete fertilizer (87-30-30 kg NPK/ha) produced an average yield of 7.1 t/ha (Table 10). Incorporating nitrogen into the soil at 5-7 days before panicle initiation had no effect on grain yield (Table 11).

Laguna sites. In dry season experiments in Laguna, average grain yields with increasing levels of nitrogen were similar. The grain yield with no nitrogen was not significantly different from yields at the farmers' level (60 kg N/ha and 150 kg N/ha) (Table 12). The application of NPK at 120-30-30 kg/ha produced 6.5 t/ha grain yield, which was similar to the yields of the no-phosphorus and no-potassium treatments (Table 10). No benefit was seen from incorporating the second application of fertilizer at 5-7 days before panicle initiation (Table 11). In the wet season, application of NPK gave no significant yield difference from no-phosphorus and no-potassium treatments (Table 10). No benefit was gained from incorporating the second application of fertilizer 5-7 days before panicle initiation (Table 11).

Camarines Sur sites. Dry season results in Camarines Sur were similar to those at Nueva Ecija and Laguna. Complete fertilizer at the rate of 120-30-30 kg NPK/ha produced an average yield of 6.5 t/ha (Table 10). Response to potassium application was not significant. As in the main experiment, soil incorporation of topdressed nitrogen at 5-7 days before panicle initiation did not increase the yield further (Table 11).

In the wet season, the highest yield (4.9 t/ha) was obtained from 29 kg N/ha (Table 12). The application of 116 kg N/ha produced yields similar to those with zero nitrogen. At the farmers' level of nitrogen (74 kg N/ha), the average yield was 4.3 t/ha. The erratic trend of yields with increasing

Table 11. Effect on rice grain yield of incorporating fertilizer nitrogen into the soil before panicle initiation in experiments in farmers' fields in 3 Philippine provinces, 1980.

Province	Sites (no.)	Grain yield (t/ha)		
		With incorporation[a]	Without incorporation	Difference[b]
		Dry season		
Nueva Ecija	2	8.5	8 4	0.1 ns
Laguna	2	6 8	6 7	0 1 ns
Camarines Sur	3	6.7	7 3	−0 6 ns
		Wet season		
Nueva Ecija	2	7 1	7 1	0 ns
Laguna	2	4 2	4 3	−0.1 ns
Camarines Sur	3	4.5	4 7	−0 2 ns

[a]By rotary weeder or by hand. [b]ns = not significant.

Table 12. Grain yields of farmers' and increasing nitrogen levels from experiments in farmers' fields in 3 Philippine provinces, 1980.

Level of nitrogen[a] (kg/ha)	Grain yield[b] (t/ha)		
	Nueva Ecija	Laguna	Camarines Sur
	Dry season		
Farmers'	5.5 ab	6 3 ab	5.7 a
0	3 6 b	5 6 b	4.3 b
60	5 8 a	6.1 ab	5 9 a
90	6 0 a	6 5 a	6 3 a
120	7 0 a	6 5 a	6.5 a
150	6 8 a	6 3 ab	6.1 a
	Wet season		
Farmers'	6 1 bc	5.6 a	4.3 b
0	4 3 d	3 5 b	4.1 b
29	5 6 c	4 8 ab	4.9 a
58	6 1 bc	4 5 ab	4 6 ab
87	7 1 a	4 8 ab	4 5 ab
116	7 0 a	4.2 ab	4.1 b

[a]Except farmers' level, all N treatments received 30 kg each of P_2O_5 and K_2O [b]Number of trials for each province are indicated in Table 9. Separation of means in a column by Duncan's multiple range test at the 5% level

levels of nitrogen was due to lodging and high grain sterility, particularly at high rates of nitrogen. A typhoon occurred during the flowering stage. Among the fertilizer combinations tested, similar yields of 4.2 t/ha were obtained with the combination of either phosphorus or potassium with nitrogen (Table 10). Responses to N, P, and K were not significant. Soil incorporation of topdressed nitrogen 5-7 days before panicle initiation did not increase the yield further (Table 11).

Consequences of new technology

Agricultural Economics Department

WORK ACTIVITIES OF CENTRAL LUZON FARM FAMILIES: AN AGE-SEX ANALYSIS

Data previously obtained in a study in three municipalities of Central Luzon, Philippines, were analyzed to identify the economic activities of men and women of various ages, to determine the relative contribution of men and women to family income, and to identify some of the sex differential factors influencing labor allocation.

Data and background information. Primary data were gathered for 1 year through a daily record-keeping project on 87 farmer households in 6 villages in Central Luzon, Philippines. The households were a stratified random sample constituting 20% of the farm population in each of 6 villages in 3 municipalities — Gapan and Guimba in Nueva Ecija and Mayantoc, Tarlac.

Farmer cooperators kept daily records on the economic activities of each family member. The data were supplemented with personal interviews. Activities were classified as:

1. Own rice farm activities — work done on the respondent's own farm by family members
2. Hired farm employment — work for others for cash, payment in kind or share of the crop
3. Nonrice farming activities on home farm — work on crops other than rice and raising livestock or poultry
4. Exchange labor — work for other farmers in exchange for their work on respondent's farm
5. Nonfarm employment — income-generating activities outside the agricultural sector
6. Maintenance and provision activities — fuel wood cutting, repairs to house or equipment, fishing, hunting, and food gathering.

The household characteristics are summarized in Table 1.

Labor contribution by sex. Women accounted for 35% of the total employment in the study households (Table 2). Women contributed a negligible amount of work requiring handling of animals or tractors for land preparation, but about 63% of the total labor in pulling and transplanting tasks. Weeding, accounting for the largest proportion of family labor in preharvest tasks, was carried out largely by men. Other preharvest tasks, which include fertilizing, spraying, irrigating and management, were also done mostly by men.

Harvesting and postharvest tasks are traditionally done by hired laborers; therefore, the total labor for those tasks is substantially greater than that indicated in Table 2. Where the number of landless laborers is limited, family labor — mostly women — is used. For this sample, threshing was commonly mechanized using the large thresher known as *tilyadora.* Although threshing is a male activity, harvesting or cutting the crop is a sex-neutral operation. The net effect was male domination of harvest and postharvest activities.

More females than males worked in some productive tasks outside the rice enterprise. Most important were nonfarm employment activities where women contributed 69% of the labor-hours. Women contributed over half the exchange labor for transplanting and harvesting, land preparation during final harrowing, and activities like piling or stacking of harvested palay.

Men did almost all the land preparation and a good deal of the pulling, weeding and other preharvest rice farming activities as well as most of the other farm activities. They also dominated in main-

Table 1. Household characteristics of sample farmers in 3 municipalities of Central Luzon, Philippines, 1973-74.

	Gapan, Nueva Ecija	Guimba, Nueva Ecija	Mayantoc, Tarlac	Total or average
Households (no.)	30	28	29	87
Family size (no.)	7.6	7.3	6.9	7.3
Male work force (no.)	2.2	2.2	2.3	2.2
Female work force (no.)	1.9	2.0	1.3	1.7
Farm owners (no.)	0	0	23	23
Leaseholders (no.)	18	26	2	46
Share-tenants (no.)	12	2	4	18
Irrigated 2-crop farms (no.)	30	15	29	74
Farm size (ha)	2.7	2.4	3.0	2.7
Yield (kg/ha) in wet season	3050	2225	3375	2883
Rice income ($/year)	597	414	1223	745
Other income ($/year)	236	246	53	178

Table 2. Allocation of work hours to male and female family members in 87 farm households in 6 sample villages of 3 municipalities of Central Luzon, Philippines, 1973-74.

	Work hours/person per year		% of total work hours contributed[a]	
	Male	Female	Male	Female
Own rice farm	641	207	79	21
Land preparation	230	4	99	1
Pulling	9	16	36	64
Transplanting	18	30	38	62
Weeding	136	65	68	32
Other preharvest tasks	121	27	82	18
Harvest, postharvest tasks	127	65	71	29
Hired farm employment	48	80	43	57
Nonrice, farm enterprises	35	27	62	38
Exchange labor	38	60	44	56
Nonfarm employment	178	490	31	69
Maintenance and provision	270	27	93	7
Total, average	1210	891	65	35

[a]Because the total work force in the sample households consists of 191 male and 154 female, the percentages here are weighted by the number of males and females

Table 3. Farm family labor force in 87 farm households in 6 sample villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Persons (no) in the labor force				
	Below 13 yr	13-16	17-21	22-65	Over 65
Male	8	41	47	98	7
Female	7	18	33	91	5

tenance activities, hunting, and fishing Maintenance activities included provision for work animals, repairing of house and equipment, and woodcutting for fuel.

Labor activities by age. Table 3 shows the distribution of the sample families' labor force by age and sex. Only 15 individuals below 13 years were considered members of the labor force. The males in that age group contributed heavily in the maintenance and provision activities and on the family farm (Table 4), but the females contributed relatively few labor hours in any activity (Table 5). Males in the 13-16 and 17-21 age groups worked significantly fewer hours than males in the 22-65 group. The latter reportedly worked 82% of a 50-week, 40-hour week "full employment" regime.

Females in the two younger age groups concentrated on work on the family rice farm or work as hired laborers for other farmers, or helped with exchange labor obligations. Those in the 17-21 age group contributed 838 hours a year — 42% of a "full employment" regime — mostly on nonfarm employment. Both men and women over 65 years were still economically active — the women allocated most of their time to low-paying or low-income-generating nonfarm activities, such as operating a sari-sari store or catching fish and other animals for sale or for home consumption.

Farm size effects. It was hypothesized that effective crop area affected male and female work participation. It was expected that farmers with more

Table 4. Work activities of males in various age groups in 87 farm households in 6 sample villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Work hours per person per year				
	Below 13 yr	13-16	17-21	22-65	Over 65
Family rice farm	80	241	474	905	672
Nonrice, farm	6	30	32	40	47
Hired farm employment	37	103	88	13	11
Exchange labor	8	19	40	45	63
Nonfarm employment	69	21	158	269	50
Maintenance and provision	340	163	133	365	162
Total	540	577	925	1637	1005

Table 5. Work activities of females in various age groups in 87 farm households in 6 sample villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Work hours per person per year				
	Below 13 yr	13-16	17-21	22-65	Over 65
Family rice farm	29	125	152	215	21
Nonrice, farm	0	0	0	45	0
Hired farm employment	33	95	122	67	54
Exchange labor	2	44	29	82	0
Nonfarm employment	0	5	535	447	1058
Maintenance and provision	0	0	0	45	0
Total	64	269	838	901	1133

Table 6. Hours of labor input by male and female household members on farms of 3 size groups for 87 farm households in 6 sample villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Work hours per year[a]					
	Male			Female		
	< 4 ha (2.7)	4-5 ha (4.1)	>5 ha (6 4)	<4 ha (2.7)	4-5 ha (4.1)	>5 ha (6.4)
Family rice farm	525	705	720	174	161	262
Nonrice, farm	79	8	8	53	6	8
Hired farm employment	54	46	42	95	50	77
Exchange labor	45	15	42	44	40	87
Nonfarm employment	222	106	173	466	563	280
Maintenance and provision	288	297	237	43	5	19
Total	1213	1177	1222	875	825	733

[a]Values in parentheses represent effective crop area, in hectares.

effective crop area would hire more labor and hence work less, and that females in households with more land would work less. The farms were rather homogeneous in size —around 3 ha — but they varied in effective crop area because of differences in irrigation.

There was no relationship between farm size reflected in effective crop area and hours of work (Table 6), although the effective crop area (2.7 ha) of the smallest size group was less than half that (6.4 ha) of the largest size group. The females in the largest size group worked more hours on the family rice farm than those on smaller farms. The differences in the nonfarm work hours among the three size groups were substantial but were not systematically related to farm size. The data strongly support the hypothesis that in this sample, farm size had no effect on total work hours of males, and only a slight one on work hours of females.

Income contribution by age and sex. Table 7 shows the average income of male and female household members of different ages. Earnings from the family farm were apportioned to family workers in proportion to hours they worked, and wage earnings reflected market wages received. The average male worker earned 3 times more than the average female worker because he worked 50% more hours and was paid at a 150% higher average wage rate. The family rice farm was the main source of income for all age groups, except for females over 65, whose main earnings were from nonfarm employment.

The average wage of males in all categories increased with age up to 65. The average wage of females of 17-21 years was only 60% of that of females under 65 (Table 8) because of the preponderance of low-wage domestic employment for the 17-21 age group. Wage rates of females were lower than those of males in all categories.

HOUSEHOLD ECONOMY OF LANDLESS WORKERS AND RICE FARMERS IN ILOILO, PHILIPPINES

The household economies of 8 landless workers and 8 farmers from a rice-growing village in Dingle, Iloilo Province, were compared. Labor activities, income transactions in cash and kind,

Table 7. Income contribution by age and sex of labor force participants in 87 farm households in 6 villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Income contribution ($/yr)					
	All ages	Below 13	13-16	17-21	22-65	Over 65
Family rice farm						
Male	295 68	12 53	70 53	127 20	502.80	169.73
Female	49 66	6 26	23.46	31.86	67.20	3 20
Nonrice, farm						
Male	8.96	0	0.40	5 86	3.73	23.60
Female	5 90	0	0	0	9.86	0.66
Hired farm employment						
Male	6.43	3 60	7 46	12.80	3.60	0 66
Female	8 72	2.00	11.60	7.33	9 46	3.73
Nonfarm employment						
Male	32.08	5.06	1.33	18.93	55.20	7.86
Female	27.00	0	0.26	26.93	33 46	44.13
Total						
Male	343.15	21.19	79.72	164 79	565.33	201.85
Female	91.28	8.26	35.32	66.12	119.98	51.72

and credit transactions were recorded through daily records for a half-year period.

Weekly summaries of the daily records provided a week-by-week profile of each household's economy. At the end of the 6-month period, the family heads and spouses reviewed the summary records with the researchers.

Sources and levels of income. Income flows for both landless workers and tenant-farmers closely followed the cycle of rice production. Some distinct differences between the two groups were, however, discernible. Generally, the landless workers had frequent but low income peaks depending upon the availability of a harvest or occasional farm jobs that paid cash wages. Rice farmers ordinarily experienced one very high income peak per season at harvest time. From that they provided for their family's rice requirements and other needs in the next 4 to 5 months, and repaid any production loan incurred during the season.

Three sources of income were farming, nonfarming, and *machine rentals*, which included income earned by renting out machinery.

Table 9 shows the average income of the sample

Table 8. Average daily wage rate, by age and sex of labor force participants in 87 farm households in 6 villages of 3 municipalities, Central Luzon, Philippines, 1973-74.

	Av daily wage rate ($)				
	Below 13 yr	13-16	17-21	22-65	Over 65
Family rice farm					
Male	1 20	2.32	2.08	4 40	2 00
Female	1.68	1 44	1.60	2.48	1 20
Nonrice, farm					
Male	—	0 24	1.44	2.72	4.00
Female	—	—	—	1.68	—
Hired farm employment					
Male	0.72	0 56	1 12	2.16	0.48
Female	0.48	0.96	0.48	1.12	0.48
Nonfarm employment					
Male	0 56	0 48	0.88	1.60	1 20
Female	—	0.40	0.40	0.56	0.32

Table 9. Sources of income of landless workers and rice farmers in 16 households in Dingle, Iloilo, Philippines, 1977-78 dry season.[a]

Income source	Landless workers (n = 8)		Rice farmers (n = 8)	
	$	%	$	%
Farming				
Own rice farm	—	—	447	58
Harvest share	164	59	5	1
Cash wages	42	15	14	2
Livestock sales	39	14	139	18
Nonfarming				
Carpentry	10	4	3	—
Buy and sell	10	4	—	—
Donations	8	3	4	1
Others	3	1	1	—
Machine rentals	—	—	154	20
Gross income	276	100	767	100

[a]Imputed value for palay is $0.13/kg.

Table 10. Sources of gross income of 2 subgroups of landless worker and farmer households in Dingle, Iloilo, Philippines, 1977-78 dry season.

Income source	Gross income ($/year per household)			
	Younger landless workers	Older landless workers	Smaller tenant-farmers	Larger tenant-farmers
Farming				
Own rice farm	—	—	308	587
Harvest share	148	175	8	3
Cash wages	31	49	1	1
Livestock sales	30	44	154	125
Nonfarming				
Carpentry	3	14	0	7
Buy and sell	0	16	0	0
Donations	6	8	0	7
Others	1	3	2	0
Machine rentals	0	0	164	143
Gross income	219	309	637	873

households during the 1977-78 dry season. The major source of income for landless workers was shares in palay harvest, comprising an average of rough rice worth $164 for the 6-month period. Fifteen percent of the household income came from cash wages for farm work such as fixing bunds, transplanting, and hauling palay sacks. Altogether, 74% of the landless workers' income came directly from farming operations on rice farms.

In contrast, rice farmers received 58% of their gross income from their own farms and 20% from their capital investments in hand tractors and other machines. Income from machine rentals ($154) almost equaled the landless workers' income from harvest shares ($164). Only 3% of the rice farmer's family income was from work on other rice farms.

Livestock sales constituted another source of income for both groups. They included sale of a fattened pig at the end of 5 or 8 months, or occasional sale of poultry eggs.

Nonfarm sources accounted for 12% of the gross income of landless workers, but only a negligible 1% for rice farmers.

The sample households were further grouped according to age of landless household heads and size of farmholding of farmers. Younger and older landless worker households differed in the number of working children per family. Older landless worker households had more working children and earned more in harvest shares, but they were proportionately less dependent on this income source (Table 10).

Size of farmholding was the best index of resource control for tenant-farmers. Farmers with larger holdings earned almost twice as much as small farmers from their own rice farms.

Expenditures. Table 11 compares the expenditures of landless workers and rice farmers. The largest single item of consumption expenses was food, 65% for the landless workers and 55% for the

Table 11. Consumption and production expenses for 6 months of landless workers and rice farmers in 16 households in Dingle, Iloilo, Philippines, 1977-78 dry season.

Expenses	Landless workers (n = 8)		Rice farmers (n = 8)	
	$	%	$	%
Consumption				
Food: a) Rice	92	39	112	34
b) Others	62	26	71	21
Clothes or personal wear	16	7	25	8
Household items	10	4	15	4
House repairs	1	1	25	8
Schooling	5	2	15	5
Transportation	10	4	15	4
Recreation, drinks or cigarettes	22	9	15	5
Medical care	4	2	17	5
Donations or others	11	5	19	6
Subtotal	233	100	329	100
Production				
Own rice farm	0	0	298	66
Other rice farms	1	17	2	—
Livestock and other farm activities	5	83	3	—
Machine investments	0	0	150	33
Subtotal	6	100	453	100
Total	239		782	

Table 12. Average monthly net income and consumption levels of landless workers and rice farmers in 16 households in Iloilo, Philippines, 1977-78 dry season.

	Young landless workers (n = 3)	Older landless workers (n = 5)	Small farmers (n = 4)	Larger farmers (n = 4)
	Monthly income and consumption ($/household)			
Gross income	36 40	51.73	106.00	149.73
a. Rice farming	29.73	37.33	52.66	102.66
b Other sources	6.67	14.40	53.33	47.06
Production expenses	0	1.73	36.00	65.20
Net income	36.26	50.00	70.00	84.53
Machinery investments	0	0	25.06	25.06
Consumption expenses	32.53	42.40	48.80	60.93
Surplus	3.73	7.60	−3.86	−1 46
	Per capita consumption ($)			
	5.70	6.06	7.18	8.96
	% spent on rice/household			
	42	39	33	27

rice farmers. Rice alone made up 39% of the landless workers' family consumption and 34% of the farmers'.

Secondary expenses among landless workers were for recreation, clothing, and donations. Rice farmers spent more, except for recreation. In particular, they spent more for house repairs, medical care, and schooling expenses.

Landless workers spent only about $6 or 3% of their total expenses for productive purposes — replacing wornout harvesting instruments such as sickles or mats for the drying of palay. At other times, a small cash outlay was used to procure a piglet or two for fattening. A few landless workers incurred labor costs when they hired other workers to finish urgent farm tasks such as weeding or harvesting.

The 8 farmers spent an average of $453 or 58% of their total expenditures for production purposes during the dry season; two-thirds was used for expenses on their own rice farms, and one-third was for installment payments for farm machinery or for maintenance costs (Table 11).

Because production inputs for landless worker households were minor, subtracting production expenses from gross income gave them a net income almost equal to their gross income. Farmer households, on the other hand, had net incomes less than 50% of their gross. A breakdown into four subgroups provides a clear picture of differences within the landless worker and farmer groups (Table 12). In terms of monthly gross income, the young landless worker families had the lowest earning capacity ($36/month) because they had smaller households or more preschool children. The farmers earned the highest income ($150/month) because of their farm size. Net incomes followed the same pattern.

Landless workers showed a small amount of savings. Rice farmers had deficits because five of them were making installment payments for farm machines.

Per capita consumption levels closely followed the pattern of total consumption because the number of family members for the four groups was similar.

Landless worker households derived 76% of their income from rice farming, 12% from other agricultural activities, and another 11% from nonagricultural activities. Because their expenses were minimal, their gross and net incomes were almost the same, averaging about $45/household monthly during the study period (Table 13).

In contrast, rice farmers grossed almost three times as much as landless workers, but about 40% of that went to production expenses (Table 12). Their net income was roughly half from rice farming, 43% from other agricultural activities, and 3% from nonagricultural activities. Although machine investments were major items in the rice farmers' accounts, the costs of installment payments during the period covered practically cancelled out any net returns from this source.

Thus, in terms of net income, the landless workers earned 1.25 times more from rice farming that did the rice farmers themselves! Furthermore,

Table 13. Labor time and net income by source for 16 study households in Dingle, Iloilo, Philippines, 1977-78 dry season.

Source	8 landless worker households	8 rice farmer households
Labor time (h/mo per household)		
Rice farming	270	108
Other agricultural activities	44	99
Nonagricultural activities	18	7
Total	332	214
Net income ($/mo per household)		
Rice farming	34.28	27.53
Other agricultural activities	5.57	22.71
Nonagricultural activities	5.02	1.33
Machinery investments	0	0.64
Total	44.87	52 21
Labor earnings ($/8 h)		
Rice farming	0.96	2.00
Other agricultural activities	0.96	1.76
Nonagricultural activities[a]	2 16	2.25
Av all activities (weighted)	1.04	1.92

[a]Including machinery earnings.

the landless workers earned almost 4 times more than rice farmers in nonagricultural activities such as carpentry and buy-and-sell enterprises. Rice farmers, however, earned 4 times more than landless workers in other agricultural activities, principally livestock sales.

Labor productivity. Landless workers invested 4 of 5 working hours in rice farming and earned $3 of $4 from this source. Rice farmers spent only half of their work hours in rice farming and derived half of their net income from it. The other half of the rice farmers' labor and a fifth of the landless workers' time were spent in other agricultural activities and in nonagricultural activities.

The wage rate earned, obtained by dividing net income by total work hours, reflects labor productivity in each economic activity. Landless workers earned, on the average, $0.96/8 hours spent in rice farming and in other agricultural activities (Table 13). That was higher than the standard daily wage of $0.82 for ordinary farm work such as transplanting or weeding. They also received the highest returns of $2.16/8 hours from nonagricultural activities. Rice farmers achieved higher labor productivity for all sources of net income.

Table 13 shows that hourly labor earnings of landless workers were only half those of rice farmers although they spent more work hours in this activity than rice farmers. That reflects the lower overall asset position of landless workers. They own no land, less livestock, and no machinery; consequently they receive no income from those assets.

Credit practices. Borrowing and lending among households may involve small or large amounts, cash or kind (usually palay), on short-term or long-term basis. A crucial difference between the two groups was the rice farmers' access to institutional credit sources. Landless workers relied mostly on relatives or close friends. The pattern of credit practices varied from household to household, depending on household size, earning capacity, access to credit sources, and occurrence of emergency situations.

Table 14 summarizes the credit practices of the 16 record-keeping households over the 6-month

Table 14. Credit practices of 8 landless and 8 tenant-farmer families in Dingle, Iloilo, Philippines, 1977-78 dry season.

	3 younger landless worker households	5 older landless worker households	4 smaller farmer households	4 larger farmer households
		Borrowing activities		
Borrowing times (no)	20	28	14	12
Creditors (no.)	11	14	10	8
Total cash borrowed ($)	12	70	110	85
Palay borrowed (kg)	144	173	148	73
Total value of loans ($)	26	88	125	93
		Lending activities		
Loans given (no.)	4	4	5	2
Persons (no.) obtaining loan	4	4	3	1
Total cash loaned ($)	28	8	12	7
Palay loaned (kg)	46	15	129	3
Total value of loans ($)	33	9	26	8

period. Landless workers tended to borrow smaller amounts more frequently for consumption purposes; rice farmers borrowed less frequently but in bigger amounts, principally for production purposes.

Nearly all of the sample households acted *as creditors* to others on a small scale, but surprisingly, the larger rice farmers lent out the least and the younger landless workers lent out the most.

Many households were involved in all four directions of credit practices: 1) the household borrowed cash or palay, 2) it paid for that loan, 3) the household lent to others, and 4) it was paid back.

The fact that a household acts as both creditor and borrower does not necessarily indicate its economic viability. Other social considerations may be involved, e.g., families may lend out the little they have as a form of security so as to have similar claims on others during future emergencies. Such loans, usually made for consumption purposes are often without interest charges. Savings may take the form of stored palay rather than cash earnings in the house: many households feel it safer to keep surplus income in kind, and palay is less likely to be spent right away.

DYNAMICS OF AGRARIAN CHANGE

A comparative study of two villages in West Java — one characterized by stagnated technology and the other by significant technological progress — was made in collaboration with the Agro-Economic Survey of Indonesia.

Study sites and data collection. One village is on undulating topography at the foot of mountains in the southern part of the Subang Regency, and is called South Village for the study. Another village — North Village — is about 20 km north of South Village and is on a flat coastal plain.

South Village was surveyed in 1979 and North Village in November-December 1979. The two villages were covered by a Rice Intensification Survey *(Intensifikasi Padi Sawah)* of the Agro-Economic Survey of Indonesia for 1968-72. The data collected from that survey provided bench mark information.

Population pressure and agrarian structure. Both villages are characterized by unfavorable land-man ratios (Table 15). In addition to rice fields, South Village had 3 ha of land for home gardens and fishponds, and North Village had 8 ha.

Table 15. Land area, population, and number of households in South and North Villages, in Subang Regency, West Java, Indonesia.

	South Village (1978)	North Village (1979)
Total rice land (ha)	24.7	65 6
Total population (no.)	419	774
Total number of households	110	191
Farm operators	83 (75)[a]	75 (39)[a]
Landless laborers	27 (25)	116 (61)
Rice land (ha) per capita	0.06	0.08
Rice land (ha) per household	0 22	0.34
Rice land (ha) per farmer household	0.30	0.87

[a]Percentage of the total number of households is in parentheses.

Although the population density was higher for South Village, the rate of population growth seems to have been much faster for North Village. Data on the number of children per mother suggest that the natural rate of population growth in South Village decelerated from about 3% to 1% per year during the past 40 years (Table 16). It appears that the population pressure on limited land resources under a constant technology had reached a saturation point a few decades ago. The government birth control program was introduced in 1975; however, the birth rate began to decline much earlier, with many wives practicing abortion by indigenous methods.

Although there were no reliable data for the old-age bracket, the comparison of average numbers of children per mother in Table 16 suggests a much faster natural rate of population growth in North Village. Moreover, the village acquired a large number of migrants. Old villagers reported that there were about 40 households in North Village in 1940. There were 191 during the survey in 1979. Assuming no change in average family size, the rate of population growth for the past 4 decades had been as high as 4%/year.

Agrarian structures in the two villages also differed. South Village was a typical peasant community with 75% of households belonging to small-farm operators and only 25% to landless laborers. In North Village 39% of households belonged to farm operators and 61% to landless laborers (Table 15). Tenancy was significantly higher in North Village (Table 17), and almost all tenants were share-

Table 16. Average number of surviving children per mother by mothers' age and estimates of the natural rates of population growth[a] in South and North Villages, Subang Regency, West Java, Indonesia, 1979.

Mother's age	South Village		North Village	
	Children (no.) per mother (n)	Annual population growth rate (%) (r)	Children (no.) per mother (n)	Annual population growth rate (%) (r)
80 years and above	4.80	3.0	n.a.	
60-79	3.93	2.3	n.a.	
50-69	3 49	1.9	n.a	
40-49	2.71	1.0	3.25	1.6
30-39	1.95	—	2.57	—
20-29	0.84	—	1.80	—

[a]Calculated by the formula: $n = -2(1 + r)^{30}$, assuming 30 years for the period of mothers' reproductive capacity. n.a. = not available.

Table 17. Distribution of farms by tenure status in South and North Villages in Subang Regency, West Java, Indonesia, 1978-79.

Tenure status	Distribution of farms (%)			
	South Village (1978)		North Village (1979)	
	Farms	Rice area	Farms	Rice area
Owner operator	81	77	48	44
Owner-tenant	16	21	15	27
Tenant operator	3	2	37	29

croppers under the 50:50 output and cost-sharing contract.

Such differences in the agrarian structure and demographic pattern can be explained by the history of the settlements. No one knew when South Village was first settled. In contrast, North Village was settled only after 1920.

Initial settlers in North Village opened a no-man's land and practiced extensive farming under a rainfed condition. Because the rice yields were low, the operational holding of about 2 ha was required for a family's subsistence. Rice yields were raised significantly after the local irrigation system was built.

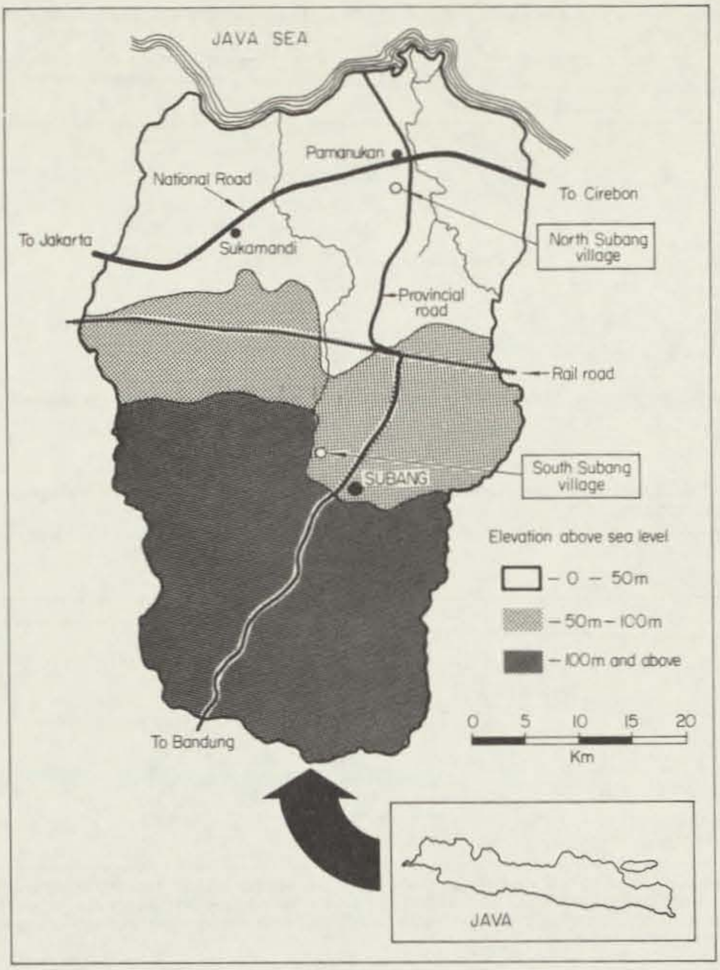
The intensification of rice farming due to irrigation development increased labor demand, and a large number of migrants flowed into the village. The new migrants came as landless laborers or sharecroppers. The same process was repeated after the extension of the Jatiluhur System, the largest irrigation system in Java, which permitted irrigation for both seasons. Through waves of migration, class differentiations between relatively large farmers and a large number of landless workers, and between landowners and tenants developed.

The Jatiluhur Irrigation System had a dramatic impact on the economy of North Village. Major laterals had been built by 1968. In 1972 secondary and tertiary laterals were completed and double-

Table 18. Changes in multiple cropping, adoption of modern varieties (MV), and rice yield in South and North Villages in Subang Regency, West Java, Indonesia, 1968-71 to 1978-79.

	South Village			North Village		
	1968-71[a]	1978[b]	Change[d] (%)	1968-71[a]	1978-79[c]	Change[d] (%)
Multiple cropping ratio[e]	1.9	1 9	0	1.5	2.0	33
Ratio of MV adopters (%)	11	14	3	7	100	93
Rice yield (t/ha):						
Per ha of crop area	2.6	2.9	12	2.4	3 4	42
Per ha of rice field area	4.9	5.5	12	3.6	6.7	86

[a]Av for dry and wet seasons. [b]1978 dry season. [c]Av of 1978-79 wet season and 1979 dry season. [d]1978 or 1979 figure minus 1968-71 figure divided by 1968-71 figure, except for the ratio of MV adopters, which is simply 1978 or 1979 figure minus 1968-71 figure. [e]Total crop area divided by total rice field area.



1. Subang Regency in West Java, Indonesia.

cropping became possible in the rice area of the village. In 1979, the whole rice area was double-cropped (Table 18).

The introduction of double-cropping was facilitated by the diffusion of modern semidwarf varieties (MV), which are early maturing and photoperiod insensitive. The Rice Intensification Survey reported that 7% of farmers planted MV in 1968-71. In 1978-79 the ratio was 100%. MV adoption rate did not differ among farm-size classes and tenure classes. The MV commonly used in 1979 were IR26, IR36, IR38, and Asahan developed by the Central Agricultural Experiment Station at Sukamandi, near North Village (Fig. 1).

The diffusion of MV, accompanied by the increased application of fertilizers, increased the average yield in the rice area from 2.4 t/ha in 1968-71 to 3.4 t/ha in 1978-79. Considering the increase in multiple cropping ratio — 1.5 to 2.0 — the average rice output per hectare of rice land per year should have increased more than 80% during the past decade.

In contrast to the dynamic changes in North Village, the economy of South Village was largely stagnant. The local irrigation system showed no significant improvement and the cultivated area had not expanded since World War II. Growing population pressure resulted in the increased fragmentation of landholdings through inheritance. The number of near-landless peasants increased, but the ratio of pure landless laborers was not so large as that in North Village (Table 15).

MV were introduced in the South Village in the late 1960s under the *Bimas* Program. But because

Table 19. Changes in inputs per hectare of rice area and input price for rice production in South Village, Subang Regency, West Java, Indonesia, 1968-71 to 1978.

	1968-71[a]	1978[b]	Change (%) from 1968-71 to 1978
Inputs			
Fertilizer (kg/ha)	191	229	20
Labor (h/ha)			
Land preparation	420	494	18
Total (preharvest)	736	928	26
Carabao and cattle for land preparation (days/ha)	16.4	9.2	−44
Real input prices[c] (in paddy)			
Fertilizer (kg paddy/kg)	1.5	1.1	−27
Labor wage[d] (kg paddy/day)	9.5	8.5	−11
Carabao rental (kg paddy/day)	6.2	9.5	53

[a]Av for wet and dry seasons. [b]Dry season. [c]Nominal price divided by paddy price. [d]Wage for land preparation, assuming an 8-hour day. Includes meals.

Table 20. Changes in inputs per hectare of rice area and input prices for rice production in North Village, Subang Regency, West Java, Indonesia, 1968-71 to 1978-79.

	1968-71[a]	1978-79[b]	Change (%) from 1968-71 to 1978-79
Inputs			
Fertilizer[c] (kg/ha)	75	209	179
Labor (h/ha):			
Land preparation	219	233	6 (42)[d]
Total (preharvest)	638	701	10 (46)[d]
Carabao and cattle for land preparation[e] (days/ha)	9.6	13.2	38
Real input prices[f] (in paddy)			
Fertilizer (kg paddy/kg)	1.5	1.0	−33
Labor wage[g] (kg paddy/day)	7.9	11.5	46
Carabao rental[h] (kg paddy/day)	8.8	14.1	60

[a]Av for wet and dry seasons. [b]Av for 1978-79 wet season and 1979 dry season. [c]Urea and triple superphosphate. [d]Outside of parentheses are the rates of increase in labor input per ha of cropped area. Inside parentheses are the rates of increase per ha of rice field area. [e]Data for wet season only. [f]Nominal price divided by paddy price. [g]Wage for land preparation, assuming an 8-hour day. Includes meals.

they were highly susceptible to brown planthopper and tungro virus disease, many farmers who had tried them went back to traditional varieties. As a result, the rate of increase in the average rice yield per hectare in this village was much slower than in North Village (Table 18).

Labor employment and wages. The different patterns of productivity growth due to both irrigation improvement and MV diffusion in North and South Villages were reflected in sharp differences in the changes in rice production inputs and input prices in the last decade (Table 19, 20).

In South Village where technology was stagnant, the input of fertilizers increased at a rate lower than the rate of decline in the real price of fertilizers (Table 19). But in North Village, where the fertilizer-responsive MV were widely adopted, the input of fertilizers was six times faster than the rate of decline in the price of fertilizers.

It appears that the population pressure on land under a stagnant technology resulted in a decline in the value of human labor relative to the values of both capital and food. In South Village, an increase in labor input was associated with a decline in real wage rate. The increase in real rental rate of draft animals (carabao and cattle) resulted in a sharp decline in the use of animal power. Hand hoeing was substituted for animal plowing and harrowing.

In contrast, an increase in labor input in North Village was associated with a significant increase in the real wage rate. The average labor input per hectare of rice crop area did not increase much; however, the labor input per hectare of rice field area increased more than 40%/decade, owing to the increase in the multiple cropping ratio (figures in parentheses in Table 20). At the same time, the use of animal power increased even more rapidly

Table 21. Changes in factor payments and factor shares in rice production per ha of crop area in South Village, Subang Regency, West Java, Indonesia, 1968-71 to 1978.

	Factor payment[a] (kg/ha)			Factor share (%)		
	1968-71[b]	1978[c]		1968-71	1978	
	Owner	Owner[d]	Tenant[e]	Owner	Owner	Tenant
Rice output	2600	2942	3080	100.0	100.0	100.0
Factor payment						
Current input[f]	345	293	321	13.3	10.0	10.4
Capital[g]	136	125	76	5.2	4.2	2.5
Labor	1257	1301	1341	48.3	44.2	43.5
Family	427[h]	438	476	16.4	14.9	15.4
Hired	830[h]	863	865	31.9	29.3	28.1
Land	0	0	1262	0	0	41.0
Operator's surplus	862	1223	80	33.2	41.6	2.6

[a]Factor payments converted to paddy equivalents by the factor-output price ratios. [b]Av for wet and dry seasons. [c]1978 dry season. [d]Av for 74 owner-farmers cultivating 20.4 ha. [e]Av for 9 tenant operators cultivating 1.8 ha. [f]Seeds, fertilizers, and chemicals. [g]Animal rental and irrigation fee. [h]Assume the same composition of family and hired labor as for 1978.

than the use of human labor, despite a rapid rise in the real cost of animal rental. It is clear that the increase in labor demand due to the technological progress outpaced the increase in labor supply due to population growth; the result was rising wages despite the effort to substitute capital (animal power) for human labor.

Changes in income distribution. Changes in the average factor shares of rice output per hectare of crop area in South Village from 1968-71 to 1978 were estimated (Table 21). Factor payments were expressed in paddy terms by multiplying factor inputs by factor-product price ratios. The average yield per hectare increased by a little more than 10%. Both the payment to hired labor and the imputed costs of family labor increased less than 5%. Operator's surplus (residual) recorded a major increase in the case of owner-farmers. For tenant-farmers, operator's surplus was almost zero, and the land rent they paid to landlords was equivalent to the owner-farmers' surplus. That shows the operator's surplus for owner-farmers consisted mainly of the return to their land. Altogether, the relative shares of labor declined and the relative share of land increased.

Table 22 attempts to show how the income (value added) from rice production per hectare was distributed between farmers and hired laborers. Farmers' income consists of operator's surplus and the returns to family labor and capital. Laborers' income consists of wage earnings from hired farm work. From 1968-71 to 1978, farmers' total income in paddy terms increased by 25%, and laborers' income increased by only 4%. Employment of hired labor increased because of more intensive cropping and substitution of human labor for animal power, but the increase was offset, to a large extent, by the decline in the wage rate. On the other hand, farmer's income increased significantly, primarily because of the increase in the return to land captured in the form of operator's surplus. The data suggest that the income distribution became more skewed.

Changes in the average factor shares of rice output per hectare in North Village from 1968-71 to 1978-79 were estimated (Table 23). The average yield per hectare for wet and dry seasons increased by 40%. Despite such rapid increase, the relative share of labor stayed almost constant. The shares of both current inputs and capital increased. As a

Table 22. Changes in shares of income from rice production per ha of crop area in South Village, Subang Regency, West Java, Indonesia, 1968-71 to 1978.[a]

	Income in paddy (kg/ha)		Income share (%)	
	1968-71	1978	1968-71	1978
Value added[b]	2255	2649	100.0	100.0
Farmer				
Family labor	427	438	19.0	16.5
Capital	136	125	6.0	4.7
Operator's surplus	862	1223	38.2	46.2
Total	1425	1786	63.2	67.4
Hired laborer	830	863	36.8	32.6

[a]Data rearranged from Table 21 for owner-operated farms. [b]Output value minus current input cost.

Table 23. Changes in factor payments and factor shares in rice production per ha of crop area in North Village, Subang Regency, West Java, Indonesia, 1968-71 to 1978-79.

	Factor payment[a] (kg/ha)			Factor share (%)		
	1968-71[b]	1978-79[c]		1968-71[b]	1978-79[c]	
	Owner	Owner	Tenant[d]	Owner	Owner	Tenant[d]
Rice output	2342	3203	3272	100.0	100.0	100.0
Factor payment						
Current input[e]	152	300	280	6.5	9.4	8.5
Capital[f]	47	154	154	2.0	4.8	4.7
Labor	947	1322	1295	40.4	41.3	39.6
Family	117	252	357	5.0	7.9	10.9
Hired	830	1070	938	35.4	33.4	28.7
Land	0	0	1495	0	0	45.7
Operator's Surplus	1196	1427	48	51.1	44.5	1.5

[a]Factor payments converted to paddy equivalents by the factor-product price ratios. [b]Av for wet and dry seasons. [c]Av of 1978-79 wet season and 1979 dry season. [d]Data for share-tenants. [e]Seeds, fertilizers, and chemicals. [f]Animal and machine rental, and irrigation fee.

result, the operator's surplus for the owner-farmers declined.

The operator's surplus for tenant farmers was almost zero, and land rent paid to landlords was equivalent to the owner-farmers' surplus. Thus, the data are consistent with the hypothesis that technological progress in North Village was biased toward a land-saving and capital-using direction, and was more or less neutral with respect to the use of labor. Such results are in sharp contrast to the case in South Village where the share of land increased sharply at the expense of the share of labor (Table 21).

The data in Table 23 are rearranged in Table 24 to show how the income (value added) from rice production per hectare was distributed between farmers and hired laborers. Both farmers and laborers recorded significant gains in absolute incomes, but their relative shares remained largely unchanged. Again, such results contrast with those in South Village where the income of laborers had no significant increase, but their relative income share declined (Table 22).

This comparative analysis has shown that growing poverty and inequality will be the fate of village economies if the efforts to generate technological progress remain insufficient to overcome the decreasing return to labor due to the growing population pressure on land.

Table 24. Changes in shares of income from rice production per ha of crop area in the North Village, Subang Regency, West Java, Indonesia, 1978-79[a].

	Income in paddy (kg/ha)		Income share (%)	
	1968-71	1978-79	1968-71	1978-79
Value added[b]	2191	2903	100.0	100.0
Farmer				
Family labor	117	252	5.3	8.7
Capital	47	154	2.1	5.2
Operator's surplus	1197	1427	54.6	49.2
Total	1361	1833	62.1	63.1
Hired laborer	830	1070	37.9	36.9

[a]Data rearranged from Table 23 for owner-operated farms. [b]Output value minus current input cost.

Cropping systems program
Environmental description

Multiple Cropping Department and Cropping Systems Components of the Agronomy, Entomology, Agricultural Economics, and Statistics Departments

IDENTIFYING PHYSICAL VARIABLES FOR CROPPING SYSTEMS RESEARCH

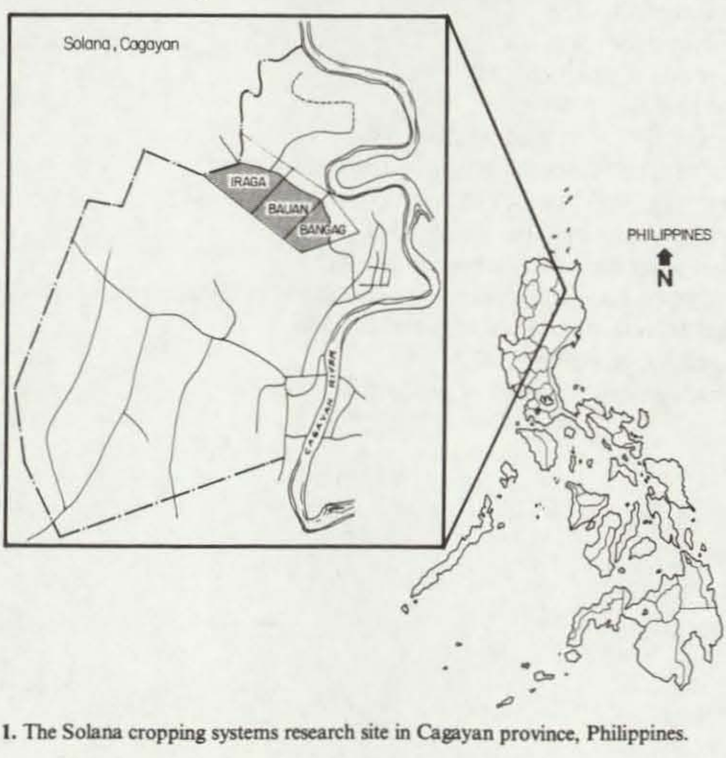
Multiple Cropping Department

In April 1980, a cropping systems project was initiated in the contiguous villages of Bangag, Bauan, and Iraga, of Solana, Cagayan province (Fig. 1), in collaboration with the Cagayan Integrated Agricultural Development Project and the Philippine Council for Agriculture and Resources Research. The project objective is to increase food production through identification of productive cropping systems that are acceptable to small-scale farmers in the central area of the Cagayan Valley. Important physical variables were analyzed and described.

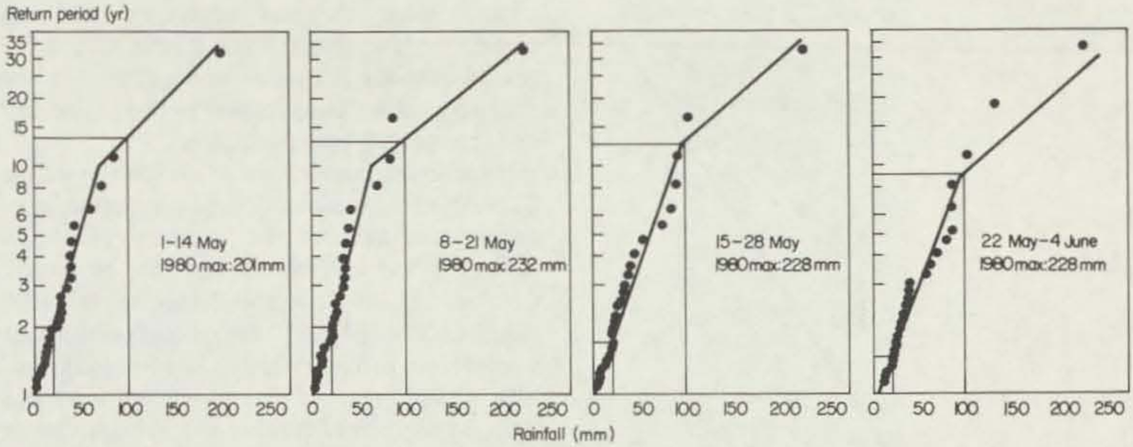
Climate. Solana is 8 km northwest of Tuguegarao. For designing alternative patterns, the major climatic parameter was rainfall. The Tuguegarao rainfall regime has 4 months (Jan-Apr) with less than 100 mm/month and 5 months (Jul-Nov) with more than 200 mm/month. The rainy season normally starts in late May, and rainfall starts to decline in December.

Using rainfall data recorded for 32 years, return period diagrams for maximum 3-day rainfall totals in the dry-wet (1 May-4 Jun and 15 Jun-12 Jul) and wet-dry (1-31 Dec) transition periods were constructed (Fig. 2-5). The intervals covered by the diagrams were selected because they corresponded to critical crop growth stages or periods in which field operations must be performed in prospective patterns. In the dry-wet transition, a rainy period with 20 mm rain/3 days should, on the average, occur 1 in 2.0 years for the 1-14 May period, and 1 in 1.7 years for the 15-28 May period (Fig. 2). The return periods indicate that rainfall sufficient to permit planting are likely to occur in most years, assuming 20 mm as adequate for germination of a large-seeded grain legume and to sustain seedlings until their roots reach the water generally present at 20-30 cm.

In most fields, however, rainfall exceeding 100 mm in a 3-day period would be severely damaging to a grain legume crop during the early growth stages. Return periods for 100 mm/3 days were in the order of 1 in 12 years for 2-week periods in May. Sowing rice as early as mungbean on dry soils would be risky because dry-seeded rice (DSR) requires a higher amount of rainfall to sustain it for 2 weeks. Three 2-week DSR establishment periods were considered between 15 June and 12 July, with

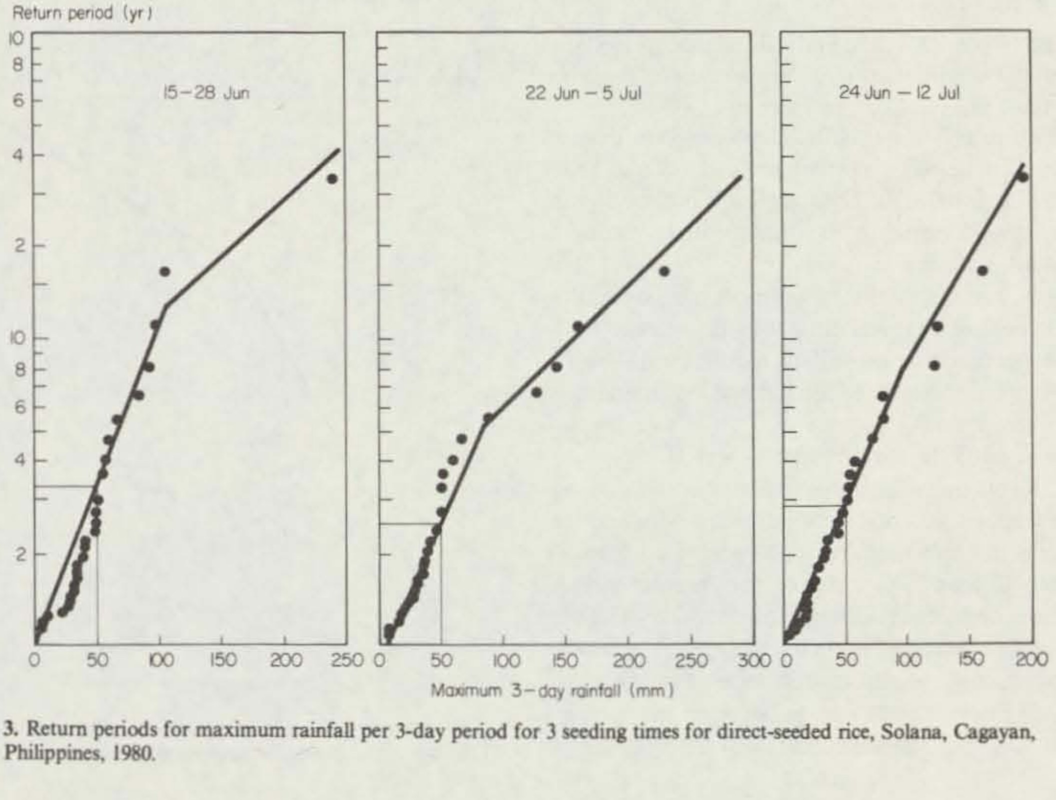


1. The Solana cropping systems research site in Cagayan province, Philippines.

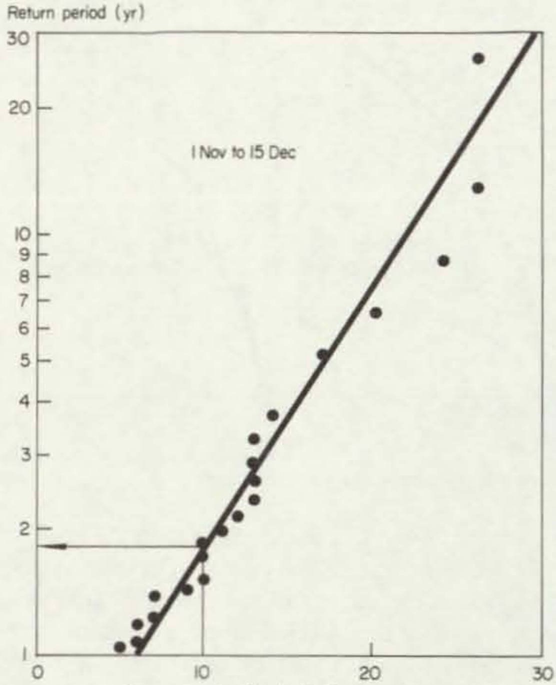


2. Return periods for maximum rainfall per 3-day period, 1 May-4 June 1980, Solana, Cagayan, Philippines.

a 1-week overlap between periods. Figure 3 shows that the return period for 50 mm rainfall in 3 consecutive days for 15-28 June is 1 in 3.3 years. The analyses for the 22 June-5 July and 29 June-12 July periods produced return periods of 1 in 2.4 and 1 in 2.9, suggesting a moderate risk of encountering dry periods that will hamper tillage or crop emergence, or both. Figure 4 shows in the 1 November-15 December period dry spells of less than 1 in 2 years (i.e., will occur in more than half of the years) suggesting that the main rice crop is often likely to come under moisture stress. For the wet-dry transition period (December), a rainfall total of 20 mm or more would be obtained in a 3-day period in about 1 in 2.4 years, suggesting that researchers must rely on residual soil moisture plus low intensity rainfall to obtain emergence (Fig. 5). On the other hand, the return period for 100 mm



3. Return periods for maximum rainfall per 3-day period for 3 seeding times for direct-seeded rice, Solana, Cagayan, Philippines, 1980.



4. Return periods for number of consecutive days with 2 mm rainfall or less, 1 November to 15 December, Tuguegarao, Cagayan, Philippines. 1980.

approaches 20 years, indicating that periods of heavy rainfall that may cause excess moisture damage are not likely in December.

Figure 6 is a pentad (5-day) diagram derived from Tuguegarao rainfall records for the years 1959-60 to 1978-79. The four levels in the diagram correspond roughly to rainfall that, during a pentad,

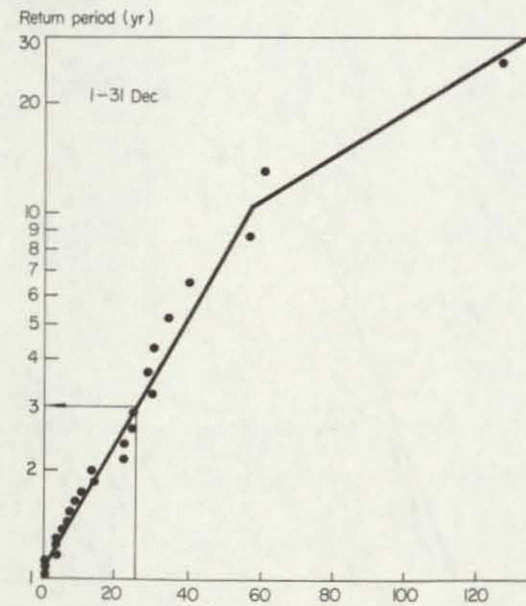
- is well below the evapotranspiration requirement of a typical annual crop — dry,
- meets about one-half the requirement — wet 1,
- meets about three-fourths the requirement — wet 2, and
- exceeds the requirement — wet 3.

The diagram illustrates rainfall pattern variability within a year and between years. Most noticeable is that substantial dry (dry and wet 1) periods occur in many years during the months of September and October, suggesting that rice yields will often be affected by stress if the crops are in the late reproductive stages at that time. On the other hand, heavy rains (wet 3) occur in many years between mid-June and mid-July. If they lead to standing water, they will depress yields of late-planted dryland crops. When information in the pentad diagram is considered together with the return period analyses, a clearer picture of variability in the rainfall pattern emerges.

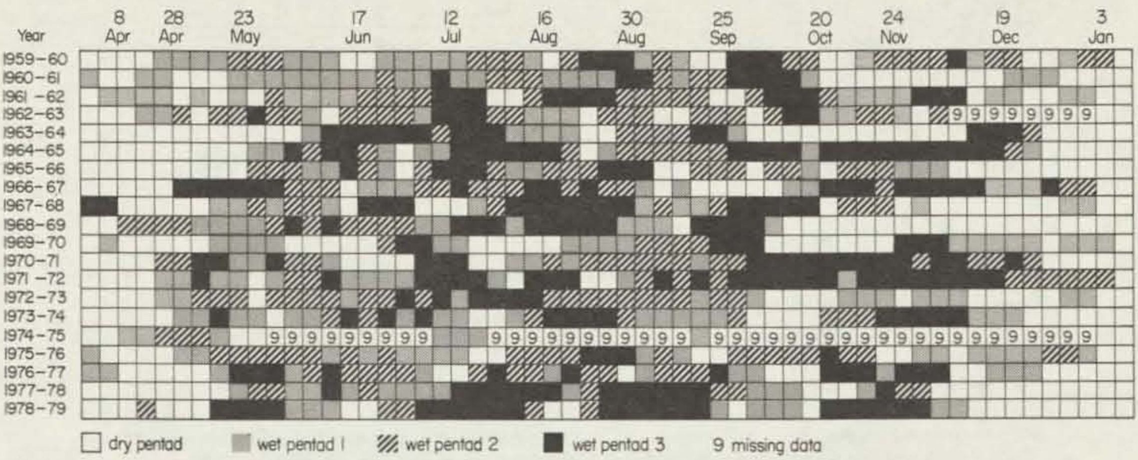
Because the research site is on terraces of the Cagayan River, seasonal floods are expected, especially during October and November (Table 1). Return period analysis showed that between 1 October and 30 November heavy rainfall (300 mm/5 days or 350 mm/7 days) occurs with about 5-year return periods (Fig. 7). Data recorded from 1958 to 1970 showed that maximum river rise occurred between 14 October and 26 November in 9 out of 13 years, suggesting that the main rice crop should be planted so as not to be in a stage vulnerable to flood damage before late November.

Return period, pentad diagrams, and periods of peak flooding were considered when cropping patterns were designed for the Solana project.

Land. A schematic diagram of the landscape at the research site is shown in Figure 8. Improved cropping patterns were designed for the *talon* portion, which was arbitrarily divided into three strata in anticipation of field water regimes as determined by field elevation.



5. Return periods for maximum rainfall per 3-day period, 1-31 December, Tuguegarao, Cagayan, Philippines, 1980.



6. Pentad (period of 5 days) diagram showing seasonal variability in rainfall for 1959-79 in Tuguegarao, Cagayan, Philippines.

First stratum. The soils of the first stratum are predominantly silty clay cloam with poor internal drainage. The traditional cropping pattern is mungbean (local), generally sown in mid-April, followed by transplanted rice in July-September.

Second stratum. The soils of the second stratum are predominantly silty clay but are less heavy than in the third stratum. Internal drainage is very poor. Water is expected to accumulate on the surface faster than in the first stratum, but slower and less deep than in the third stratum. The traditional cropping pattern is the same as in the first stratum. Standing water is expected to remain longer in the second stratum than in the first, and mean water depth is expected to be greater.

Third stratum. The third stratum occupies the lowest part of the *talon.* Water is expected to accumulate faster than in the second stratum and fields are expected to remain flooded for long periods. Because of its great distance from the villages and the susceptibility to flooding, fields in the third stratum are often expected to remain idle during the early wet season, or late wet season, or both.

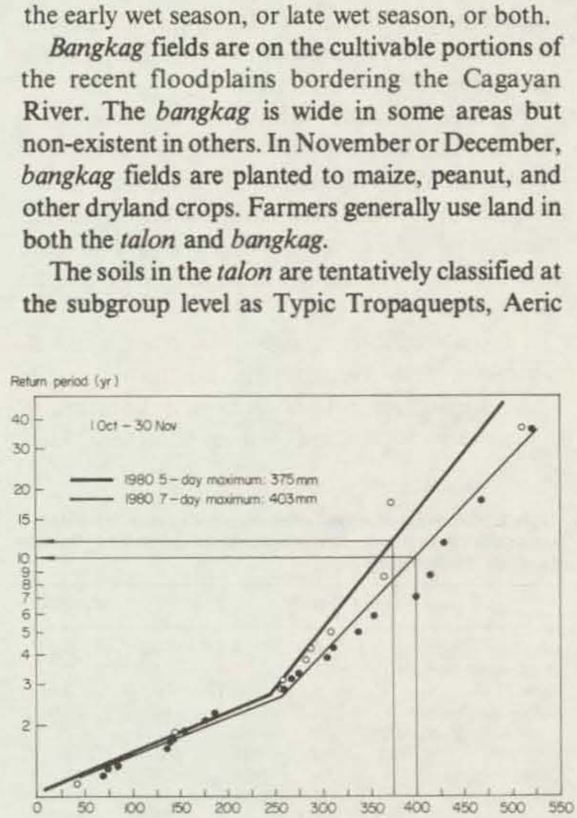
Bangkag fields are on the cultivable portions of the recent floodplains bordering the Cagayan River. The *bangkag* is wide in some areas but non-existent in others. In November or December, *bangkag* fields are planted to maize, peanut, and other dryland crops. Farmers generally use land in both the *talon* and *bangkag.*

The soils in the *talon* are tentatively classified at the subgroup level as Typic Tropaquepts, Aeric

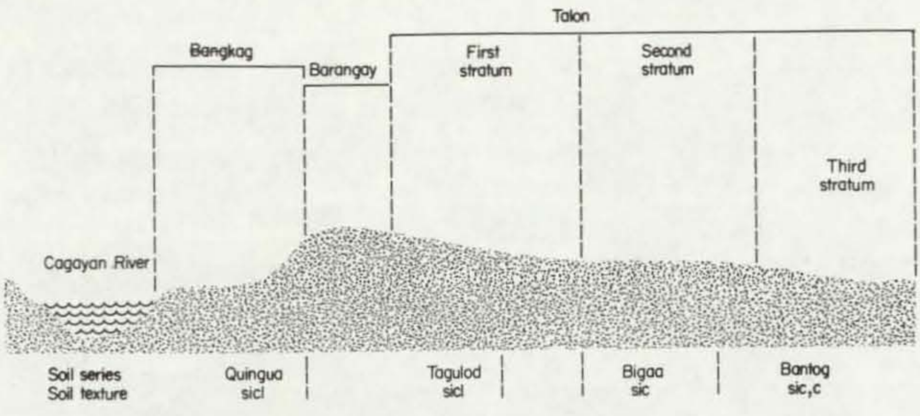
Table 1. Distribution of months in which flooding occurs in the Solana area, Cagayan, Philippines.

Month	Occurrence (%) of	
	Damaging floods[a]	Peak heights[b]
June	6	0
July	19	8
August	9	0
September	3	8
October	25	38
November	34	31
December	9	15

[a]From log kept by PAGASA official, 32 years, 1947 to 1978. Damage refers to crops on recent river flood plain (bangkag) or higher landforms. [b]From records kept by Public Works, 13 years, 1958 to 1970. Mean depth was 19.3 m, maximum depth was 22.2 m, and minimum depth was 16.2 m.



7. Return periods for maximum rainfall per 5- and 7-day periods, 1 October to 30 November, Tuguegarao, Cagayan, Philippines. 1980.



8. Schematic representation of landscape at the cropping systems site, Cagayan Valley, Philippines. The strata do not coincide with the soil series. sicl = silty clay loam, sic = silty clay, c = clay.

Tropaquepts, and Fluvaquentic Eustropepts. At the family level all would be characterized as fine, montmorillonitic, and isohyperthermic. Chemical and textural analyses of samples taken from the surface soils of different strata are in Table 2. Phosphorus and potassium levels are adequate for rice and other annual crops.

Fields in the *talon* portion of the site are on an alluvial plain landform unit within an alluvial subsystem. Similar landform units are found in the general target area. Other landform units (interhill miniplains and rivercut plains), thought to have similar field water regimes, are also extensive in the target area.

To locate land on other alluvial-plain, interhill-miniplain, and rivercut-plain landforms in the Cagayan Valley, a four-category land classification system was adopted and used to characterize land in the target area and then in the entire Cagayan Valley (Fig. 9). The four categories and the basis on which they are interpreted are shown in Table 3. In the classification, 4 land systems, 10 land subsystems, 30 landform units, and 75 land surface units were recognized. Land subsystem and landform unit classes under the four land systems are shown in Figure 10. A diagram showing several landform units of the alluvial and alluvial-colluvial land subsystems is presented in Figure 11.

Land surface units are regarded as the largest land units that can be managed uniformly with respect to the sequence of crops planted and the dates of planting. They are usually defined on the basis of relative elevation within a landform unit

Table 2. Chemical analyses of surface soils taken from different strata (S) in the cropping systems research site, Solana, Cagayan, Philippines.[a]

	S1	S2	S3	*Bangkag*
pH	6.3	6.2	6.2	6.6
Organic carbon (%)	1.3	1.4	1.7	1.2
Total N (%)	0.11	0.12	0.14	0.13
Cation exchange capacity (meq/100 g)	34.6	41.8	44.5	32.9
K (ppm)	260	335	261	268
Olsen P (ppm)	29	24	21	12
Clay (%)	37.7	54.1	59.3	31.6
Silt (%)	55.7	43.3	39.6	67.8
Sand (%)	6.6	2.6	1.0	0.6
Textural class	sicl	sic	sic	sicl

[a]sicl = silty clay loam, sic = silty clay.

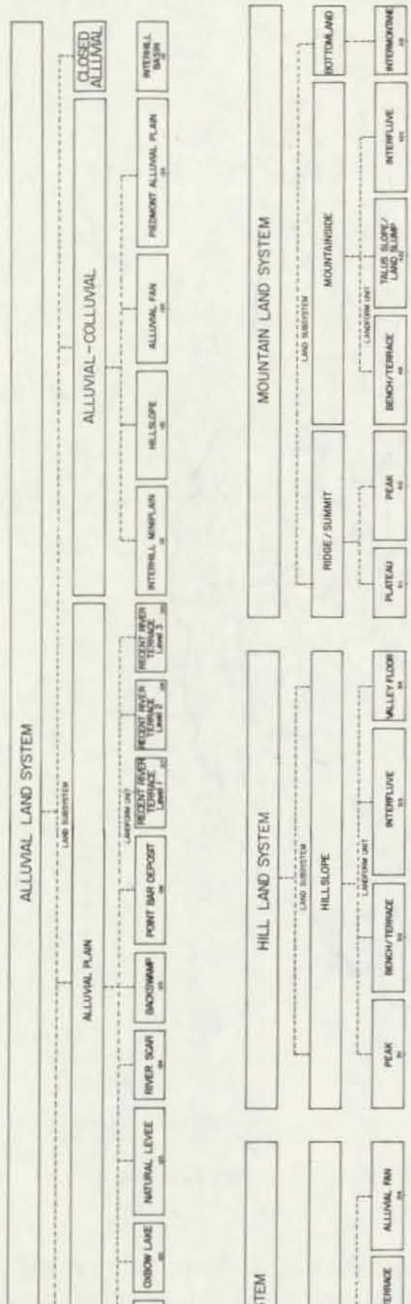
Table 3. Four hierarchal categories in a land classification system being tested in the Cagayan River basin, Philippines, 1980.

Hierarchal category	Interpreted on
Land system	1:250,000-1:1,000 topographic map with contour interval of 100 to 400 m.
	1:250,000 composite color LANDSAT imagery.
Land subsystem	1:50,000-1:250,000 topographic map with contour interval of 20 to 100 m.
	1:20,000 to 1:50,000 air photos.
Landform unit	1:10,000-1:50,000 topographic map with contour interval of 5 to 20 m.
	1:10,000 to 1:20,000 air photos.
Land surface unit	1:5,000-1:15,000 air photos.
	1:10,000-1:50,000 topographic map with contour interval of 5 to 20 m.

9. Land systems in the Cagayan River basin: A = alluvial, P = plain, H = hill, M = mountain.

(e.g., upper and lower slopes of an alluvial fan; inner and outer sectors of a river scar) and slope shape or position (concave and convex slopes of a recent river terrace; crest, inland-facing, and river-facing positions of a natural levee). Examples of landform units from major land subsystems on which rice is grown are shown in Figures 12 and 13.

In cropping systems research projects an attempt is made to take advantage of the correlation between landforms and soil bodies in a system of land classification. To obtain a limited but objective evaluation of the establishment of such correlation, soil profile data (17 variables) from 26 soils on land surface units from 7 short transects were subjected to cluster analysis. Despite some deviation, the five clusters identified in the analysis generally agreed with profile groupings according to three landform unit classes as shown in Table 4. As the clusters were reduced to four and three, the distinction between the alluvial plain and the inter-



10. Classes with land system, land subsystem, and landform unit categories in the Cagayan River basin landform classification system, Philippines.

hill miniplains was not maintained.

By enabling us to identify land with characteristics similar to those where research is being conducted, the classification system promises to provide a basis for extrapolating research results obtained at a site of only about 1,000 ha to a much larger area of the Cagayan Valley.

FARMERS' WEED CONTROL PRACTICES

Cropping Systems Component of the Agronomy Department

Farmers in the Solana area were interviewed to determine their land preparation methods and weed control practices for transplanted rice and mungbean.

The farmers recognized two landforms — *parang* and *kalayakan* — for which land preparation methods varied slightly.

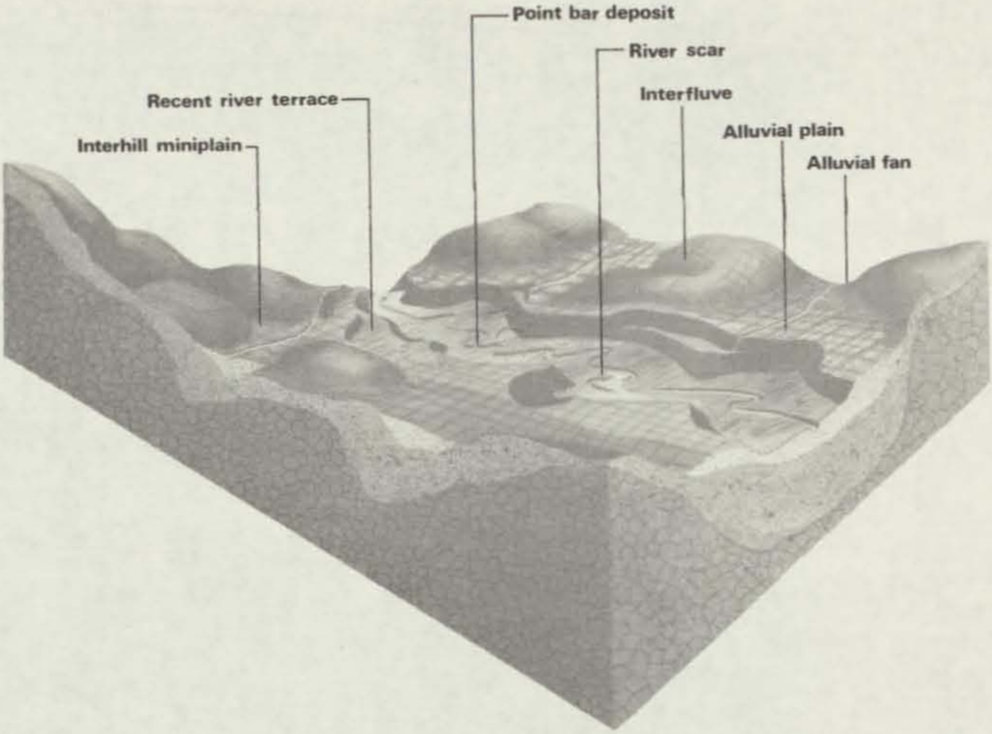
The fields were plowed once or twice, and most of the farmers harrowed two to four times before

Table 4. A cross-comparison of 5 CLUSTAN clusters (euclidean matrix on 17 soil variables, Ward's fusion method) with landform unit classes (n = 26).

Cluster	Alluvial plain (no.)	Interhill miniplain (no.)	Recent river floodplain (no.)
A	4		
B	3		
C	2	6	
D		7	
E	1		3

Table 5. Land preparation methods for transplanted rice and mungbean based on a farmer survey, Solana, Cagayan Valley, Philippines, 1980.

Land preparation method	Farmers (no.) using the practice			
	Rice		Mungbean	
	Parang	*Kalayakan*	*Parang*	*Kalayakan*
Plowings (no.)				
0	0	0	23	22
1	16	29	17	17
2	43	23	17	9
Harrowings (no.)				
1	3	4	17	11
2	20	7	9	8
3	17	21	4	2
4	16	14	4	5
5	3	3	0	0
6	1	3	0	0



11. To aid agricultural technicians in recognizing landform units in a large target area, diagrams can show the typical recurrent pattern of landform units within land subsystems. This diagram shows several landform units within alluvial and alluvial-colluvial land subsystems in the Cagayan Valley, Philippines.

transplanting rice (Table 5). For mungbean, the fields either were not plowed or were plowed once or twice. Fields that were plowed generally received one or two harrowings. When the fields were not plowed, furrows were opened for planting.

Most of the transplanted rice fields were either

12. An extensive alluvial plain of an alluvial land subsystem is in the foreground. A river-cut plain is in distant background. Cagayan Valley, Philippines, 1980.

13. Interhill miniplain, interfluve, and swamp landform units in a river-cut plain land subsystem. Cagayan Valley, Philippines, 1980.

Table 6. Farmers' weed control practices for transplanted rice and mungbean based on a farmer survey, Solana, Cagayan Valley, Philippines, 1980.

Weed control practice	Farmers (no.)	
	Transplanted rice	Mungbean
No weeding	12	17
One hand weeding	24	42
Two hand weedings	1	1
Herbicide	3	0
Herbicide + one hand weeding	15	0
Herbicide + two hand weedings	4	0
Maintaining water in the field	1	0
Interrow cultivation	0	0

hand weeded once or received a herbicide treatment and one hand weeding (Table 6). Mungbean was generally weeded once. However, 20% of the rice fields and 28% of the mungbean fields were not weeded. Most farmers did the first hand weeding 3 or 4 weeks after planting or transplanting (WT). Of the farmers who weeded their fields, 58.7% weeded mungbean 4 weeks after planting. Of those that transplanted 35.0% did the first weeding 4 WT, and 22.5% did so 3 WT.

One farmer applied butachlor at 0.6 kg a.i./ha; the others applied 2,4-D. All applied less than 0.25 kg a.i./ha, except one who applied 0.6 kg a.i./ha. Rates of application of both herbicides were lower

Table 7. Weed species growing in farmers' fields before land preparation for transplanted rice[a] Solana, Cagayan Valley, Philippines, 1980.

Weed species			
Stratum 1		Stratum 2	Stratum 3
Plowed before mungbean was planted	Not plowed before mungbean was planted		
Echinochloa colona	*C. dactylon*	*C. dactylon*	*E procera + E. stagnina*[b]
Cyperus rotundus	*E. colona*	*E. colona*	*Paspalum sp.*
Cynodon dactylon	*Eriochloa procera + Echinochloa stagnina*[b]	*C. rotundus*	*E. colona*
Ipomoea aquatica		*E procera + E. stagnina*[b]	*C. dactylon*
		I. aquatica	*Leersia hexandra*
		Commelina diffusa	*I. aquatica*

[a]Only species that comprised 5% or more of the weed flora by dry weight are listed Strata are seen in Figure 8 [b]Together these two species comprised more than 5% of the weed flora by dry weight.

than the recommended rate.

Major weeds. The major weeds growing in farmers' fields before land preparation for transplanted rice are listed in order of importance by stratum in Table 7. *Echinochloa colona* and *Cynodon dactylon* were important components of the weed flora in all strata. *Cyperus rotundus* was more important in strata 1 and 2 and in the fields that were not plowed before planting mungbean. A *Paspalum* sp. and *Ipomoea aquatica* were more important in strata 2 and 3, the lower strata.

The major weeds growing in association with transplanted rice in the *kalayakan* are listed in Table 8. All except *Scirpus supinus* var. *lateriflorus* and *Ischaemum rugosum* were observed before land preparation for rice, indicating the carryover effect of weeds from an unprepared field to one that was transplanted after land preparation. Differences in the relative importance of the weeds varied with time of sampling.

The *Paspalum* sp., *C. dactylon,* and *Eriochloa procera* + *Echinochloa stagnina* decreased in importance, but the others increased in importance. *E. colona* and *Leersia hexandra,* which were relatively important before land preparation, were only minor weeds of transplanted rice.

FARMERS' CURRENT INSECT CONTROL PRACTICES

Cropping Systems Component of the Entomology Department

A survey of current insect control practices was made among 45 farmers at the Solana site in 1980.

Farmers' awareness of pests. Farmers were asked to name or describe insect pest problems they encountered at each growth stage and rank the pests on a scale of 10 to 0 in terms of importance (10 = most important pest). Farmers ranked the rice bug *Leptocorisa oratorius* as the most important pest, followed by caseworm *Nymphula depunctalis* and armyworm *Mythimna separata* (Table 9). Only one farmer mentioned deadheart as a damage symptom.

Rats and birds were pest problems for half of the farmers. Few farmers mentioned specific diseases. Yellowing, wilting, and spotted leaf symptoms were described in phrases rather than named.

Twenty-two percent of the farmers could recall no rice pest outbreak in their experience, but 56% cited rice bug outbreaks as recently as 1979. Rice caseworm outbreaks occurred in 51% of farmers' fields, mostly more than 5 years ago.

When shown color prints or actual specimens all farmers interviewed recognized rice bug and 96%

Table 8. Major weeds growing in association with transplanted rice in the *kalayakan* area. Solana, Cagayan Valley, Philippines, 1980.

Weeds[a]
Commelina diffusa
Paspalum sp.
Ipomoea aquatica
Cynodon dactylon
Echinochloa stagnina
Scirpus supinus var. *lateriflorus*
Eriochloa procera
Monochoria vaginalis
Ischaemum rugosum

[a]Listed in order of importance Only species that comprised 5% or more of the weed flora by dry weight are listed.

Table 9. Ibanag (local dialect) names and relative importance of rice pests reported in a survey of 45 rainfed wetland rice farmers. Solana, Cagayan, Philippines, 1980.[a]

Pest name		Farmers describing pest (%)	Rank[b]
Ibanag	English		
Dangaw	Rice bug (*Leptocorisa oratorius*)	100	9.3
Kutalo	Rice caseworm (*Nymphula depunctalis*)	84	7.2
Arabas	Rice armyworm (*Mythimna separata*)	100	6.8
Bau	Rats	51	4.1
Tuggi	Stem borer (*Scirpophaga incertulas*)	58	4.0
Billit, mammana	Birds	49	4.0
Ararawan	Mole cricket (*Gryllotalpa africana*)	20	1.1
Aplat	Rice leaffolder (*Cnaphalocrosis medinalis*)	13	0.8
Antatado	Rice greenhorned caterpillar (*Melanitis leda*) Rice skipper (*Pelopidas mathias*)	7	0.6
Tungro	Tungro disease	2	0.2
Dudun	Grasshoppers	2	0 1
Kroiya	Field crickets	2	0 1
Kin amanaw y don	Whorl maggot (*Hydrellia sasakii*)	2	0 1

[a]All names were volunteered by farmers without aid from interviewer. [b]Scale of 10-0: 10 = most important, 0 = not mentioned.

recognized armyworm. Caseworm was named by 87% of the farmers interviewed. Only 11% could name stem borer as the cause of deadhearts or whiteheads and only 1% knew that leaffolder-damaged leaves were caused by the larva of an insect. No farmer could name a rice leafhopper or planthopper, either by recall or sight, and none associated whorl maggot damage symptoms with an insect.

Chemical control. Insecticides were used by 47% of farmers interviewed. Farmers preferred emulsifiable concentrates (EC) over wettable powder (WP) and granular (G) formulations. Of those who responded to the question of formulation preference, all chose liquids — 81% said liquids were more effective because control was quicker. The most popular insecticides — Thiodan EC, Gusathion EC, and Folidol EC — are relatively inexpensive, broad-spectrum chemicals. The more expensive Brodan EC and Furadan G are associated with modern rice technology. Liquid formulations are recommended at 0.75 kg active ingredient/ha, but farmers greatly underdosed (Table 10). Insecticides were applied in low spray volumes — a range of 16-204 liters/ha — which explained the low dosages.

Table 10 Insecticide usage on rice by 45 farmers surveyed at Solana, Cagayan, Philippines, 1980.

Insecticide[a]		Frequency[b] of use (%)	Dosage[c] application (kg a.i./ha)
Brand name	Common name		
Thiodan 35 EC	endosulfan	47	0.05
Gusathion 40 EC	azinphos-ethyl	19	0.10
Folidol 50 EC	methyl-parathion	19	0.08
Brodan 31 EC	chlorpyrifos	7	0 07
Furadan 3 G	carbofuran	3	[d]
Malathion 57 EC	malathion	2	0 09

[a]EC = emulsifiable concentrate, G = granular. [b]Based on total applications mentioned by farmers. [c]Based on area of field, spray volume, number of tablespoons per sprayerload, and formulation of insecticide as recalled by farmers [d]Not determined

Among the farmers interviewed, 23% owned knapsack sprayers and the rest borrowed them. Farmers reported they sprayed a field 1 to 4 times in 1979. Most (45%) of the applications were at the reproductive growth stage, followed by tillering stage (27%), seedbed (21%), and ripening stage (6%). The mean value of insecticides applied on rice was $2.30 (range of $0.34 to 8.50/ha). Most farmers (87%) bought insecticides themselves rather than using credit (13%).

Only 10% said extension workers guided them in insecticide use, and 90% decided on their own. Farmers applied insecticide in response to observed pests 50% of the time and to pest damage 40% of the time. Only 10% followed a schedule. Among insecticide users, 67% felt they were applying sufficient insecticide. Cited as constraints to using more insecticide were, in order of priority, lack of cash, knowledge, sprayer, water, and labor.

Cultural control. Farmers practiced few cultural control methods. Only 54% reported having used any cultural methods (Table 11). Removing weeds that sheltered insect pests was practiced by 33% of farmers.

Natural enemies. Most farmers could name at least one natural enemy of rice insect pests. Only

Table 11. Cultural control methods against rice insect pests, practiced by 45 Ibanag farmers in Solana, Cagayan, Philippines, 1980.

Method	Farmers reporting method used (%)
Removing weeds[a]	33
Removing infested plants[b]	29
Place food[c] in field	16
Prayers	13
Removal by hand[d]	9
Synchronous planting	7
Planting date	4
Crop rotation	2
Cutting rice seedlings	2
Placing plant parts in field	2

[a]Alternate host of rice insect pests. [b]Seven farmers reported removing stem borer infested tillers. [c]Rice. [d]Armyworms from seedbeds.

three classes of natural enemies were mentioned: spiders (87%), frogs (53%), and birds (18%).

Insect-resistant varieties. About half of the farmers interviewed (49%) could name a rice variety that they felt had resistance to at least one insect pest. The traditional Wagwag varieties grown by all farmers were cited by 33% as having general insect resistance. Sixteen percent named IR varieties even though few planted them.

Rodent control. Only 51% of the Solana farmers surveyed reported that they had undertaken measures to control rats. Some (13%) had used rodenticides but 51% knew that removing weeds from their fields would decrease rat infestation (Table 12). The farmers cited dogs (53%) and man (27%) as natural enemies of rats but no one mentioned snakes.

WORK ROLES OF FAMILY MEMBERS

Cropping Systems Component of the Agricultural Economics Department

In a study of the capacity of farm households to undertake more intensive cropping patterns the activities performed by households and the division of tasks between women and men were examined. The amount of time spent on different activities and its relation to wealth status and family life cycle were considered.

Households studied were selected from three wealth categories:

- those that usually run short of rice for consumption,
- those that produce just enough rice each year, and
- those that usually have a surplus of rice for disposal.

Three stages in the family life cycle of households were distinguished:

- childbearing stage (one or two parents and all children younger than 10 years),
- child-rearing stage (children older than 10 and also children younger than 5), and
- child-leaving stage (all children older than 5 years).

Labor data were collected from 25 of 100 farm households in an Iloilo village, Philippines. Through daily records and recall the labor time spent by sample households on 7 groups of activities was estimated for the crop year 1978-79. Table 13 shows the division of labor between wife and husband.

Women performed most of the home production activities, which included cooking, washing clothes, child care, and house repair. Their nonfarm economic activities were marketing of farm produce, selling pastries, and petty merchandizing. Women grew vegetables and minor field crops, raised pigs, and helped in planting, weeding, and harvesting of field crops, on their own farms and on others'.

Men grew several field crops with rice as the main crop, and grazed the carabaos. When crops were not growing, men engaged in some home production activities, chiefly carrying water and house repair. A few men had casual employment as carpenters.

Table 12. Cultural control methods against rodents in rice fields, reported by 45 farmers in Solana, Cagayan, Philippines, 1980.

Method	Farmers reporting method used (%)
Removing weeds[a]	51
Prayers	13
Place food in field[b]	11
Cutting grass in nearby fields	7
Lucky planting dates	7
Digging rat burrows[c]	4
Scarecrows	4
Placing flags in field	4
Synchronous planting	2

[a]Weeds act as alternate food source as well as shelter for rats [b]After harvest, as a reward to the rats for not causing excessive damage. [c]Some farmers fear that by digging out rats, the rat will seek revenge by selectively destroying their fields.

Table 13. Division of work time among 25 farm households in an Iloilo village, Philippines, 1980.

Activities	Work time (%)	
	Husbands	Wives
Rice production	86	14
Maize production	67	33
Production of vegetables and minor field crops	59	41
Labor on other farms	68	32
Animal raising	61	39
Nonfarm enterprises	46	54
Home production activities	14	86

The effect of the family life cycle on the labor patterns is shown in Tables 14-16. At the earliest stage of the family life cycle women spent most of their time in home production because of their child care responsibilities. At later stages children took over many of the home production activities, and the mother spent more time on the farm and other activities.

Children took over part of the grazing of the carabaos from the men. A man thus spent more time on farm activities during the critical child-rearing stage when household composition required relatively high food production. When the household was on the child-leaving stage, both wives and husbands spent less time on farm activities. The wife increased her time for all the nonfarm activities. The husband increased his time for home production.

To increase family income directly, wives in the rice-deficient group spent less time on home production and more time working for other farmers, on other economic activities, and on their own rice

Table 14. Allocation of work hours among wives in 25 farm households in an Iloilo village, Philippines, 1980.

Household group	Wives' work hours/yr						Daily average[a] (h)
	Farm production			Farm wage labor	Other enterprises	Home production	
	Rice	Other crops	Livestock				
By wealth category							
Rice deficient	68	67	122	149	258	1179	5.0
Rice sufficient	46	96	580	20	119	1452	6 3
Rice surplus	32	99	1213	—	322	1497	8.7
By stage in life cycle							
Childbearing	34	75	428	24	189	1885	7.2
Child-rearing	95	82	436	112	146	1070	5 3
Child-leaving	40	96	607	62	236	1201	6.1
Average	52	86	516	63	202	1361	6 2

[a]Excludes walking times to fields; computed as total per year divided by 365.

Table 15. Allocation of work hours among husbands in 25 farm households in an Iloilo village, Philippines, 1980.

Household group	Husbands' work hours/yr						Daily average[a] (h)
	Farm production			Farm wage labor	Other enterprises	Home production	
	Rice	Other crops	Livestock				
By wealth category							
Rice deficient	251	140	979	147	193	178	5 2
Rice sufficient	261	145	1230	50	125	275	5.7
Rice surplus	219	125	794	—	120	262	4 2
By stage in life cycle							
Childbearing	252	165	1613	90	148	312	7.1
Child-rearing	301	172	992	140	244	119	5.4
Child-leaving	225	110	792	37	102	255	4.2
Average	251	140	1070	77	149	238	5 3

[a]Excludes walking times to fields, computed as total per year divided by 365

Table 16. Allocation of work hours among children in 25 farm households in an Iloilo village, Philippines, 1980.

Household group	Children's work hours/yr						
	Farm production			Farm wage labor	Other enter-prises	Home produc-tion	Daily average[a] (h)
	Rice	Other crops	Live-stock				
By wealth category							
Rice deficient	164	82	365	226	11	605	4 0
Rice sufficient	209	104	674	114	7	713	5 0
Rice surplus	165	34	534	16	13	552	4 5
By stage in life cycle							
Childbearing	0	0	0	0	0	5	0
Child-rearing	374	173	664	302	28	1216	7 6
Child-leaving	200	194	795	138	5	739	5 7
Average	186	134	541	139	9	648	4 5

[a]Excludes walking times to fields; computed as total per year divided by 365

production (Table 14). Husbands in the same group worked more on other farms than their wealthier counterparts, and spent less time on home production (Table 15). Animal-raising time for low income households usually was reduced because owners did not keep livestock.

Children played an important role in farm labor and earnings (Table 16). They worked on other farms for wages far more than their parents, and greatly assisted in farm and home production. Their livestock work was confined to caring for the carabao while mothers raised pigs. Children were largely excluded from economic enterprises such as marketing and petty merchandizing.

CONSUMPTION PATTERNS IN FARM HOUSEHOLDS

Cropping Systems Component of the Agricultural Economics Department

Daily records of the 1975-79 cash income and expenses of about 40 farmers in each of three Philippine areas were analyzed with a linear expenditure system model. The analysis showed what proportions of income increments or *marginal budget share* farmers allocated to each of various expenditure items.

Table 17 shows the average and marginal shares of four major expenditure categories in the budgets of farm owner-operators and tenant farmers. The patterns of average expenditures were quite similar. Food took more than 30% of the budget and farm inputs 20%. The marginal shares indicated how farmers spent any increases in income. It was apparent that farm operators were more inclined than tenants to spend for personal and household needs. The marginal share of household items was higher than the average and marginal food expenditures were less than the average, indicating an overall decline in the food share of the budget as income increased. That was expected.

Tenant farms were inclined to reduce the share of personal needs as well as food and household items as their incomes increased. In each case the marginal share was less than the average budget share. More striking for tenants, however, was the high marginal budget share (32%) of farm inputs. Tenant farmers spent a higher proportion of their cash income increases on farm inputs. Their investments in cash inputs were usually about matched by their landlords, and the product, after paying harvesters, was divided equally by tenants and landlord.

The number of family members in a household should affect the manner in which income is spent, particularly for items such as food and clothing. The linear expenditure system was estimated for

Table 17. Budget shares by tenure class for farm owner-operators and tenants based on analysis of daily records of 40 farmers in each of 3 Philippine areas, 1975-79.

Expenditure item	Budget shares (%) by tenurial class			
	Owner-operator		Tenant	
	Av	Marginal	Av	Marginal
Food and beverage	0.34	0.29	0 37	0 32
Personal needs	0 25	0.26	0 20	0 17
Household items	0 21	0.25	0 23	0 19
Farm inputs	0 20	0 20	0 20	0 32

Table 18. Budget shares by household size based on analysis of daily records of 40 farmers in each of 3 Philippine areas, 1975-79.

Expenditure item	Budget shares (%) by size of household			
	Large household		Small household	
	Av	Marginal	Av	Marginal
Food and beverage	0.34	0 34	0 39	0.28
Personal needs	0.26	0.22	0.16	0 24
Household items	0.21	0 22	0 23	0.23
Farm inputs	0 19	0 22	0 22	0 25

small and large households by dividing the original sample at the medium household size—5 members. The average budget share of food plus personal items was larger for large households, but expenditures were more highly weighted toward personal items than in small households (Table 18). Apparently, food can be more easily *stretched* over a large household than can personal items. On the other hand, as incomes increased the large household's budget share on food remained constant, with some decline in personal expenditures. Small households were inclined to sharply increase expenditures for personal items while cash food purchases declined.

The analysis indicated that farmers were willing to invest cash resources in farm inputs and to expand farm investments as a share of all expenditures as incomes increased. Revision of the model was started to incorporate information on the consumption of farm produce and transactions in kind that are not reflected in a cash expenditure model. The revised model will permit comparison of expenditure patterns between areas where the degree of production for consumption may differ.

LABOR REQUIREMENTS FOR CULTURAL OPERATIONS

Cropping Systems Components of the Agricultural Economics and Statistics Departments

Labor data on selected crop operations from farm records at a cropping systems research site in Pangasinan, Philippines, were analyzed to identify factors responsible for the variation in the labor requirement data and to estimate the labor requirements for selected crop operations and field crops.

Frequency distributions, range, variance, and coefficients of variation of the labor data were computed to study the variability and to check for extreme observations. Skewness and kurtosis of each frequency distribution were computed to test the normality of the distribution. In addition, Shapiro Wilk-W statistics were used as a supplemental test of normality. Through this analysis, extreme values in the labor data were observed and the distribution of labor data was found to be nonnormal and positively skewed.

The factors hypothesized to affect labor usage were plot size, seed rate, fertilizer rates, insecticide rate, and crop yield.

Effect of plot size on labor usage. Data on labor usage for each selected crop operation were plotted against plot size to examine the effect of plot size on labor usage. Because of the large fluctuations observed, an acceptable range of labor data for each selected crop operation was determined. Data falling outside the acceptable range were excluded to improve data quality. Simple correlation coefficients (r) between plot size and labor usage were computed. In 15 of 26 cases, the correlations between labor usage and plot size were negative and significant (Table 19). This indicates that labor use estimates tended to be higher with smaller plot size.

Effect of other factors on labor usage. Other factors examined for effects on labor usage were seeding rate (kg/ha) for direct-seeded wetland rice and mungbean, fertilizer rate (kg/ha) for fertilization, insecticide rate (ml/ha) for insecticide application, and crop yield (kg/ha) for harvesting transplanted rice (TPR), dry-seeded wetland rice (DSWR), and mungbean.

Seeding rate. The effects of seeding rate (kg/ha) on labor usage for planting operation of DSWR and mungbean are shown in Figure 14. For DSWR, the correlation coefficient (r = 0.03 ns) indicated no association between seeding rate and labor usage. For mungbean, a slight positive and significant correlation between seed rate and labor usage was indicated (r = 0.28 **).

Fertilizer rate. Fertilizer rate and first and second fertilization for TPR were associated, as indicated by the correlation coefficients (.32** and .33**). However, there was no significant association between fertilizer rate and labor usage for the first and the second fertilization for DSWR (r = .06 ns and .01 ns) (Fig. 15).

Table 19 Simple correlation coefficients (*r*) between plot size and labor use per ha, and variability in labor data for selected crop operations after excluding outliers Pangasinan, Philippines, 1978-79.

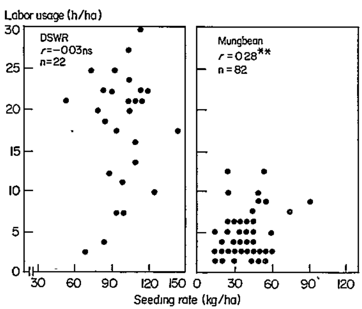
Operation	Crop[a]	Order of operation[b]	Sample size	Mean m-h/ha	Min m-h/ha	Max h/ha	CV	r
Plowing	TPR	1st	86	55 0	16 5	129 5	39 5	−0 34**
		2d	21	49 8	14 7	98 0	43.5	−0.48*
	DSWR	1st	30	50 9	16 2	88 0	39.7	−0.17
		2d	15	37.5	23 8	56 6	28 7	−0.31
	Mungbean	1st	60	56 1	7.0	200 0	54 8	−0 14
Harrowing	TPR	1st	92	28 2	4 1	107 9	70 4	−0 22*
		2d	57	24 5	9 0	111.7	68 9	−0 26*
		3d	19	16 9	8 0	33 5	45 1	−0 45*
	DSWR	1st	31	19 5	3 5	65.0	73 9	−0 41*
Planting	TPR	—	110	134.2	31 0	349 0	42 9	−0 28*
	DSWR	—	35	20.7	2 0	35 0	42 3	0 02
	Mungbean	—	95	6 3	1.0	29 0	111 6	−0 32*
Fertilization	TPR	1st	97	10 3	1.5	74 3	124 4	0.09
		2d	59	6 4	1.4	18 0	52 9	−0 52**
	DSWR	1st	33	16 6	2 4	52 8	71 2	0.19
		2d	24	10 7	1.4	22 0	54 7	−0 24
Insecticide application	TPR	1st	60	9 0	3 1	26 0	48 6	−0 38**
		2d	17	8 3	2 7	12 5	36 5	−0 49*
	DSWR	1st	23	8 6	3 3	16 9	43 2	−0.10
	Mungbean	1st	82	10 0	2 4	43 5	72 0	−0 31**
		2d	55	9.5	2.4	43 5	67.6	−0 29**
		3d	40	8 3	2 2	24 0	50 3	−0 41**
		4th	24	13.7	2 3	43.5	66 4	−0.67**
Harvesting	TPR[c]	—	112	251 3	48 0	919 0	59 3	0 06
	DSWR[c]	—	38	210 8	66 0	653 0	59 9	−0 30
	Mungbean	—	86	89 8	6 0	360.0	69 6	−0.20

[a]TPR = transplanted rice, DSWR = dry-seeded wetland rice. [b]A dash (—) means not applicable [c]Includes threshing.

Insecticide rate. Results indicate an association between insecticide rate and second application of insecticide for TPR ($r = .70^*$) and first insecticide application for mungbean ($r = .40^{**}$) This implied a tendency for insecticide application to increase as higher rates of insecticides are applied on the same area of land (Fig. 16-17). Development of the crop canopy may be a factor causing the increased association of labor time and insecticide rate on rice between first and second applications.

Crop yield. The effects of crop yield on harvesting time were examined in TPR, DSWR, and mungbean. No apparent relationship between labor (h/ha) for harvesting and the amount harvested (kg/ha) was observed either in TPR or in DSWR (Fig. 18). However, harvest time of mungbean was related to its yield ($r = .25^*$).

Such factors as planting, first insecticide application, and harvesting of mungbean, and first and second fertilization and insecticide application for TPR showed no dependence on other crop operations, implying that labor requirements for the former operations could be estimated independently of the level of the other factors.

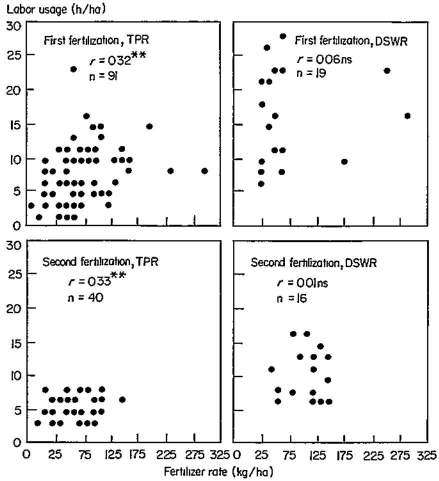


14. Effect of seeding rate on estimate of labor usage for planting of dry-seeded wetland rice (DSWR) and mungbean crop Pangasinan, Philippines, 1978-79

ESTIMATES OF LABOR REQUIREMENTS FOR SELECTED CROP OPERATIONS

Cropping Systems Components of the Agricultural Economics and Statistics Departments

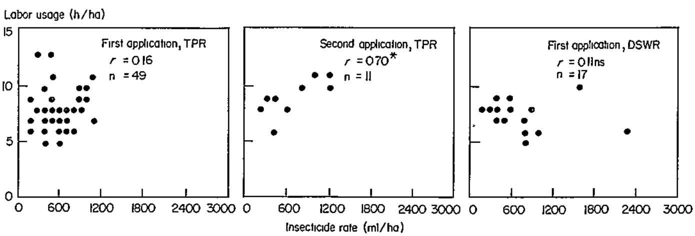
Estimates of labor requirements — except for planting, first insecticide application and harvest-



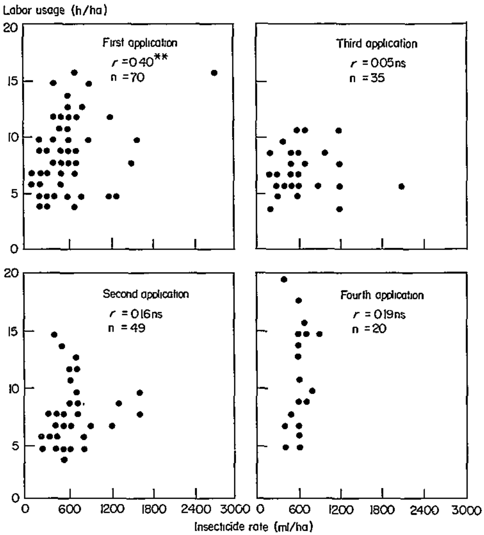
15. Effect of fertilizer rate on estimate of labor usage for fertilization of transplanted rice (TPR) and dry-seeded wetland rice (DSWR) crops. Pangasinan, Philippines, 1978-79.

ing of mungbean, and fertilization and second insecticide application in TPR — were obtained as simple averages of labor usage within the acceptable range. For planting, first insecticide application, and harvesting of mungbean and fertilization in TPR, estimates were obtained as simple averages at three levels — low, medium, and high — of the factor being considered. Estimates of labor requirement for higher order operations, with the exception of insecticide application for TPR and mungbean, were consistently smaller than those for the lower order operations. Results indicated that labor requirement for wetland plowing is higher than that for dryland plowing, and which was also the case for harrowing.

DSWR and mungbean are usually broadcast. Labor requirements for planting were much higher in DSWR (20.6 hours/ha) than those at different

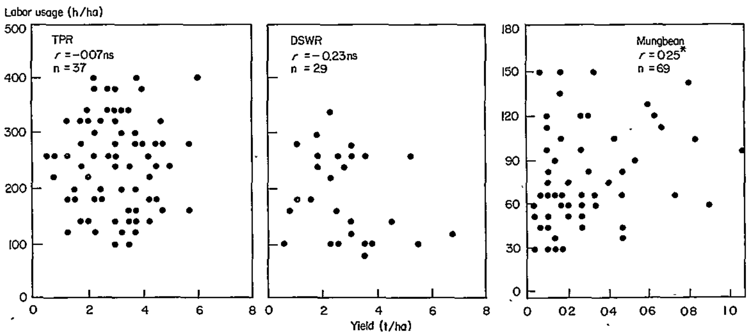


16. Effect of insecticide rate on estimate of labor usage for insecticide application for transplanted rice (TPR) and dry-seeded wetland rice (DSWR) crops Pangasinan, Philippines, 1978-79



17. Effect of insecticide rate on the estimate of labor usage for insecticide application for mungbean Pangasinan, Philippines, 1978-79

levels of seeding rate (3.6, 3.3, and 4.5 hours/ha at low, medium, and high levels) for mungbean. Labor requirements for planting mungbean at the medium seeding rate were lower than at low level, possibly because of the small correlation value between seeding rate and labor usage.



18. Effect of yield level on the estimate of labor usage for harvesting transplanted rice (TPR), dry-seeded wetland rice (DSWR), and mungbean crops. Pangasinan, Philippines, 1978-79.

Table 20. Estimated labor requirements for selected crop operations. Pangasinan, Philippines, 1978-79.[a]

Operation	Crop[b]	Order of operation	Factor affecting labor requirement	Level of factor[c]	Sample size	Labor requirement (h/ha) Mean ± SE
Plowing	TPR	1st	—	—	59	51.7 ± 1.3
		2d	—	—	15	43.7 ± 2.3
	DSWR	1st	—	—	18	46 1 ± 2.3
		2d	—	—	9	34.1 ± 2.3
	Mungbean	1st	—	—	49	51 1 ± 2.3
Harrowing	TPR	1st	—	—	75	23.3 ± 1.2
		2d	—	—	53	20 9 ± 1.1
		3d	—	—	14	15 3 ± 1.3
	DSWR	1st	—	—	27	16.1 ± 1.4
Planting	TPR	—	—	—	87	126 9 ± 3.1
	DSWR	—	—	—	22	20.6 ± 0.9
	Mungbean	—	Seed rate	L (<26 kg/ha)	27	3.6 ± 0.5
				M (27-38 kg/ha)	27	3 3 ± 0.3
				H (>38 kg/ha)	28	4.5 ± 0.6
Fertilization	TPR	1st	Fertilizer rate	L (<95 kg/ha)	32	6 1 ± 0 5
				M (96-125 kg/ha)	29	6 6 ± 0 8
				H (>125 kg/ha)	30	9.4 ± 0.6
		2d	Fertilizer rate	L (88 kg/ha)	15	5 0 ± 0 4
				H (89-125 kg/ha)	15	6 0 ± 0 3
				M (>125 kg/ha)	10	6.3 ± 0.6
	DSWR	1st	—	—	19	16.4 ± 1.5
			—	—	16	10.8 ± 0.9
Insecticide application	TPR	1st	—	—	49	8.2 ± 0 3
		2d[d]	Insecticide rate	783 ml/ha	11	8 9 ± 0 3
	DSWR	1st	—	—	17	7.5 ± 0 3
	Mungbean	1st	Insecticide rate	L (<600 ml/ha)	24	7 0 ± 0 6
				M (600-900 ml/ha)	24	9.1 ± 0.5
				H (>900 ml/ha)	22	10 0 ± 0.7
		2d	—	—	49	8 3 ± 0 4
		3d	—	—	35	7.3 ± 0.3
		4th	—	—	20	11.4 ± 1 0
Harvesting	TPR[e]	—	—	—	87	239.5 ± 8 7
	DSWR[e]	—	—	—	29	189.4 ± 14.1
	Mungbean	—	Yield	L (<131 kg/ha)	25	68.4 ± 6 0
				M (132-305 kg/ha)	23	74 9 ± 7 0
				H (>305 kg/ha)	23	85.5 ± 6.7

[a]A dash (—) means not applicable. [b]TPR = transplanted rice, DSWR = dry-seeded wetland rice [c]L = low level, M = medium, H = high. [d]Functional relationship is determined and is linear with 2 h/1,000 ml. Mean insecticide rate = 783 ml/ha [e]Includes threshing.

Labor requirement for fertilization varied from 5 hours/ha (at the low rate of fertilizer) in second fertilization of TPR to 16.4 hours/ha for first fertilization of DSWR. In all cases, labor requirement for fertilization was higher in DSWR than in TPR. The situation was the reverse in the case of insecticide application. The highest labor usage for insecticide application was 11.4 hours/ha (fourth application in mungbean).

Harvesting time of TPR was much higher than that of DSWR. The estimate of labor requirements for the second insecticide application was obtained at the average insecticide rate of 783 ml/ha with an additional labor requirement of 2 hours/ha for every 1,000 ml/ha increase in insecticide used (Table 20).

EFFECT OF MANAGEMENT ON RICE YIELD

Cropping Systems Component of the Agricultural Economics Department

In an analysis of dryland rice production by 33 farmers in Batangas, Philippines, the management factor included in a Cobb-Douglas production function explained a large proportion of variations in rice yield.

Labor and fertilizer were the two inputs believed to be importantly related to the management factor. It was proposed that management effects on yield were reflected through the proper usage of fertilizer — the amount and the right time of application, and the quality of labor input and the correct timing of farming operations. The Nielson management model and the pattern analysis technique were used to quantify the management factor.

Management grouping. The pattern analysis technique was used to sort 33 farmers into 3 groups without a priori knowledge of any kind of classification involving the group whatsoever. The farmers were grouped on the basis of their responses to questions relating to the Nielson management model. Table 21 shows the categories of information obtained from a survey used to class farmers into three management groups. Pattern analysis does not determine the principal factors that make the groups different. But simply put, farmers within a group were more similar to one another, according to characteristics and responses in Table 21, than to farmers in either of the two other groups. The hypothesis advanced was that the groups formed were of different managerial capabilities and any cluster was as homogenous a management group as possible.

A comparison of the mean characteristics of groups identified through pattern analysis was done by *t*-test. The farmers in management group 3 (M_3) were younger and had less farming experience. In terms of yield, the younger farmers performed better than the old ones. Their survey responses showed them to be more knowledgeable in technical agriculture than farmers in management groups 1 and 2 (M_1 and M_2). They tended also to be more receptive to change and had greater aspirations in life. They regarded a progressive farmer as one who owns a farm and cultivates it, not one just getting higher yields. They had a general idea of which crops have better prices. They were also better decision makers in the sense that they related and studied information from all sources and experimented before finally adopting a farm technology.

On the whole, M_3 farmers possessed characteristics that were indicative of good managerial capabilities as compared to M_1 and M_2 farmers. There was not much apparent difference between M_1 and M_2 farmers.

Table 21. Category of information[a] obtained for 33 Batangas farmers, Philippines, 1980.

V1 =	biography information
	Age
	Educational attainment (years)
	Experience in farming (years)
	Size of family
	Ownership of fixtures and buildings, e g., house, water tanks, etc.
	Material possessions, e.g. furniture, radio, etc.
	Ownership of farm implements
V2 =	technical knowledge information
	Knowledge of fertilizer and fertilizer use
	Knowledge of chemicals and proper usage
	Knowledge of pests, diseases, and corresponding damages
	Knowledge of farming in general
V3 =	attitude and motivation information
	Attitude toward savings
	Attitude toward loans
	Pattern of expenditures
	Attitude toward community and its problems
	Attitude toward farming as an occupation
	Aspirations in life
	Reaction to changes in prices of farm crops
P =	process information
	Source of farm information
	Use of farm information
	Adoption of farm technology
	Implementation of farm technology adopted

[a]Information for V1 was taken from the Asset and Valuation Survey Schedule; the information for V2, V3, and P were taken from a Management Survey Schedule.

A function assuming conventional inputs to rice production was fitted by regression of the form:

$$Y = b_o + b_j x_j + b_h X_h + e \qquad (1)$$

where y = estimated yield/ha (log),
x_1 = fertilizer, kg N/ha (log),
x_2 = labor, hours/ha (log),
x_3 = rainfall, mm rain (log),
X_4 = dummy for date of planting,
X_5 = dummy for tenancy,
X_6 = dummy for previous crop planted,
X_7 = dummy for intercropping,
b_o, b_j, b_h X_8 = the parameters estimated, and
e = error term.

The management factor was incorporated with the use of dummy variables representing the management groups. Three regression models were formulated to determine the effect of management on yield through the general productivity level (intercept) (model 1), the factor elasticity (model 2), and both the general productivity level and factor elasticity (model 3).

Model 1 is described by the equation;

$$y = b_o + \Sigma\, b_j x_j + \Sigma\, b_h X_h + \Sigma\, d_g M_g + e, \qquad (2)$$

where d = management coefficient and
M = management dummy.

Model 2 is described as

$$y = b_o + \Sigma\, b_j x_j + \Sigma\, b_h X_h + \Sigma\, c_{gj} M_g x_j + e, \quad (3)$$

where c_{gj} = coefficient for management-input interaction term.

Model 3 is described as

$$y = b_o + \Sigma\, b_j x_j + \Sigma\, b_h X_h + \Sigma\, d_g M_g + \Sigma\, C_{gj} M_g x_j + e, \quad (4)$$

The regression results are presented in Table 22. The model with only the conventional inputs is significant at the 1% level and the variables explained 35% of the variation in rice yield. The unexplained part of the variation may have been due to possible measurement errors, specification errors, and random factors. The measurement errors may have arisen due to the recall type of gathering information. Specification errors may have included the absence of the management factor and soil type in the model. The soil variable was excluded because of the difficulty in soil sample collection and analysis. It is believed however, that soil is an important factor that affects the yield of Dagge.

Fertilizer, rain, and a share-tenancy dummy were significant variables. The coefficients for fertilizer, labor, and rain were the production elasticities in the context of the Cobb-Douglas functional form and indicated the expected percentage change in yield as a result of a 1% change in an input, while others are held constant. For instance, a 1% increase in the level of nitrogen will result in a 0.38% increase in yield when other inputs are fixed at a certain level. Similar interpretations can be made for labor and rain.

The antilog of the coefficient for the share-tenancy dummy was 0.78. This indicated that at the same level of all inputs the general level of yield of share-tenants was 22% lower than that of owner-operators. Similar interpretations can be made for the coefficients of the other dummy variables.

Inclusion of the management group dummy variables in the production function significantly improved the fit of the new models as indicated by an increase in R^2 from 0.35 to about 0.56. Analysis of variance test supported the significant inclusion of management in production analysis.

Management is believed to have a greater effect on yield through the factor elasticity of fertilizer and labor than through the general level of productivity. In model 3A, the coefficient of fertilizer was insignificant, contrary to that in the other models, implying that the differential effect of fertilizer had been absorbed by the management factor. The

Table 22. Multiple regression coefficients for three models of Batangas (Philippines) farmers, with conventional inputs and the management factor included. 1980.[a]

Variables (coefficients)		Conventional inputs	Multiple regression coefficient for given model					
			1	2A	2B	3A	3B	
X_1	(b_1)	0.378***	0.114*	0.202***	0.117*	−0.051	0.088
X_2	(b_2)	0.110	0.154**	0.148**	0.198***	0.137**	0.031
X_3	(b_3)	0.107**	0.126***	0.125***	0.119***	0.139***	0.134***
X_4	(b_4)	−0.044	−0.020	−0.025	−0.20	−0.018	−0.025
X_5	(b_5)	−0.107***	−0.054*	−0.058*	−0.052*	−0.050*	−0.076**
X_6	(b_6)	−0.011	0.005	0.003	0.007	−0.006	0.006
X_7	(b_7)	−0.004	−0.006	0.009	−0.010	−0.005	−0.002
M_1	(d_1)	na	−0.257***	na	na	−0.593**	−0.234
M_2	(d_2)	na	−0.115***	na	na	−0.619*	−0.897***
M_1X_1	(c_{11})	na	na	−0.140***	na	0.179	na
M_2X_1	(c_{21})	na	na	−0.054***	na	0.277	na
M_1X_2	(c_{12})	na	na	na	−0.102***	na	−0.010
M_2X_2	(c_{22})	na	na	na	−0.043***	na	0.309**
Constant (log)		1.594	1.336	1.201	1.301	1.534	1.613
R^2		0.35	0.56	0.55	0.56	0.57	0.59
$\bar{R}^2$		0.31	0.52	0.51	0.52	0.53	0.54
SE		0.1444	0.1199	0.1211	0.1201	0.1196	0.1172
F-Value		8.61	15.56	15.00	15.47	13.03	13.97
d f		7,112	9,110	9,110	9,110	11,108	11,108

[a]* = significant at 10% level, ** = significant at 5% level, *** = significant at 1% level. na = not applicable.

Table 23. Estimated marginal products by management groups among 3 models of Batangas (Philippines) farmers. 1980.

Model and variable	Management group	Elasticity (b_i)	Mean value of inputs	Average physical product (kg/unit)	Marginal physical product (kg/unit)	Marginal value product
Model 2A						
Fertilizer	1	0.0622	49	27.71	1.72	0 36
(kg N/ha)	2	0.1483	63	29 54	4 38	0.92
	3	0.2025	91	26 00	5.26	1.11
Model 2B						
Labor	1	0.0963	385	3.52	0.34	0 07
(h/ha)	2	0.1548	532	3.50	0 54	·0.11
	3	0.1982	386	6.13	1.21	0 26

same was true of labor in model 3B. This could be interpreted to mean that membership to a particular group has some effect on yield regardless of fertilizer or labor usage. But, logically, that is not so. Hence, model 2A (2B) is the appropriate model to determine and analyze the effect of management on yield of Dagge.

Considering fertilizer input first (2A), the results (Table 22) showed that for M_1, increasing fertilizer level by 1% should give 0.06% increase in yield (i.e. b + c, or 0.202 − 0.140), when other factors are fixed. The increase is 0.15 % for M_2 and 0.20% for M_3. M_3 farmers were better managers of fertilizer input than the M_2 farmers, who in turn were better managers than M_1 farmers. For labor input (2B), it can be deduced that M_3 farmers were better managers of labor input than M_2 farmers who were better than M_1 farmers.

Marginal returns to factors of production. The relative efficiency or inefficiency of resource allocation was determined by comparing the marginal value product (MVP) of inputs with their respective prices or opportunity costs. In the absence of data for opportunity costs, the normal market prices of inputs provided a basis of comparison. Optimal resource allocation occurs when the MVP of a resource is equal to the unit cost of hiring or employing that resource.

In determining optimum resource allocation, the daily wage rate of $1.07 for labor was used. The prices of ammonium sulfate (21-0-0; $0.19/kg) and urea (45-0-0; $0.21/kg) were used as bases for computation of the price of nitrogen ($0.60/kg). The price of Dagge was $0.90/kg.

Table 23 presents estimated factor marginal products by management group. Comparing the MVP of fertilizer with the cost of nitrogen, it can be said that M_3 and M_2 farmers were *quite efficient* in the allocation of this input. Considering the labor input, it appeared that M_1 and M_2 farmers were inefficient but M_3 farmers were efficient in labor input allocation.

Cropping systems program

Design of cropping patterns

Multiple Cropping Department and Cropping Systems Component of the Entomology Department

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CROPPING PATTERNS FOR SOLANA

Multiple Cropping Department

Cropping patterns for Solana were designed for the three strata described in the section Environmental Description. Physical factors were assessed to determine the suitability of crops in each stratum. The potential crops for each stratum were listed on a work table and a two-part judgment was made regarding the adequacy or hazard of several factors that determine the agronomic potential of each crop. The work table for stratum 1 is included as Table 1. The first part of the judgment required a rating for the factor if typical conditions prevail. The second part of the judgment required a rating that suggested the degree of annual variability in the factor. Of the several factors likely to affect yields, water excesses, water shortages, and wind and flood hazards were prominent for many crops. The key factor in designing the patterns was the expected field water regime.

For all patterns the dryland crop component was limited to mungbean. For rice crops, either transplanting (TPR) or dry-seeding (DSR) were specified according to the expected field water regime. From the analysis of rainfall data (mean monthly rainfall, return period diagrams, and pentad diagrams), landscape features, river flood data, and discussions with farmers, it was estimated that rainfall would be sufficient to start and sustain a DSR crop planted in early June in stratum 2, but that the crop must be harvested by late September to avoid deep flooding. Short-duration TPR crops might also fit in strata 2 and 3 if transplanted by late June and harvested by late September. In stratum 1, mungbean planted after early rains in May and harvested about 70 days later in mid-July, to be followed by TPR, was considered as an alternative to DSR. A mungbean -TPR pattern would not differ considerably from current practices, but a rice variety (IR36) with higher yield potential and shorter field duration than the traditional variety, and a mungbean variety with higher yield potential and about the same field duration were available.

For the period between early October and late November, when flooding was expected as a hazard, a TPR crop in the vegetative stage was thought best suited — or least vulnerable. A variety with improved plant type (high yield potential), moderate height (115-125 cm), and good submer-

Table 1. Work table for physical adaptation of crops to stratum I at the Solana cropping systems research site, Cagayan, Philippines, 1980[a]

Crop and variety	Field period	Water sufficiency		Excess water		Solar radiation		Day length	Temp°C		Nitrogen[b]		Phosphorus[c]		Potassium[d]		Nutrients		Toxicity		Miscellaneous hazards		Expected yield (t/ha)
		Av	Risk	Av	Risk	Av	Risk		Av	Risk	Av	Risk	Av	Risk	Av	Risk	Av	Risk	Av	Risk	Av[e]	Risk	
Mung (CES 1D-21)	Apr-Jul	G	L	Mo	M	G	L	S	O	L	NN/I?	L	NP	L	NK	L	None		None		F	L	0.9
Mung (local Aranya)	Apr-Jul	G	L	Mo	M	G	L	S	O	L	NN/NI	L	NP	L	NK	L	None		None		F	L	0.4
DSR (IR36)	Jun	G	M	Mo	L	G	L	NS	O	L	N_{80}	L	NP	L	NK	L	None		None		F	L	4
TPR (IR36)	Oct-Dec	VG	L	Mo	L	G	L	NS	O	L	N_{80}	L	NP	L	NK	L	None		None		F	L	4
																					W	L	
																					W	L	
TPR (IR42 or RD19)	Sep-Jan	G	L	Mo	L	G	L	NS/S	O	L	N_{80}	L	NP	L	N	L	None		None		M	M	4
																					F	L	
Mung (CES 1D-21)	Dec-Feb	F-G	M	Mo	M	G	L	S	O	L	NN/I?	L	NP	L	NK	L	None		None		None		0.8
Mung (local)	Dec-Mar	F-G	M	Mo	M	VG	L	S	O	L	NN/NI	L	NP	L	NK	L	None		None		None		0.3
Cowpea (Vita 3 or All Season)	Apr-Jul	G	L	Mo	M	G	L	S	O	L	NN/I?	L	NP	1	NK	L	None		None		F	L	1.0
Cowpea (Vita 3 or All Season)	Dec-Mar	G-G	M	Mo	M	VG	L	S	O	L	NN/I?	L	NP	L	NK	L	None		None		None		0.9
TPR (local)	Jul-Jan	VG	L	Mo	L-M	G	L	S	O	L	NN	L	NP	L	NK	L	None		None		W	L	2.0

[a]VG = very good, G = good, F = fair, L = low, M = medium, Mo = moderate, S = sensitive, NS = insensitive; O = optima. [b]NN = no nitrogen needed, I = inoculant, NI no inoculant, N and a number = kg of nitrogen fertilizer/ha. [c]NP = no phosphorus needed. [d]NK = no potassium needed. [e]W = wind, F = flood.

Table 2. Approximate costs and returns of cropping patterns to be tested in Solana, Cagayan, Philippines, 1980-81.

Stratum	Crop[a]	Expected yield (t/ha)	Expected value ($/ha)	Cost ($/ha)		Returns ($/ha)
				Total material	Total labor	
1	Mungbean	0 9	540 00	66 00	150 00	324.00
	IR42 or IR36	4.0	613 30	102.00	158 65	352 65
	Mungbean	0.8	480 00	66 00	118.00	296 00
	Pattern: MG — TPR — MG		1633 30	234 00	426.65	972 65
2	IR36	4 0	613.30	133 30	162 90	317 05
	IR42	4 0	613 30	102.00	158 65	352.65
	Mungbean	0 8	480.00	66 00	118 00	296.00
	Pattern: DSR — TPR — MG		1706 65	301 30	439.60	965 70
	IR36	4 0	613.30	102.00	158 65	352.65
	IR42 or RD19	4.0	613 30	96.65	170.25	346.40
	Mungbean	0.8	480.00	66.00	118 00	296.00
	Pattern: TPR1 — TPR2 — MG		1706 65	264.65	446 90	995.05
3	IR36, IR42, IR52	4 0	613 30	96 65	170 25	346 40
	IR42 or RD19	4.0	613.30	96.65	170 25	346.40
	Mungbean	0 8	480.00	76.00	119 30	271 30
	Pattern: TPR1 — TPR2 — MG		1706.65	269 30	459 85	977.45

[a]MG = mungbean, TPR = transplanted rice, DSR = dry-seeded rice.

gence tolerance was indicated for this main rice crop. Also indicated was a photoperiod-sensitive variety that would flower in late November or early December and be ready for harvest in early January.

Table 2 presents estimated costs and returns of the patterns. For stratum 1, costs and returns were computed on the basis of the inputs specified for each crop in Table 3 and the expected yields listed in Table 1. An initial farm management survey, conducted to provide information for the design phase, indicated that cash inputs were kept at a low but efficient level for the new patterns.

The traditional cropping patterns in the three strata involve one crop of TPR between July and October and generally a mungbean crop planted in mid-April.

Cropping patterns designed for the three strata are presented in Figure 1. In stratum 1 two patterns that differed only in rice varieties were specified. The four patterns designed for stratum 2 differed only in the method of establishing the first rice crop and an attempted mungbean crop following the second rice crop. In stratum 3, only one new pattern appeared to be sensible. Following discussion of the designed patterns with farmer-cooperators, the distribution of designed patterns by stratum was as given in Table 4.

Tests of rice varieties for rainfed, flood-prone lands. Because the Solana research site is on the terraces of the Cagayan River, seasonal floods occur, especially during October and November. Between 1 October and 30 November, severe rainy periods with about 5-year return periods occur (see Fig. 7 Environmental Description section) and flood lower landscape positions. Strata 2 and 3 will have flood in most years; flooding in stratum 1 will occur only in extreme cases. The performance of modern rice varieties under different water regimes in actual field conditions was studied.

Varieties used were RD19, RD17, IR42, IR36, IR52, and UPL Ri-5. All except RD19 are photoperiod insensitive. Seedbeds were sown in early August. Five of seven experiments originally planned were planted: two in stratum 2 and three in stratum 3. Fields in the first stratum were not planted because soil moisture before severe flooding was insufficient for puddling. Three experiments (two in stratum 2 and one in stratum 3) were totally destroyed by flooding from 29 October to 10 November. Those fields were transplanted between 12 and 22 September with 40- to 51-day-old seedlings, which were apparently not well established when flooding occurred.

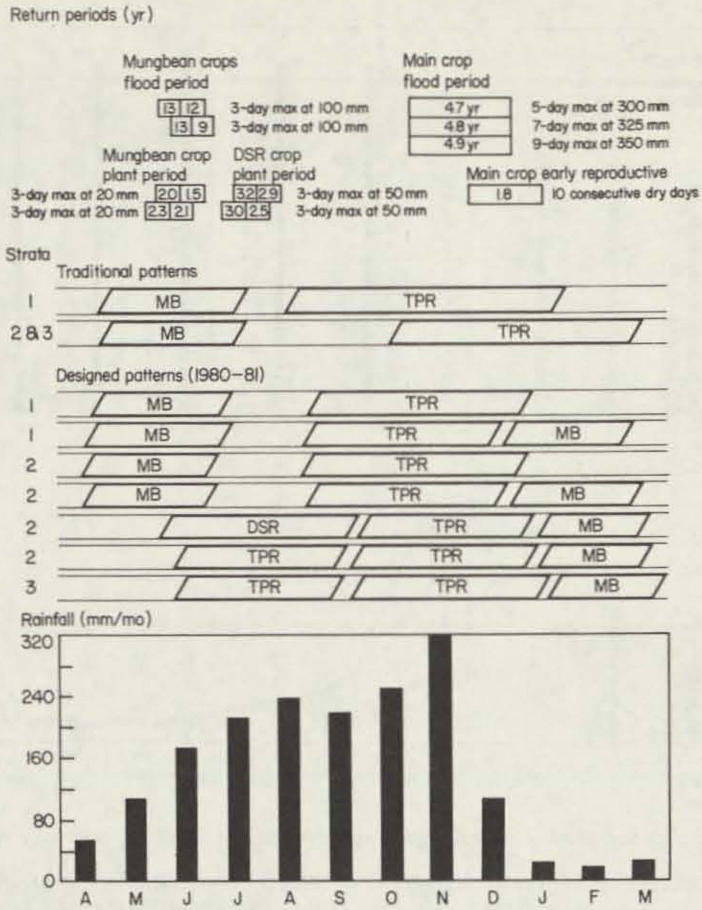
Postflood ratings show severe damage or total failure on all sites except two (Table 5). The surviving varieties in sites 5 and 6 were RD19, RD17, C171-136, and IR52. IR36 and IR42 were at post-heading stages during the flood period and all productive tillers were ruined. Figure 2 shows the heights of six varieties with respect to water depths over time in two experiments. When severe flood-

Table 3. Component technology summaries and estimated costs of inputs for cropping patterns to be tested in stratum 1, Solana, Cagayan, Philippines, crop year 1980-81.

	Crop	Variety	Tillage operation level	Labor cost ($)	Seeding			Insect control		
					Rate	Material cost ($)	Labor cost ($)	Method	Material cost ($)	Labor cost ($)
Pattern 1: UC — TPR — UC2										
C1	Mungbean	CES ID-21	Full	20.00 (60 h)	25 kg, drilled in rows, 25 cm	20.00	$10.00	Monocroto- phos 202 R (0.25) at 2 and 12 DE[a]	36 00	$6.30 (30 h)
C2	TPR	IR36	Conven- tional	23.30 (100 h)	50 kg (25 × 25 cm)	10.00	$30.00 (150 h)	(Economic threshold)	33.30	3.30 (15 h)
C3	Mungbean	CES ID-21	Zero	None	25 kg, furrow or drill		(Other factors similar to C1 of pattern 1)			
Pattern 2: UC1 — TPR — UC2										
C1 and C3	Mungbean	CES ID-21	(other factors similar to C1 and C3 of pattern 1, respectively)							
C2	TPR	IR42	Conven- tional (old seed- lings)	(other factors similar to C2 of pattern 1)						

	Crop	Variety	Tillage operation level	Labor cost ($)	Weed control			Disease control			Fertilizer		Harvesting
					Method	Material cost ($)	Labor cost ($)	Method	Material cost ($)	Labor cost ($)	Material cost ($)	Labor cost ($)	
Pattern 1: UC — TPR — UC2													
C1	Mungbean	CES ID-21	Full	20.00 (60 h)	Interrow cultiva- tion or spot weeding	None	3.30 (10 h)	62 5 g Maneb/ 25 kg seeds Benomyl (0 125 kg a.i.)	10 00	2.00 (8 h)	None	None	1/5 share
C2	TPR	IR36	Conven- tional	23.30 (100 h)	2,4-D (0 5) or spot weeding	5 30	2 00 (8 h) 13.30 (80 h)	None	None	None	80 kg N 1/2 basal 1/2 40 DT[b] ($53.30)	1 30 (6 h)	1/7 share
C3	Mungbean	CES ID-21	Zero	None									
Pattern 2: UC1 — TPR — UC2													
C1 and C3	Mungbean	CES ID-21	(other factors similar to C1 and C3 of pattern 1, respectively)										
C2	TPR	IR42	Conven- tional (old seed- lings)	(other factors similar to C2 of pattern 1)									

[a]Days after emergence [b]Days after transplanting



1. Proposed cropping pattern designs for 1980-81, Solana, Cagayan, Philippines. MB = mungbean, TPR = transplanted rice, DSR = dry-seeded rice.

ing occurred, the early transplanted varieties (7 Sep) were obviously taller than the late-transplanted varieties (22 Sep). The taller plants survived severe flooding.

The average yields from plots 5 and 6 are given in Table 6. Varieties C171-136, RD17, RD19, and IR52 produced significantly higher yields than IR42 and IR36. The higher yielding varieties were taller and produced more productive tillers and

Table 4. Distribution of designed cropping patterns by stratum, Solana, Cagayan, Philippines, crop year 1980-81.

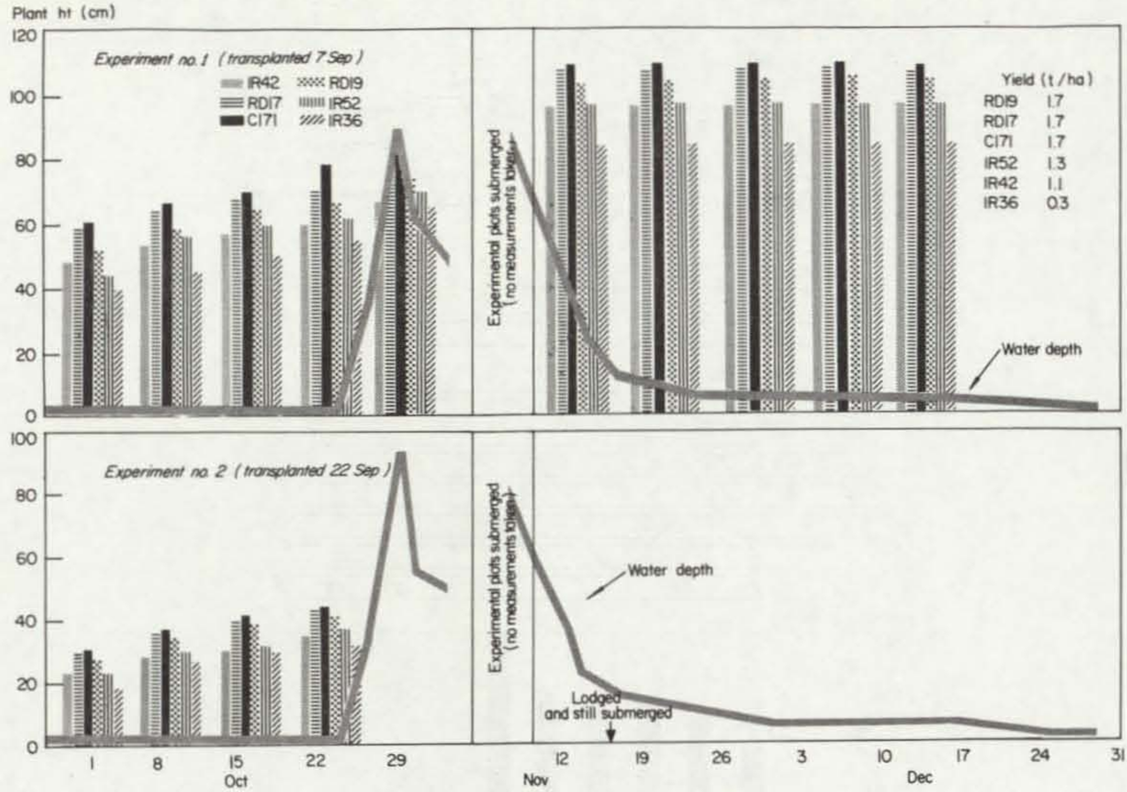
Cropping pattern[a]	Cropping patterns (no.)			
	Stratum 1	Stratum 2	Stratum 3	Total
MB — TPR	6	6	8	20
MB — TPR — MB	11	—	—	11
DSR — TPR — MB	—	5	—	5
TPR — TPR — MB	—	5	9	14
Total	17	16	17	50

[a]MB = mungbean, TPR = transplanted rice, DSR = dry-seeded rice.

Table 5. Flood damage ratings on transplanted rice under different water regimes after 2 typhoons, Solana, Cagayan, Philippines, 1980.[a]

Variety	5 November					17 November				
	Stratum 2		Stratum 3			Stratum 2		Stratum 3		
	3	4	5	6	7	3	4	5	6	7
RD19	S	S	1	1	1	4	4	2	2	3
RD17	S	S	1	1	1	4	4	2	2	3
C171-136	S	S	1	1	1	4	4	2	2	4
IR52	S	S	2	2	1	4	4	3	3	4
IR42	S	S	2	3	S	4	4	3	3	4
IR36	S	S	3	3	S	4	4	4	4	4

[a]Flood damage rating code used: S = still submerged or lodged at the time of rating, 1 = slight damage to none, 2 = moderate, 3 = severe, 4 = total failure. [b]Figures under each stratum refer to site numbers within the stratum.



2. Height of 6 rice varieties after transplanting of seedlings of 2 ages, Solana, Cagayan, Philippines, crop year 1980-81.

total dry matter. In another experiment at two sites in stratum 3 during the same period, RD17, C171-136, RD19, and an IRRI line (IR4432-52-6-4) also survived the flooding and outyielded 3 local varieties — Wagwag-aga, Wagwag tawataw, and Wagwag Java. IR4432-52-6-4, RD17, and RD19 yielded between 1.6 and 1.7 t/ha, Wagwag tawataw and Wagwag Java yielded 1.4 t/ha each, and Wagwag-aga yielded 0.5 t/ha. IR42 yielded 1.2 t/ha.

INSECT CONTROL RECOMMENDATION FOR DRY-SEEDED BUNDED RICE IN SOLANA

Cropping Systems Component of the Entomology Department

Dry seeding of rice is an introduced method of crop establishment in Solana. Insect control recommendations based on results from cropping systems research in Iloilo and Pangasinan province were tested by the growth stage partitioned yield

Table 6. Yield performance of transplanted rice cultivars under different water regimes. Solana, Cagayan, Philippines, 1980 wet season.[a]

Yield rank	Cultivar	Yield (t/ha)	Total dry matter (t/ha)	Plant ht (cm)	Productive tillers (no.)
1	C171-136	1.75 a	2.45 a	117 a	12 ab
2	RD17	1.71 a	2.62 a	117 a	12 ab
3	RD19	1.69 a	2.80 a	114 b	12 ab
4	IR52	1.34 a	1.71 b	101 bc	13 a
5	IR42	1.12 b	1.42 b	98 c	11 b
6	IR36	0.30 c	1.31 c	85 d	6 b
Av		1.32	1.89	105	11
	CV (%)	19	19	1.5	8

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

Table 7. Development of a chemical insect control recommendation for rainfed dry-seeded bunded IR36 rice, using the growth stage partitioned yield loss method. Solana, Cagayan, Philippines, Jun-Nov 1980.[a]

Treatment	Plant stand 34 DE[b] (no. plants/m row)	Tillers 60 DE[b] (no /m row)	Yield[c] (t/ha)
Complete protection[d]	45 abc	208 ab	1 33 a
Omit seed or seedling protection	31 c	129 c	0.75 bc
Omit vegetative protection	63 a	190 abc	1 04 ab
Omit reproductive protection	47 abc	225 a	1 37 a
Omit ripening protection	54 ab	187 abc	1 34 a
Untreated	36 bc	141 bc	0 34 c
Recommended practice; economic thresholds[e]	34 bc	137 c	0.57 c
1.5 kg a.i carbofuran/ha in seed furrow plus vegetative, reproductive, ripening protection	54 ab	186 abc	1 29 a

[a]Av of 5 replications (fields). DE = days after crop emergence Separation of means in a column by Duncan's multiple range test ($P = 0.05$) [b]5-m row sample area [c]20-m² sample area [d]Seed or seedling protection: 4 g a i bendiocarb/kg seed (seed treatment), vegetative protection: 1 kg a.i. monocrotophos (Nuvacron 200 SCW 30%)/ha 25, 35, 45 DE; reproductive protection: 1 kg a i. Brodan EC (11.5% BPMC + 20% chlorpyrifos)/ha 55, 65, 75 DE; ripening protection. 1 kg a i γ-BHC (Agrocide 20 EC)/ha spray 87 DE. [e]No insect surpassed the economic threshold in any field

loss method. Granular carbofuran was tested at a high dosage (1 kg a.i./ha) to determine if it would stimulate rice yields in Solana.

Two typhoons occurring before harvest greatly reduced yields but significant losses to insects occurred during the seed or seedling stage (Table 7). Damage by an ant *Solenopsis geminata,* which removed rice seeds before seedling emergence, was suspected. Ants were prevalent along the bunds and during flooding ant colonies with eggs were seen floating on the water in large balls.

Seed treatment with bendiocarb was more effective than carbofuran in controlling ants.

CHEMICAL INSECT CONTROL RECOMMENDATIONS FOR ILOILO

Cropping Systems Component of the Entomology Department

Chemical insect control practices were tested in cropping pattern trials conducted in farmers' fields in Iloilo province in 1976-79. Each year a specific chemical insect control practice was designed for each crop in the cropping patterns being tested. A procedure for designing recommendations was developed from tests in Iloilo and Pangasinan (Annual report for 1978).

Economic evaluation of the recommended practices for the Iloilo cropping patterns — DSR and wet-seeded rice (WSR) as first crops, TPR as second crop and cowpea as last crop — was done in 1980.

The criteria for judging the merit of an insect control practice were insecticide application cost, net returns above total variable costs, and benefit-cost ratio from insecticide use. The calculation of net returns was based on the prevailing socio-economic conditions at the Iloilo site. Yield loss during harvesting and threshing was estimated to be 5%. It is a common practice for harvesters to receive 1/6 (17%) of the crop. Most Iloilo farmers are share-tenants and the common practice is for the tenant to pay the owner 33% of his harvest share. Therefore 47% (the product of sequentially deducting 5%, 17%, and 33%) was deducted from the yields to cover those costs. Total material costs including insecticides and preharvest labor were then subtracted. Interest on material costs was also deducted —12% on rice and 9% on cowpea (estimated to be the true cost of borrowed capital at 3%/month).

The benefit-cost ratio calculated for insecticide usage was based on chemical cost and labor for application.

Dry-seeded rice. The early planting of DSR, timed with the start of the rainy season, produced an effective cultural control of insect pests. The only potential threat to the crop was white stem borer. Light trap collection, however, showed that with resumption of the rainy season, the stem borer flights were low, indicating a high mortality over the dry season. There were only isolated cases when populations of other potential insect pests — leaffolder and rice bug — reached economic injury levels.

The yield responses to insecticide recorded in

Table 8. Economic evaluation of chemical insect control practices for dry-seeded bunded wetland rice [a] Oton, Iloilo, Philippines, 1977-79.

Insecticide: Treatment	Insecticide: Cost[b] ($/ha)	Yield (t/ha)	Net returns above TVC[c] ($/ha)	Benefit: cost from insecticides[d]
1977[e]				
1 kg a.i carbofuran G/ha basal (recommended practice)[f]	35	5.51 a	209 a	7 89 a
Complete control	162[g]	5 35 ab	69 b	1.51 a
0.5 kg a.i. carbofuran G/ha basal	18	4 34 bc	133 ab	4.32 a
Untreated	0	3.88 c	114 b	—
1978[h]				
0.5 kg a.i. carbofuran G/ha basal (recommended practice)	18	4.75 a	166 a	7.09 a
Complete control[i]	71	4.96 a	129 a	2.27 a
1 kg a.i. carbofuran G/ha basal	35	5.02 a	170 a	4.98 a
Untreated	0	3 99 b	124 a	—
1979[j]				
0.5 kg a i carbofuran G/ha basal (recommended practice)	18	3 99 a	105 a	−0.03
Complete control[k]	328	3 96 a	−207 b	−0.03
Untreated	0	4 03 a	127 a	—

[a]Within years, separation of means in a column by Duncan's multiple range test ($P = 0.05$). All costs based on 1978 prices: $0.15/kg rice, $0.14/man-h. [b]Chemical cost, 12% interest, labor for application [c]TVC = total variable cost, including total material costs (12% interest), preharvest labor costs, 5% harvest loss, 1/6 harvesters' share, 33% landlords' share. [d]Chemical cost and labor application. [e]Av of 4 replications (fields). [f]1.5 kg a.i. carbofuran G/ha basal in seed furrow, 0.75 kg a i. monocrotophos EC at 30, 45, 60, 70 DE (days after emergence). [g]2 kg a.i carbofuran G/ha soil incorporated (SI) before last harrowing; 0.75 kg a.i. monocrotophos EC/ha 35, 55, 65 DE (days after emergence). [h]Av of 6 replications (fields). [i]0 5 kg a i carbofuran G/ha basal in seed furrow; 0.75 kg a i endosulfan EC/ha at 45, 55 DE; 0.75 kg a i carbaryl WP/ha at 70, 80 DE. [j]Av of 5 replications (fields). [k]1 kg a.i monocrotophos EC/ha at 5, 15, 25, 35, 45, 55, 65 DE; 1 kg a i. γ-BHC EC/ha at 75, 82, 89 DE.

1977 and 1978 (Table 8) were less a result of insect control than of direct plant growth stimulation by carbofuran (Annual report for 1979). No significant yield increases were recorded from additional foliar applications of insecticide (complete control). From the evidence over the 3-year testing period the recommendation for DSR is economic thresholds (Table 9).

First crop, wet-seeded rice. WSR as a first crop in a two-rice cropping pattern is designed to be planted in June, one month after DSR. Because of erratic rainfall in some years, WSR was planted later — July in 1978 and August in 1979. Insect pest populations were more abundant in the later plantings — caseworm *Nymphula depunctalis,* white stem borer, leaffolder, and rice bug.

Insect pest populations were, however, generally low during 1976-79. In 1976 and 1979 there was no yield response from insecticide used (Table 10).

No practice produced significant net returns above the untreated control in any year. Carbofuran soil incorporation produced significant yield increases over the untreated control in 1977 and 1978, but not in the other years. Use of economic thresholds is the recommendation for WSR.

Second crop, transplanted rice. A high degree of risk from drought is associated with second crop TPR. Yields were ganerally lower than for DSR or WSR. In 1979 it was not possible to establish the crop and in 1977 drought seriously reduced yields, making all net returns from insect control practices negative (Table 11).

An analysis of the results of the 3 years of testing does not support any one insect control practice. Second crop TPR was much more responsive to insecticides than other rice crops. Yield responses were due to insect control and to plant growth stimulation by carbofuran. In 1978 carbofuran soil incorporation at transplanting gave a yield of 2.89 t/ha, which was a significant increase from the untreated (2.34 t/ha) but was far below the yield potential from insecticide use. The spectacular yield of the complete control (4.66 t/ha) included the influence of insect control but in the light of greenhouse studies, it was suspected that the combination of carbofuran treatments in the seedbed and at transplanting were responsible for much of the yield increase. Because of drought in 1979 the relative importance of each of the applications at the site was not tested.

Insect pests — caseworm, white stem borer, leaffolder, and rice bug — occurred at much higher populations on second crop TPR than on first crop rice. However, insect species varied greatly from

Table 9. Insect pest economic thresholds recommended for insecticide usage in rice. Iloilo, Philippines, 1980.

Insect pest	Threshold[a]
Vegetative stage	
Caseworm *Nymphula depunctalis*	Seedbed: >25% leaves cut Field: >15% leaves cut
Other defoliators (armyworm *Mythimna separata*, cutworm *Spodoptera litura*, greenhorned caterpillar *Melanitis leda*, skipper *Pelopidas mathias*)	Seedbed. >50% defoliation Field: >25% defoliation
Whorl maggot *Hydrellia sasakii*	Field: 10-14 DT >10% damaged leaves
White stem borer *Scirpophaga innotata*	Field: >15% deadhearts
Vegetative stage	
Leaffolder *Cnaphalocrocis medinalis*	Field: >15-20% damaged leaves
Brown planthopper *Nilaparvata lugens*	Field: >2/tiller
Reproductive stage	
Stem borer	>5% deadhearts
Leaffolder	>10% damaged flag leaves
Defoliators	>15% defoliation
Brown planthopper	>1/tiller
Ripening stage	
Rice bug *Leptocorisa* spp.	$>8/m^2$

[a]DT = days after transplanting.

Table 10. Economic evaluation of chemical insect control practices for first crop wet-seeded rainfed rice[a] Oton, Iloilo, Philippines, 1976-79

Insecticide: Treatment	Insecticide: Cost[b] ($/ha)	Yield (t/ha)	Net returns above TVC[c] ($/ha)	Benefit: cost from insecticides[d]
		1976[e]		
Complete control[f] (recommended practice)	152	5.07 a	119 b	−0.06 a
Economic threshold[g]	28	4.75 a	218 a	−2 24 a
Untreated	—	5 12 a	275 a	—
		1977[e]		
Economic threshold[h] (recommended practice)	17	4 78 ab	205 a	2 63 a
Complete control[i]	162	5 15 ab	90 b	2.38 a
1.5 kg a.i carbofuran G/ha SI	52	5 31 a	212 a	0 65 a
Untreated	—	4 52 b	200 a	—
		1978[j]		
Economic threshold[k] (recommended practice)	26	4 19 bc	146 a	3.88 a
Complete control[l]	76	5.01 a	161 a	3.17 a
1 kg a i carbofuran G/ha SI	25	4 52 ab	162 a	4.58 a
Untreated	—	3.57 c	123 a	—
		1979[m]		
Economic threshold[n] (recommended practice)	9	2 68 a	44 a	8 67 a
Complete control[o]	328	2 85 a	−262 b	0.35 a
1 kg a.i. carbofuran G/ha SI	35	2.61 a	4 a	2 22 a
Untreated	—	2.16 a	10 a	—

[a]Within years, separation of means in a column by Duncan's multiple range test at the 5% level. All costs based on 1978 prices: $0 15/kg rice, $0 14/man-h [b]Chemical cost, 12% interest, labor for application. [c]TVC = total variable cost, including total material costs (12% interest), preharvest labor costs, 5% harvest loss, 1/6 harvesters' share, 33% landlords' share. [d]Chemical cost and labor for application. [e]Av of 6 replications (fields). [f]2 kg a.i. carbofuran G/ha soil incorporated (SI) before last harrowing, 0.75 kg a.i. monocrotophos EC/ha 35, 55, 65 DE (days after emergence). [g]0.75 kg a i. monocrotophos EC/ha 72 DE. [h]0.75 kg a.i. endosulfan EC/ha 40 DE [i]1 5 kg a.i carbofuran G/ha SI; 0 75 kg a i. monocrotophos EC/ha 35, 45, 65 DE. [j]Av of 5 replications (fields) [k]0 75 kg a.i. endosulfan EC/ha 25 DE; 0.75 kg carbaryl WP/ha 65 DE. [l]1 kg a.i. carbofuran G/ha SI; 0.75 kg a.i. endosulfan EC/ha 45 DE; 0.75 kg a i. carbaryl WP/ha 55, 65, 75 DE. [m]Av of 4 replications (fields). [n]0.75 kg a.i. carbaryl WP/ha 30 DE. [o]1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35, 45, 55, 65 DE; 1 kg a i — BHC EC/ha 75, 82, 89 DE.

Table 11. Economic evaluation of chemical insect control practices for second crop transplanted rainfed rice.[a] Oton, Iloilo, Philippines, 1976-78.

Insecticide: Treatment	Insecticide: Cost[b] ($/ha)	Yield (t/ha)	Net returns above TVC[c] ($/ha)	Benefit: cost from insecticides[d]
		1976[e]		
Complete control[f] (recommended practice)	179	5.17 a	67 b	1.22 a
Economic threshold[g]	17	4.41 b	169 a	5 52 a
Untreated	—	3.86 b	142 a	—
		1977[h]		
1.5 kg a.i. carbofuran G/ha SI (recommended practice)	52	1.76 ab	−98 b	0.39
Complete control[i]	103	1.79 a	−127 c	0 72
Untreated	—	1.40 b	−56 a	—
		1978[j]		
1 kg a.i. carbofuran G/ha SI	35	2 89 b	39 b	2.66[k]
Complete control[l]	96	4 66 a	120 a	4 05
Untreated	—	2.34 c	32 b	—

[a]Within years, separation of means in a column by Duncan's multiple range test at the 5% level All costs based on 1978 prices: $0 15/kg rice, $0 14/man-h [b]Chemical cost, 12% interest, labor for application [c]TVC = total variable cost, including total material costs (12% interest), preharvest labor costs, 5% harvest loss, 1/6 harvesters' share, 33% landlords' share [d]Chemical cost and labor for application. [e]Av of 6 replications (fields). [f]2 kg a.i. carbofuran G/ha soil incorporated (SI) before last harrowing; 0.75 kg a.i monocrotophos EC/ha 30, 40, 50, 60 DT (days after transplanting). [g]0.75 kg a i endosulfan EC/ha 65 DT. [h]Av of 4 replications (fields) [i]1.5 kg a.i carbofuran G/ha SI; 0.75 kg a.i endosulfan EC/ha 40, 60, 70 DT. [j]Av of 5 replications (fields). [k]Insufficient error degrees of freedom for statistical test of significance. [l]1 kg a i carbofuran G/ha SI in seedbed and before transplanting; 0.75 kg a.i. endosulfan EC/ha 35, 45 DT; 1 kg a.i. carbaryl WP/ha 60, 70 DT.

year to year and from field to field. Economic injury levels were surpassed each year, but not on the same growth stages of the crop.

The analysis of the trials indicates economic thresholds as the recommendation for second crop TPR.

Cowpea. Low yields and consistent negative net returns from cowpea for 1976-79 illustrate the effects of the sudden onset of the dry season in Iloilo in November-December. Yields increased over the years as a result of use of reduced tillage to establish cowpea after rice harvest.

The 1976-79 trials showed that significant cowpea yield losses occurred at the preflowering and postflowering stages in roughly equal proportions. Beanfly (*Ophiomyia phaseoli*), thrips (*Thrips palmi*), leafhopper (*Amrasca biguttula*), and flea beetle (*Medythia suturalis*) were the key preflowering insect pests. Bean pod borer (*Maruca testulalis*) and aphid (*Aphis craccivora*) were the principal postflowering pests.

Two applications of monocrotophos 2 and 12 days after crop emergence (DE) at low dosages (0.25 kg a.i./ha) gave optimal preflowering protection. The suboptimal yields in the 1979 trials (Table 12) were believed due to failure of the postflowering chemical control practice with carbaryl, which was not highly effective against the bean pod borer. Therefore the recommendation was 0.75 kg a.i. endosulfan/ha at 30 and 40 DE as postflowering protection.

These 1976-79 trials illustrate that economically acceptable insect control recommendations cannot be developed from existing technology without undergoing field trials at a site. The fact that the insect control technology emanating from research stations was not *ready to go* was demonstrated by the difficulty encountered in determining economically optimal recommendations for farmers.

Table 12. Economic evaluation of chemical insect control practices for cowpea after rainfed wetland rice.[a] Oton, Iloilo, Philippines, 1976-79.

Insecticide: Treatment	Insecticide: Cost[b] ($/ha)	Yield (t/ha)	Net returns above TVC[c] ($/ha)	Benefit· cost from insecticides[d]
		1976[e]		
0.75 kg a.i. monocrotophos EC/ha 5, 15, 35 DE (recommended practice)	81	0.02 b	−193 b	0 11[f]
Complete control[g]	134	0 13 a	−225 a	0.39
Untreated	—	0.02 b	−117 c	—
		1977[h]		
0.25 kg a i endosulfan EC/ha 15 DE (recommended practice)	7	0.38 b	−45 a	3.19 a
Complete control[i]	66	0.54 a	−71 b	1.56 a
Untreated	—	0 29 c	−56 ab	—
		1978[j]		
0.25 kg a.i. monocrotophos EC/ha 2, 12 DE; 0.75 kg a.i. carbaryl WP/ha 35 DE (recommended practice)	30	0 30 a	−84 a	3.05[f]
Complete control[k]	254	0.42 a	−314 b	0.51
Untreated	—	0.07 b	−100 a	—
		1979[l]		
0 25 kg a.i. monocrotophos EC/ha 2, 12 DE, 0.75 kg a i carbaryl WP/ha 25, 35 DE (recommended practice)	40	0 49 b	−55 a	3 64 a
Complete control[m]	218	0 67 a	−197 c	1.01 b
Untreated	—	0.14 c	−87 b	—

[a]Within years, separation of means in a column by Duncan's multiple range test at the 5% level. All costs based on 1979 prices: $0 30/kg seed, $0.14/man-h. [b]Chemical cost, 9% interest, labor for application [c]TVC = total variable costs, including total material costs (9% interest), preharvest labor costs, 5% harvest loss, 1/6 harvesters' share, 33% landlords' share. [d]Chemical cost and labor for application. [e]Av of 5 replications (fields). [f]Insufficient error degrees of freedom for statistical test of significance [g]0.75 kg a i monocrotophos EC/ha 5, 15, 25, 35, 50 days after emergence (DE). [h]Av of 12 replications (fields). [i]0.5 kg a i endosulfan EC/ha 1, 5 DE; 1 kg a i endosulfan EC/ha 30, 40 DE [j]Av of 4 replications (fields) [k]2% wt/wt carbofuran seed treatment; 0.05 kg a i. decamethrin EC/ha 25, 35, 45 DE [l]Av of 16 replications (fields). [m]0 5 kg a i monocrotophos EC/ha 2, 9, 16 DE; 0 03 kg a i decamethrin EC/ha 25, 35, 45 DE.

Cropping systems program

Testing of cropping patterns

Rice Production Training and Research Department and Cropping Systems Component of the Agricultural Economics Department

Rice Production Training and Research Department

Tests of the continuous rice production model and the *sorjan* cropping system continued in 1980.

Continuous rice production model. The continuous rice production model maintained a yield of 20.1 t/ha. Yields in the previous 3 years ranged from 20.3 to 23.6 t/ha per year. Figure 1 gives weekly yields for 1977-80.

Tests of various plot sizes (Annual reports for 1977, 1978, 1979) have indicated that the system is adapted to year-round irrigation. An 800-m^2 plot in a 1-ha farm was found to be the minimum economical size.

The variability of the 1980 production from the rice garden was influenced more by solar radiation than by other factors as in previous years (Fig. 2). Typhoon damage occurred but the loss was reduced because rice in each plot was at a different growth stage. There was no obvious insect buildup or conspicuous rat damage at IRRI in 1980. Severe rat damage in October-December was reported in a farmer's test of the model when there was no other crop in the surrounding fields. Yields reported from farmers' tests in the Philippines were as good as or better than at IRRI (Table 1).

Table 1. Yields from continuous rice production models in fully irrigated Filipino farmers' fields, 1979-80.

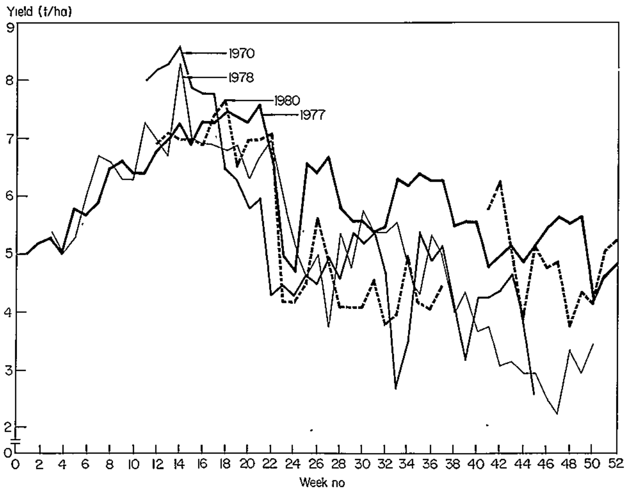
Site	Area planted (ha)	Yield (t/ha per year)	Time in operation (mo)
Batangas	1	33.1	24
Bicol	9 5	18 1	24
Bukidnon	365[a]	18.0	48
IRRI	1	20.1	48

[a]Three crops per year only

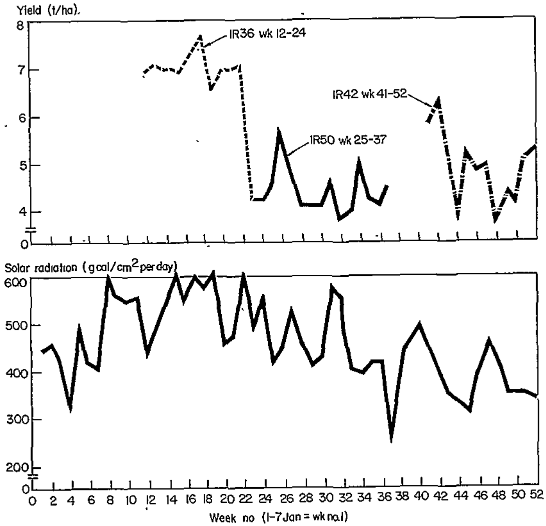
The weekly net income from the IRRI model was \$65.30. A Batangas farmer obtained a weekly net income of \$69.10. Both models had 800-m^2 plots and a 1-ha farm. Production costs are given in Table 2.

Sorjan. The *sorjan* cropping system was tested in rainfed and irrigated (heavy clay soils) fields in 1980. In rainfed plots at IRRI soybean gave the highest net return (\$1,845/ha), followed by mungbean and maize (Table 3). Sorghum's negative returns were due to low yield.

On *sorjan* beds the yield of soybean following maize was low, but yield of maize following soybean was high. This indicates soybean enrichment



1. Weekly yield for 1977-80 in a continuous rice production model. IRRI.



2. Weekly yield of IR36, IR50, and IR42 and average weekly solar radiation in the continuous rice production model. IRRI, 1980.

of the soil. Soybean following soybean did not show an allelopathic effect, but yields of mungbean following mungbean did (Table 4).

In irrigated wetland plots, the *sorjan* system produced 3 crops in sequence in 1980. Raising the beds of *sorjan* eliminated flooding of the bed soil even during typhoons. Granulated soil conditions developed on the raised beds and production of moderately high yields of dryland crops resulted. Average single harvest yields are in Table 5. Yield of each single harvest of rice in the sinks averaged 6.1 t/ha.

Testing of the *sorjan* system in farmers' fields continued. Irregular rains and typhoons resulted in combinations of lack and excess of water and low yields of dryland crops at several sites but moderately high yields of wetland rice (Table 6).

Table 2. Cost of production (labor and materials) per 800-m² plot at IRRI and on a Batangas farm, 1980.

Activity	Time (h)		Cost ($) Labor		Cost ($) Materials		Total cost ($)	
	IRRI	Batangas	IRRI	Batangas	IRRI	Batangas	IRRI	Batangas
Land preparation	6 79	9.00	9.12	2 40			9 12	2 40
Seed and seedbed	6.98	0.70	1.40	1.05	0.71	1.26	2 11	1.40
Planting	12.55	8 00	2.51	1.60			2.51	1.60
Fertilizing	0.71	3.00	0 14	0.60	6 07	15 22	6.21	15 82
Weed control	0 30	10.00	0.06	2.00	0 36		0.42	2 00
Insect control	0 79	2 00	0 16	0 40	2.95	2 82	3 11	3 22
Irrigation	4 49	4 48	0.89	0.89	3 51	3.51	4.40	4.40
Harvesting	27.50	60.00	5.50	12.00			5.50	12.00
Total	60 70	97.18	19.79	20.10	13 61	22.81	33 40	42.91

Table 3. Cost and returns for first-crop dryland crops on rainfed *sorjan* beds and sinks. IRRI, 1980.

Crop	Yield (t/ha)	Variable cost ($/ha)			Returns ($/ha)	
		Material	Labor[a]	Total	Gross	Net
Maize	2 88	207	115	322	576	254
Soybean	2.30	225	64	289	2146	1845
Mungbean	0.98	182	344	526	1372	846
Sorghum	1.05	148	104	252	168	−84
Rice	1 95	261	192	453	388	−65
Rice (sinks)	2 17	286	212	498	434	−64

[a]Includes the cost of construction of *sorjan* beds.

CROPPING SYSTEMS SIMULATION

Cropping Systems Component of the Agricultural Economics Department

Simulation was used to investigate and analyze the decision-making process and risk-taking of individual households. Through observation, introspection, and interview the following aspects of decision making were described and analyzed:

- What are the types of decision situations the farmer encounters?
- Under what kind of conditions do they develop?
- What are the choices open to a farmer in such a situation and what are the expected outcomes?
- What is the decision rule he applies?

Farmers were asked to elaborate their farm plans for the coming cropping season by indicating cropping patterns, expected input levels, and expected timing of operations (including the initial plow sequence). Discussions with farmers with respect to the feasibility and "riskiness" of cropping patterns revealed that farmers' plans are conditioned by the onset of the growing season and usually consist of several alternative cropping strategies. To understand their cropping pattern choice in relation to expected growing season duration, farmers were asked to evaluate the expected onset and termination of ponding water in their parcels (Fig. 3). To relate their crop choices and planned fertilizer levels to expected returns, farmers were asked to express their subjective probabilities of crop yield at given fertilizer levels (Fig. 4).

During the growing season, farm operations monitored on a day-to-day basis through a daily recording system were evaluated weekly. Farm operations were plotted on a cropping system chart indicating crop areas, and date and type of operation for all parcels. Unexpected deviations from the farm plan were discussed with farmers, and bi-

Table 4. Comparative yields of the first 2 crops in 8 rainfed cropping patterns in a *sorjan* system and a flatbed system at IRRI in 1980. The third or fourth crops will be harvested in 1981.

System	Pattern and crop yield (t/ha)		Total grain yield (t/ha) for 2 crops
	Rice — rice — cassava		
Sorjan bed	2.0	1.0	3 0
Flat bed	2.3	1.2	3.5
	Maize — soybean — maize — soybean		
Sorjan bed	3.4	1.6	5.0
Flat bed	1 8	1.2	3.0
	Mungbean — sorghum — mungbean — sorghum		
Sorjan bed	0.9	1.8	2.7
Flat bed	0 9	1.6	2.5
	Maize — soybean — cassava		
Sorjan bed	2.5	1.7	4.2
Flat bed	1.9	1.2	3.1
	Sorghum — mungbean — sorghum — mungbean		
Sorjan bed	1.6	0.6	2.2
Flat bed	2 5	0.2	2.7
	Soybean — maize — soybean — maize		
Sorjan bed	2.3	4 0	6.3
Flat bed	2.6	1.9	4.5
	Soybean — soybean — soybean — soybean		
Sorjan bed	2.0	1.3	3.3
Flat bed	2.6	1.2	3.8
	Mungbean — mungbean — mungbean — mungbean		
Sorjan bed	1 3	0.2	1.5
Flat bed	0.9	0.2	1.1

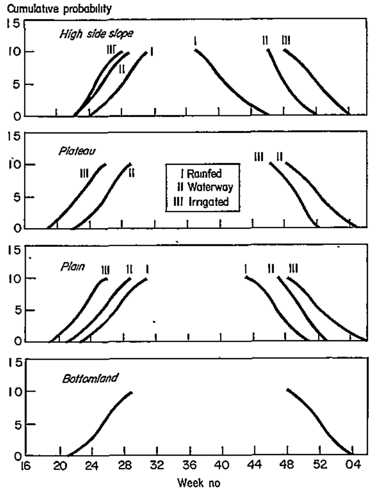
Table 5. Average single crop yields of dryland crops on *sorjan* beds and rice in sinks on irrigated heavy clay soils at IRRI, 1980.

Crop	Variety	Maturity (days)	Av yield (t/ha)
Soybean	Clark 63	90	2 2
Mungbean	CES 1D-21	68	0 9
Sorghum	Cosor 3	110	3 2
Cowpea	EG No 3	72	0.9
Rice	IR36	110	6 1

weekly yield expectations were used to keep in touch with the farmers' feelings with regard to the status of their crop (Fig. 5). Whenever necessary, short interviews were conducted concerning specific management tasks that occurred during the growing season — cut-off dates for planting crops, whether to consider a crop a failure, whether fertilizer was available, and whether it could be applied.

The result of one year of monitoring was a sequence of decision situations within cropping patterns and across crops. Their occurrence was related as much as possible to *context conditions* such as rainfall, soil moisture content, pest or weed infestation, labor or cash shortages, and low-high crop prices. When for each decision situation options, choice determinants, and actual choices were adequately described, actual choices were grouped in *option categories* and related to a common choice determinant from which, finally, a decision rule could be abstracted. Farmers' consensus regarding the preciseness of a rule was arrived at after farmers' evaluation of that rule.

An obvious limit to this approach is that the set of decision situations and rules are appropriate only in the context of the specific characteristics of the cropping year in which they were observed.



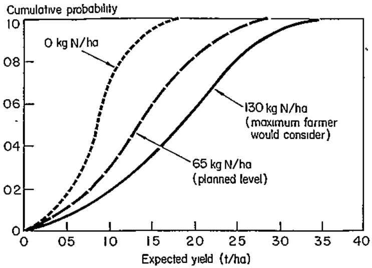
3. Farmers' cropping plans are based upon their expectations of water availability, expressed here as the probability of flooding by week of the year (1-7 January = week 1). IRRI, 1980.

Choice situations encountered in one year might not occur in other years and it would take a large number of years of observations to make a complete inventory. The same applies to the outcomes of choice — a good choice in one year might be disastrous in another. Simulation offers a solution here by incorporating the following major components:

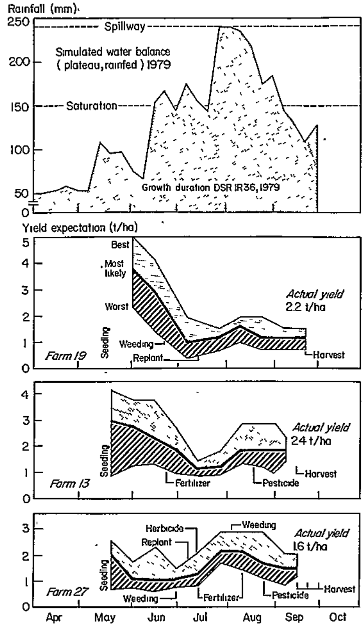
Table 6. Performance of dryland crops on raised beds and rice varieties in sinks when direct-seeded in dry soil on *sorjan* beds before the start of the rainy season, at 5 sites in the Philippines, 1980 wet season.

Site	Yield[a] (t/ha)								
	Dryland crop[b]				Wetland rice[c]				
	Rice (IR36)	Maize (UPCA Var. 1)	Soybean (Clark 63)	Mungbean (CES 1D-21)	IR36	IR50	IR38	IR52	IR54
Basista, Pangasinan	2 9 c	4.2 a	1.4 b	0.3 b	4 4 a	3.4 ab	3.0 b	3.1 b	3.1 b
Urdaneta, Pangasinan	4 6 a	0.0 c	1 8 b	0.3 b	4.8 a	5.0 a	4.5 a	4.5 a	4 2 a
Apalit, Pampanga	2.0 d	—	0.4 c	0.0 b	4 7 a	4.5 a	4.6 a	4.5 a	4.2 a
Banga, South Cotabato	3.5 b	3.6 a	2.8 a	1.9 a	3.5 ab	3.3 ab	2 9 b	3.9 ab	4.1 a
Kidapawan, North Cotabato	0.0 c	2.1 b	1.5 b	1.5 a	5 4 a	2 9 c	5.7 a	4 2 b	5.5 a

[a]Av of 3 replications [b]Separation of means in a column by Duncan's multiple range test at the 5% level. [c]Separation of means in a row by Duncan's multiple range test at the 5% level.



4. Farmers expressed their expectations of rice yield in relation to fertilizer application in a manner that permitted estimation of subjective probabilities of yield response. IRRI, 1980.



5. Farmers' expectations of yield from specific plots vary as the season progresses because of the effect of weather and pests on the crop. IRRI, 1980.

- A sequential crop establishment simulation model to test the technical feasibility of cropping patterns; that is, whether and when crops can be planted and in what area they can be established, given certain technical task performance requirements.
- A crop status simulation that relates sequential crop yield development to context conditions as drought, floods, weed and pest infestation; determines task performance requirements to control or respond to those conditions; and relates yield development to actual task performance (including fertilization).
- A cropping system simulation that incorporates the factor endowments of the individual households as well as other factors such as product prices, and includes decision rules regarding priorities in landscapes, crops, and management.

Decision making in the model is conditioned as much as possible by the basic physical characteristics of agricultural production and input-output market forces, whereas heuristic decision rules related to individual factor endowments and context conditions determine choice. The initial purpose of the simulation is *not* to find out what is the best way of making decisions, but merely how farmers *think* they can best manage a complex agricultural system and how this varies across different categories of farmers with different factor endowments and risk-taking capacities. Once the system is specified so as to simulate the decision situations the farmer faces, how often they occur, how effective farmers' decision rules are in adapting management to changing context conditions measured by the distribution of outcomes they generate, and how this might differ across categories of farmers, it will be possible to evaluate farmers' perception and assumption of risks and the actual extent of risk-taking. Then certain decision rules, particularly those related to new crop production technology, may be improved through experimentation with the model.

Table 7 shows the results of a sequential crop establishment simulation model for testing the technical feasibility of a pattern. The simulated farmers' plan was to plant a dry-seeded rice crop (DSR), to be followed by a wet-seeded rice crop

Table 7. Simulation, with 16 years of rainfall, of the performance of a cropping systems strategy. Tigbauan, Iloilo, Philippines, 1980.

	Plain (0.20 ha)	Plateau (0.20 ha)
	Patterns realized (%)	
DSR	6	6
WSR — mungbean	25	31
Total single rice	31	37
DSR — WSR — mungbean	—	19
WSR — WSR — mungbean	25	6
DSR — WSR	31	25
WSR — WSR	12	12
Total double rice	68	62
	Pattern failure (%)	
DSR early failures[a]	40	20
2d crop failed[b]	36	50
	Mean turnaround	
	6.5 days (6-11)	10 days (6-18)

[a]Failures due to early drought stress or flooding. [b]Crops with simulated yields below 300 kg/ha.

(WSR), and then by a mungbean crop. Certain decision rules permitted revision of the plan to delete any of the crops depending on soil moisture, or substitute wet seeding for dry seeding if the onset of rains was too abrupt. Planting of plots on both the plain and plateau landscape positions was simulated for 16 years of rainfall through 1970 in Tigbauan, Iloilo, with speed of planting constrained by family labor and one carabao.

The planned pattern was executed 19% of the years, and only on the slightly drier plateau. Because of more rapid water accumulation on the plain position, wet seeding often replaced dry seeding, such that a rice - rice - mungbean sequence was possible 25% of the time. Rice - rice using both planting methods was planted more than 60% of the time on both landscape positions. Failure of the dry-seeded rice crops — 40% on the plain and 20% on the plateau — was due to either drought stress or flooding.

Other crop sequences have been simulated and various new technologies can be examined by using the technique. One of the more useful aspects of the research is the degree to which farmers' subjective expectations of technology performance in relation to environment have been elicited, encouraging the view that farmer information can be used in the technology design and testing process.

Cropping systems program

Component technology development and management

Multiple Cropping Department and Cropping Systems Components of the Agronomy, Entomology, and Plant Pathology Departments

WEED SCIENCE

Cropping Systems Component of the Agronomy Department

Land preparation methods for weed control in dry-seeded rice. *Time of land preparation.* Three methods of land preparation for dry-seeded rice (DSR) were evaluated:

- weedy fallow during the dry season followed by (fb) one plowing and two harrowings at the onset of the rains in May,
- one plowing and one rototilling in April fb rototilling in May just before planting, and
- one plowing and one rototilling in April fb weekly harrowings until May when the field was again rototilled.

The methods of land preparation affected crop establishment and weed growth. The crop stand 2 weeks after emergence (WE) in the plot that was harrowed weekly was double that in the other plots. But the fine tilth achieved in that plot favored weed emergence. Consequently, the time required for hand weeding the plot was 32% and 44% more than that for weedy fallow and the plot that received one plowing and one harrowing in April.

Land preparation method also affected the composition of the weed flora (Table 1) and the efficiency of weed control with herbicides (Table 2). Failure to control *Paspalum distichum* in the weedy-fallow plot resulted in complete yield loss for the butachlor treatment.

Yields in the weeded plots were unaffected by the stand reductions caused by poor tilth at the time of planting. Herbicide performance improved as the degree of land preparation in April increased. On plots that had been harrowed weekly, only one herbicide treatment yielded significantly less than the hand-weeded check. On the weedy-fallow plots, four herbicide treatments yielded less than the hand-weeded check (Table 2). The average yield in the herbicide-treated weedy-fallow plots was 39% less than that in the plots that were harrowed weekly.

In Iloilo and Pangasinan, herbicide performance was not improved by maintaining the field weed free by tillage during he dry season.

Stale-seedbed and zero tillage. In a dry-seeded wetland rice trial at IRRI, five land preparation and five postplanting weed control methods were examined for their effect on weed growth and rice yield.

The land preparation methods were

- One plowing fb one harrowing. The field was disk-plowed in April and rototilled once before planting.
- Two plowings fb two harrowings, both operations at 2-week intervals.
- Zero tillage. Weeds were controlled with 1.5 kg a.i. glyphosate/ha before planting.
- Stale seedbed using a harrow. The field was plowed and rototilled in April, weeds were allowed to grow for 2 weeks after the germinating rain. The field was then harrowed and the crop was planted the next day.
- Stale seedbed using paraquat. This is the same as the preceding method except that paraquat application replaced harrowing.

At 40 days after emergence (DE), the total weed weight in the unweeded plots was significantly lower in plots that were prepared by the stale-

Table 1. Effect of land preparation methods on relative dry weight of weed species in the no-weeding plots 40 days after emergence. IRRI, 1980 wet season.

Weed species	Weedy fallow	One plowing + one rototilling	One plowing + one rototilling + weekly harrowing
	Relative dry weight (%) of weeds		
Ipomoea triloba	27.7	25.4	53.5
Paspalum distichum	26.7	14.6	5.6
Ipomoea aquatica	20.3	0.0	0.0
Echinochloa glabrescens	16.3	12.9	17.9
Echinochloa colona	2.1	31.3	1.1
Others	6.9	15.8	21.9
	Total weed wt (g/m²)		
	112.6	181.6	139.8

[a]Av of 3 replications. Land preparation was in April.

Table 2. Effect of land preparation methods and weed control treatments on grain yield of dry-seeded wetland IR50 rice.[a] IRRI, 1980 wet season.

Weed control treatment[b]	Grain yield (t/ha)		
	Weedy fallow	One plowing + one rototilling	One plowing + one rototilling + weekly harrowing
Weeded 14 DE fb 35 DE	4.3 a	4 4 a	3.7 a
Propanil, 2 5 kg a i /ha	3.2 ab	4.4 a	4 3 a
Oxadiazon, 0.75 kg a.i./ha, PE	2 9 abc	3 8 a	3.5 a
Thiobencarb + propanil, 2.5 + 1.25 kg a.i./ha, 8 DE	1.5 cd	4.1 a	3.4 ab
Butachlor + propanil, 1.5 + 1.25 kg a.i /ha, 8 DE	2.6 bc	2.3 b	3.4 ab
Thiobencarb, 3 0 kg a.i./ha, PE	1 8 bcd	2.1 b	2.0 b
Butachlor, 2.0 kg a.i./ha, PE	0.0 e	2.2 b	3.1 ab
Untreated	0.6 de	0.0 c	0.0 c

[a]Av of 3 replications. Land preparation was in April Separation of means in a column by Duncan's multiple range test, 5% level. [b]fb = followed by, DE = days after emergence, PE = preemergence, a.i. = active ingredient, + means that the herbicides were tank-mixed and applied at the same time.

seedbed technique (Table 3). The composition of the weed flora also varied. Broadleaf weeds and sedges dominated in the stale-seedbed plots, and grasses dominated in the other plots.

The weed pressure in the unweeded plots was such that no or little yield was obtained. Herbicides failed to control the weeds in the conventionally prepared and the zero-tillage plots, but achieved good weed control in the stale-seedbed plots (Table 4.) The highest yield in the hand-weeded plots was obtained with zero tillage, but it required more than 1,700 hours of weeding/ha, compared to the 700 hours in the stale-seedbed plots that were treated with paraquat.

Time, method, and rate of nitrogen application. In several dry-seeded wetland rice trials at IRRI, it was found that

- Weed weights in the unweeded plots 60 DE were significantly lower when nitrogen was broadcast 14 DE than when it was broadcast and incorporated before planting.
- Weed weights were significantly higher 35 DE with basal application of 60 kg N/ha than with 0 or 20 kg N/ha.
- Yields from plots weeded once were significantly lower than those from plots weeded twice when nitrogen was broadcast and incorporated or broadcast after the first weeding. No significant difference was observed, however, when nitrogen was broadcast and plowed in, and broadcast without incorporation.
- Failure to weed greatly reduced the nitrogen uptake of rice 60 DE (Table 5).

Rice cropping systems. The effects of tillage,

Table 3. Effect of land preparation method on relative dry weight and total weed weight in unweeded plots of dry-seeded IR50 wetland rice.[a] IRRI, 1980 wet season.

Weed species	1 plowing + 1 harrowing	2 plowings + 2 harrowings	Stale seedbed + harrow	Stale seedbed + paraquat	Zero tillage
		Relative dry weight (%) of weeds			
Paspalum sp.	61.1	52.6	5 2	1.0	36.5
Ipomoea triloba	7 1	5 3	1.8	0 0	20.5
Melochia corchorifolia	5.7	17.5	1 4	2.7	0 0
Commelina diffusa	16 9	9.0	17.8	35 5	3.3
Cyperus rotundus	0.5	0.3	25.5	19.9	0.8
Digitaria sp.	3.2	4.8	6.1	0 7	10.1
Imperata cylindrica	1.4	0.0	0.0	0.0	19.8
Ludwigia octovalvis	0.0	0.0	19.4	12.4	0.0
Others[b]	4 1 (7)	10 5 (5)	22.8 (10)	27.8 (13)	9.0 (10)
		Total weed wt (g/m²)			
	341.8	460.8	86.8	82.2	269 0

[a]Av of 3 replications. [b]Number of species indicated in parentheses.

Table 4. Effect of land preparation methods and weed control treatments[a] on the yield of dry-seeded wetland IR50 rice[b] IRRI, 1980 wet season.

Land preparation method	Yield (t/ha) No weeding	Butachlor (2.0) fb 2,4-D (0.5)	Thiobencarb (3 0) fb 2,4-D (0.5)	Pendimethalin (2.0) fb 2,4-D (0 5)	Hand weeding 14 DE fb 35 DE[c]
Zero tillage	0.0 a	0.0 b	0 0 b	0 8 b	3.5 a
One plowing + one harrowing	0.0 a	0.0 b	0.0 b	1.1 b	2 0 b
Two plowings + two harrowings	0.0 a	0.5 b	0.8 b	0.9 b	3.2 ab
Stale seedbed + harrow	0 0 a	1.9 a	2.7 a	2 9 a	2.9 ab
Stale seedbed + paraquat	0.5 a	2 5 a	3.5 a	2.6 a	2 7 ab

[a]Herbicide rates in kg a i /ha are in parentheses. Residual herbicides were applied at preemergence. fb = followed by. [b]Av of 3 replications Separation of means in a column by Duncan's multiple range test, 5% level. [c]Days after emergence

fertilizer level, and weed control method on weed growth and rice yield were studied in three cropping patterns: continuous transplanted irrigated rice, one crop of rainfed transplanted rice per year, and dry-seeded wetland rice fb transplanted rice (TPR).

Continuous transplanted irrigated rice. The first crop of IR36 was transplanted in March 1979 and the two other crops were planted as soon as land preparation was completed. There were two levels of land preparation: minimum tillage consisting of one plowing fb one harrowing a week later, and conventional tillage consisting of one plowing fb three weekly harrowings. Three levels of fertilizer nitrogen (0, 40, and 80 kg/ha in the wet season and 0, 60, and 120 kg/ha in the dry season) and 6 weeding treatments were tested.

For all three crops the degree of land preparation and the level of applied nitrogen had little effect on the composition of the weed flora 40 days after transplanting (DT). However, the major weed species varied between crops (Table 6).

Nitrogen levels produced no significant difference in weed weight 40 DT in the first two crops, but in the third crop weeds were significantly less in the plots that received no fertilizer than in those that were fertilized.

In the first crop, failure to weed significantly reduced rice yield at all nitrogen levels: 40%, 45%, and 66% at 120, 60, and 0 kg N/ha. Weeds did not cause a significant yield reduction at any nitrogen level in the second crop, but in the third, yield reduction was significant only at the highest nitrogen level.

Weeding treatments within each nitrogen level generally caused no significant difference in yield. Herbicides (2,4-D, thiobencarb and butachor fb hand weeding or 2,4-D) were as effective as one hand weeding in controlling weeds.

In the first and third crops there was no significant difference in yield between the plots that received 120 kg N/ha and those that received 60 kg N/ha. Both yielded significantly higher than those that received no fertilizer. In the second crop, there was a significant increase in yield with each incre-

Table 5. Effect of weed control on nitrogen uptake of dry-seeded wetland IR50 rice and weeds 60 days after emergence (DE).[a] IRRI, 1980 wet season.

Treatment	Nitrogen uptake (kg/ha) Experiment 1 Rice	Experiment 1 Weeds	Experiment 2 Rice	Experiment 2 Weeds
Weeded[b]	51.0	8.8	42 2	5.1
Unweeded	26.0	25.0	22 8	24.5

[a]Av of 8 N fertilizer treatments with 3 replications each [b]14 and 35 DE.

Table 6. Major weed species growing in the unweeded plots of 3 crops of transplanted rice grown in sequence at 40 days after transplanting. IRRI, 1979 dry and wet seasons.

Major weed species: First crop	Second crop	Third crop
Echinochloa glabrescens	*Monochoria vaginalis*	*Echinochloa* sp.
Echinochloa crus-galli ssp. *hispidula*	*E. glabrescens*	*P. distichum*
	P. distichum	*Scirpus maritimus*
Cyperus difformis		*M. vaginalis*
Paspalum distichum		*Fimbristylis littoralis*
Echinochloa colona		*C. difformis*

ment in nitrogen.

Weed growth was generally greater in the conventionally tilled plots than in the minimum-tillage plots. In the first crop yield losses due to weeds were greater in the conventionally tilled plots than in the minimum-tillage plots (64% vs 34%). In the second crop, weeds caused no significant yield reduction at either tillage level. In the third crop a significant yield reduction due to weeds was observed in the conventionally tilled plots.

One crop of rainfed transplanted rice. Land preparation for one crop of rainfed TPR consisted of

- keeping the field weed free by tillage during the dry season, and
- preparing the land as soon as there was sufficient water for puddling. Nitrogen levels were 0, 40, and 80 kg N/ha.

At 40 DT, the weight of weeds growing in association with IR36 averaged 25.1 g/m^2 across fertilizer levels and land preparation methods. *Monochoria vaginalis* and *Paspalum distichum* were the major weed species. Land preparation method and fertilizer level had little effect on the composition of the weed flora.

Grain yield was not affected by land preparation method. But fertilizer application gave significantly higher yield on land kept weed free by tillage during the dry season. No such difference was observed on land prepared when the field had accumulated sufficient water for puddling.

Dry-seeded wetland rice fb transplanted rice. Levels of land preparation for dry-seeded rice (DSR) were similar to those for rainfed TPR. The major weeds with DSR were *Echinochloa* sp., *Fimbristylis littoralis, Cyperus iria, Melochia corchorifolia,* and *Leptochloa chinensis.* The composition of the weed flora was affected little by land preparation and fertilization (0, 60, and 120 kg N/ha). Neither nitrogen level nor time of land preparation had an effect on weed weight 40 DE.

The grain yield of DSR was low because of heavy weed growth, lack of sustained weed control, and drought. The average yield of the plot that was weeded twice was ony 1.0 t/ha across land preparation methods and fertilizer levels. The no-weeding plots had no yield and the plots treated with herbicides gave an average yield of only 0.4 t/ha.

Echinochloa glabrescens, E. crus-galli ssp. *hispidula, M. vaginalis,* and *Cyperus difformis* were the major weeds in TPR. Again the weed flora was not affected by the fertilizer level or the tillage method for DSR.

The level of applied nitrogen had no effect on the total weed weight 40 DT (av 204.5 g/m^2 in the no-weeding plots). Herbicides alone failed to control the weeds adequately. Weed weight was significantly reduced only when hand weeding was used either alone or in combination with a herbicide.

Weed control for dryland crops after rice. *Paraquat application.* To determine the importance of preplanting application of paraquat in zero tillage establishment of dryland crops after wetland rice, mungbean and sorghum were planted in plots, half of which were treated with paraquat at 0.75 kg a.i./ha before planting.

The major weed species growing in association with the crops were *Echinochloa colona, Digitaria* sp., *F. littoralis,* and *L. chinensis.* Paraquat before planting had no effect on the composition of the weed flora. But at 30 DE weed weights in the paraquat-treated mungbean and sorghum plots were 23% and 18% less than in the untreated plots.

Weeding in both the paraquat-treated and untreated plots did not significantly increase the grain yield of mungbean. In the sorghum plots weeding produced a significant yield increase. Increasing the weedings to two did not result in a significant yield increase over plots that were weeded once.

The use of paraquat gave an average yield increase of 44% for mungbean and 46% for sorghum probably because of the lower weed weight and the lack of early weed competition in the paraquat-treated plots.

Chemical weed control. The effect of preemergence herbicides on weed control in maize, mungbean, and cowpea planted after a regular dryland rice was studied in the 1979 wet season.

The principal weeds in the field were *C. rotundus, Digitaria sanguinalis, Eleusine indica,* and *Ageratum conyzoides.* All chemicals adequately controlled one or some species, except *C. rotundus.* The weed population was low because of scanty rainfall late in the season. Consequently, the untreated check did not significantly differ in yield from the hand-weeded and the herbicide-treated plots (Table 7).

All crops were tolerant of butachlor and pendimethalin. Maize was moderately susceptible to butralin and dinitramine; mungbean to dinitra-

Table 7. Effect of liquid herbicides applied before crop and weed emergence on weed control and yield of dryland crops planted after rice.[a] IRRI, 1979 late wet season.

Treatment[b]	Herbicide rate[c] (kg a.i /ha)	Maize		Mungbean		Cowpea	
		Weed wt (g/m²)	Yield (t/ha)	Weed wt (g/m²)	Yield (t/ha)	Weed wt (g/m²)	Yield (t/ha)
Two hand weedings (2 and 5 WE)	—	3 a	4 04 a	11 a	0.58 a	0 a	1.54 a
Butachlor	2.0	41 c	4.60 a	43 abc	0 60 a	55 c	0.73 c
Oxadiazon	1.0	20 bc	4.13 a	21 abc	0.52 ab	29 bc	1.29 abc
Oxyfluorfen	0.5	23 c	4.54 a	17 ab	0 35 b	30 c	0.78 bc
Pendimethalin	2.0	20 bc	3.83 a	51 bc	0 42 ab	20 bc	1.37 ab
Untreated check	—	52 c	4.09 a	75 c	0.47 ab	78 c	1.02 abc
One hand weeding (3 WE)	—	7 ab	4.00 a	45 abc	0.48 ab	6 b	1.09 abc
Butralin	2 0	25 c	3.62 a	42 abc	0.47 ab	20 bc	1.42 a
X-150	4.0	22 c	4.12 a	21 abc	0 40 ab	16 bc	0.99 abc
Dinitramine	1.5	49 c	3.57 a	16 a	0.34 b	18 bc	1 02 abc

[a]Av of 3 replications. Separation of means by Duncan's multiple range test, 5% level. [b]WE = weeks after emergence. [c]a.i. = active ingredient.

mine, oxyfluorfen, and X-150; and cowpea to oxyfluorfen and X-150.

Time of planting. To determine the effect of time of planting on weed growth and crop yield, four dryland crops (mungbean, cowpea, maize, and sorghum) were planted at IRRI at three different times after dry-seeded wetland rice using zero tillage. The major weeds were *E. colona, F. littoralis, Cyperus kyllingia,* and *Lindernia anagallis.* Weeds growing in association with the crops planted 24 November were significantly less than those in the 16 October and 30 October plantings (Table 8). Weed weight was significantly higher for sorghum planted on 24 November than for the other crops.

The grain yield of most crops was affected by time of planting. Mungbean planted on 16 October had a significantly higher grain yield than that planted on 30 October. The 24 November planting gave no yield because of severe infestation of *Cercospora* leaf spot. The 24 November planting of cowpea gave significantly higher yields than the other plantings. Maize yield was not affected by time of planting except in the plots weeded twice. Sorghum planted 16 October and 30 October yielded significantly more than that planted 24 November.

Weeding requirements varied with the crop and the time of planting (Table 9). For all crops except sorghum, yield decrease due to weeds was greatest in the 30 October planting. In most cases, one weeding or no weeding produced optimum yields. Mungbean planted 16 October and sorghum planted 24 November had to be weeded twice.

Competitive ability of mungbean cultivars. Eight

Table 8. Effect of time of planting on total weed weight in the unweeded plot 30 days after emergence.[a] IRRI, 1979 dry and wet seasons.

Crop	Total weed wt (g/m²)		
	16 Oct	30 Oct	24 Nov
Mungbean	233.6 a	200.4 a	51.0 bc
Cowpea	134.8 a	130.2 a	42.6 bc
Maize	200.6 a	214 4 a	43.6 c
Sorghum	173.4 a	264.2 a	105.2 ab

[a]Av of 3 replications Separation of means in a column or row by Duncan's multiple range test, 5% level.

Table 9. Effect of weeding regime and date of planting on grain yield of dryland crops planted after dry-seeded wetland rice. IRRI, 1979 dry and wet seasons.

Crop and weeding regime	Grain yield (t/ha)		
	16 Oct	30 Oct	24 Nov
Mungbean			
Weeded twice[b]	1.7 a	0 9 a	0.0
Weeded once[c]	1.3 b	1.0 a	0.0
No weeding	1.3 b	0.4 b	0.0
Cowpea			
Weeded twice[b]	1.8 a	2.0 a	2.4 a
Weeded once[c]	1.7 a	1.7 ab	2 5 a
No weeding	1 6 a	1.5 b	2.3 a
Maize			
Weeded twice[d]	1.9 a	2.2 a	1.7 a
Weeded once[e]	1 6 a	1 9 a	1.7 a
No weeding	1.4 a	1 5 b	1.2 b
Sorghum			
Weeded twice[d]	3 2 a	4 1 a	2 5 a
Weeded once[e]	3.0 a	4.2 a	1.4 b
No weeding	2.2 b	2.4 b	0.2 c

[a]Av of 3 replications Separation of means in a column within each crop by Duncan's multiple range test, 5% level [b]1 and 3 weeks after emergence (WE). [c]2 WE. [d]1 and 4 WE [e]3 WE.

Table 10. Effect of weeding on grain yield and other characters of mungbean.[a] IRRI, 1980 wet season

Character	Weeded[b]	Not weeded[c]
Plant ht (cm) 5 WE	79 2 b	87 2 a
Leaf area index 5 WE	4.1 a	3.4 b
Pod length (cm)	10.0 a	9 5 a
Pods (no./plant)	13 2 a	10 5 b
Seeds (no./pod)	12 2 a	11.7 a
100-seed wt (g)	5 3 a	5.3 a
Yield (kg/ha)	969 0 a	516 0 b

[a]Separation of means in a row by Duncan's multiple range test, 5% level. WE = weeks after emergence. [b]Av of 3 replications, 2 weeding treatments, and 8 mungbean cultivars [c]Av of 3 replications and 8 mungbean cultivars

mungbean cultivars in a dryland field were tested for their competitive ability against weeds. The dominant weed species in the experimental area was *Cyperus rotundus*.

The cultivars did not significantly differ in competitive ability against weeds. The average weed weight in the unweeded plots at harvest was 135 g/m^2.

Weed competition caused a significant increase in plant height and a significant decrease in leaf area index, number of pods per plant, and grain yield (Table 10). Weeds also reduced plant stand. Other characters were unaffected by weed competition.

Reduced tillage for establishment of a second crop of transplanted rice. Where two or more crops of transplanted rice are grown annually, the second or third crop is usually planted in conventionally prepared fields 2 to 4 weeks after the harvest of the previous crop. The practice wastes cropping time and requires much water for land soaking, evaporation, and seepage.

In an irrigated transplanted rice fields, which had been prepared conventionally and weeded twice, four levels of tillage (Table 11) before planting the second transplanted crop were tested.

Weeds harvested 35 DT weighed from 15.4 to 79.2 g/m^2. The weights were highest in the plots that received the least land preparation (Table 11). Land preparation also affected the weed flora. No weed species accounted for more than 10% of the total dry weight in all methods of land preparation. *M. vaginalis*, *E. glabrescens*, and *E. colona* were major weeds in three land preparation methods (Table 11).

Because the weed population was low, there was no significant difference in rice yield (av, 3.0 t/ha) among tillage and weed control treatments. The data suggest the potential of using zero or reduced tillage in a second transplanted rice crop provided that weeds are adequately controlled in the first crop.

Weed suppression with azolla. *Azolla pinnata* (500 g fresh weight/m^2) was inoculated into a field immediately after rice was transplanted. The azolla rapidly covered the water surface and caused a 71.9% reduction in total weed weight 50 DT. It suppressed by 91.8% the major weed *C. difformis*, which was 65.5% by weight of the weed flora in the unweeded plot. *F. littoralis* and *P. distichum*, the only other weeds that comprised more than 10% of the weed flora by weed weight, were suppressed 67.2 and 30.1%.

Azolla was equivalent to one hand weeding but inferior to two hand weedings in reducing weed growth (Table 12). The rice yield in the azolla-inoculated plots was statistically similar to that in the plots that were weeded once or twice and significantly greater than that from the unweeded check.

Table 11. Effect of land preparation method on relative dry weight, total weed weight, and number of weed species in the unweeded plots 35 days after transplanting IRRI, 1979 dry season.

Weed species	One plowing + one harrowing	One plowing + three harrowings	One harrowing	Zero tillage
	Relative dry weight (%)			
Monochoria vaginalis	21.1	20.1	53 4	7 1
Echinochloa glabrescens	0	30.8	12.9	13 6
Echinochloa colona	29.1	0	11.4	44.0
Cyperus iria	20.6	16 2	0.1	0
Fimbristylis littoralis	18.1	13 3	0.6	6.0
Cyperus difformis	0.1	5 5	4 4	29.3
	Total weed wt[b] (g/m^2)			
	41.2 (10)	15 4 (7)	79.2 (12)	64 8 (5)

[a]Av of 3 replications. Only species with relative dry weights greater than 10 in 1 land preparation method are listed. [b]Total number of species is in parentheses

Table 12. Effect of weed control method on weed weight and yield of transplanted rice.[a] IRRI, 1979 dry season.

Treatment	Weed wt (g/m^2) at 50 DT[b]	Yield (t/ha)
Weeded twice	18 0 c	3.7 a
Azolla inoculated	41.0 b	3.4 a
Weeded once	24.2 bc	2.8 a
No weeding	198 0 a	1.8 b

[a]Av of 2 nitrogen levels and 3 replications. Separation of means in a column by Duncan's multiple range test, 5% level. [b]Days after transplanting.

Response of weed species to flooding. Seedlings of *Rottboellia exaltata* at the early 2-leaf stage were transplanted to pots in the greenhouse and subjected to various watering regimes.

Flooding to a depth of 2 cm had no effect on plant survival. But 65% and 85% of the seedlings were killed when the soil was flooded to a depth of 4 and 6 cm at transplanting (0 DT). Flooding at 7, 14, and 21 DT did not cause a significant reduction in the number of seedlings.

Plants that were flooded at 0 DT were significantly shorter than those on well-drained or saturated soils. Later flooding had little effect on plant height (Table 13).

Shoot dry weight was significantly lower at all flooding depths when flooding occurred 0 DT, and at the 6-cm flooding depth when flooding occurred 7 DT. Shoot weight was not reduced by later flooding (Table 13).

Root dry weight was significantly lower in all flooding treatments and at all times of flooding than in the treatments that were not flooded. Flooding 0 DT was particularly detrimental to root development as was flooding to a depth of 6 cm 7 DT.

Adventitious roots, a possible adaptation to survival under flooding, were produced by plants that were 14 days or older at the time of flooding. Younger plants had none.

Tubers of *C. rotundus* were collected and grown under well-drained, saturated, and flooded conditions. The average plant height, shoot dry weight, and dry weight of the underground portions of the plants produced from tubers collected from a well-drained field were 31.3, 47.7, and 42.0% less than those from tubers collected from a wetland field.

SOIL AND CROP MANAGEMENT

Multiple Cropping Department

Maize responses to nitrogen fertilizer. Irrigation and nitrogen fertilizer interactions were studied with high yielding maize hybrids grown during the dry season in partially irrigated rice-based cropping systems.

Two maize hybrids (*x*P218 and *x*306B) were seeded in February and thinned to 66,000 plants/ha 3 weeks after emergence. Fertilizer rates of 68, 133, and 200 kg N/ha were compared. One-half of the nitrogen plus 40 kg P_2O_5/ha was applied at planting and the remaining nitrogen was applied 24 days after seeding (DS). All plots received irrigation at planting and 24 DS. Additional irrigation was applied at 52 DS on 1/3 of the treatments, and at 52 and 68 DS on 1/3 of the treatments. Treat-

Table 13. Effect of depth and time of flooding on plant height, shoot and root dry weight of *Rottboellia exaltata* plants 8 weeks after transplanting.[a] IRRI, 1980 wet season.

Soil treatment[b]	Av plant ht (cm)	Shoot dry wt (g/plant)	Root dry wt (g/plant)
Well-drained	71.0 b	1 32 b	0.50 b
Saturated	79 7 ab	1.55 ab	0.71 a
Flooded 2 cm, 0 DT	47.7 c	0.43 c	0.10 de
4 cm, 0 DT	30 8 d	0.30 c	0.05 e
6 cm, 0 DT	12 7 e	0.06 c	0.02 e
2 cm, 7 DT	66.6 b	1.03 b	0.28 cd
4 cm, 7 DT	67.1 b	1.05 b	0.23 cd
6 cm, 7 DT	50 3 c	0.52 c	0.10 de
2 cm, 14 DT	75.9 ab	1 25 b	0.23 cd
4 cm, 14 DT	80.0 ab	1 36 b	0.28 cd
6 cm, 14 DT	67.2 b	1.25 b	0 23 cd
2 cm, 21 DT	85 8 a	1.95 a	0.32 c
4 cm, 21 DT	80.1 ab	1.41 b	0.30 c
6 cm, 21 DT	73.5 ab	1.25 b	0 23 cd

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test, 5% level. [b]DT = days after transplanting

Table 14. Chemical and physical properties of soil for a maize and fertilizer experiment. IRRI, 1980.

Analysis	Unit	Soil layer	
		0-20 cm	20-40 cm
pH	—	6.8	6.8
Organic carbon	%	1.28	0.69
Total nitrogen	%	0.14	—
Available potassium (Olsen)	ppm	26 0	—
Exchangeable potassium	meq/100 g	1.14	0.86
Exchangeable magnesium	meq/100 g	10.1	10.7
Exchangeable calcium	meq/100 g	19 2	20 3
Cation exchange capacity	meq/100 g	33.7	37.5
Clay	%	43.4	41.1
Silt	%	40.3	33.7
Sand	%	16.3	25.2

Table 15. Nitrogen in ear leaf tissue of 2 maize hybrids at the silking stage. IRRI, 1980 dry season.

Nitrogen rate (kg/ha)	Nitrogen (%)		
	xP218	x306B	Mean
68	2.71	2.30	2.51
200	2 88	2.64	2.76
Mean	2.80	2.47	2 64
CV_a = 7%, CV_b = 6%			

ments were arranged in a split-plot design, with irrigation treatments in the main plots and nitrogen × variety treatment combinations in the subplots. The physical and chemical properties of the soil in the experimental area are presented in Table 14.

Nitrogen percentages from ear leaves sampled from treatment combinations receiving 68 and 200 kg N/ha at silking are summarized in Table 15. The analysis of variance shows that nitrogen percentage was significantly affected both by nitrogen fertilizer and by variety, but not by their interactions. Irrigation did not significantly influence maize growth based on a nitrogen sufficiency range of 2.7-3.5% of leaf tissue at silking. *x*306B was slightly deficient even where 200 kg N/ha had been applied; *x*P218 had a borderline nitrogen deficiency at the low nitrogen level, but nitrogen was adequate at the high nitrogen level.

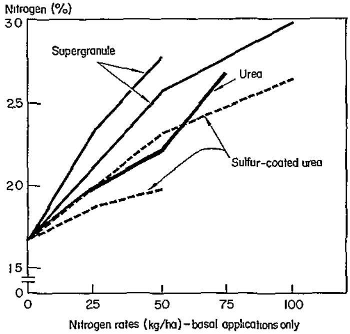
Grain yield data are presented in Table 16. Both irrigation rate and nitrogen rates significantly affected yields. The yield difference between hybrids was not significant. No significant interactions were detected. Analysis of variance showed that the grain yield response to nitrogen was predominantly linear. On the average, the response was about 12.6 kg grain/kg N applied; this was low compared to rates observed by others. The results suggest that, although reasonably high yields could be obtained, nitrogen was not efficiently used and that the yield potential of at least one of the test hybrids was not fully exploited because of nitrogen deficiencies even at 200 kg N/ha. The most intense irrigation treatment increased yield by an average of 0.66 t/ha over the least intense irrigation. An unseasonal 100 mm rain in late March reduced the irrigation effect from what it would be in a more normal year.

Because of low nitrogen efficiency in the first trial, a second trial tested the response of one maize variety (IPB-114) to three nitrogen sources and two methods of fertilizer application over four fertilizer levels. The experiment was planted in October 1980 with a randomized complete block design. Sulfur-coated urea (SCU, 38% N), urea supergranules (SG, 46% N), and granular urea (46% N)

Table 16. Effect of nitrogen rate and irrigation regime on grain yield of 2 maize hybrids. IRRI, 1980 dry season.

Irrigation regimes[a]	Grain yield (t/ha) at given per-ha N rate								Irrigation mean	Fertilizer mean
	xP218				x306B					
	68 kg N	133 kg N	200 kg N	Mean	67 kg N	133 kg N	200 kg N	Mean		
I-1	3 73	4.87	5 81	4.80	3.82	4.49	5.50	4.60	4.70	67 = 4.18
I-2	4 38	5.23	5.82	5.14	4 06	5 12	5.82	5.00	5.07	133 = 5.12
I-3	4.53	5.47	5.94	5 31	4.57	5 54	6 08	5 40	5.36	200 = 5 83
Mean	4.21	5.31	5.86		4.15	5.05	5.80			
Variety mean				5.08				5.00		
				CV_a = 9%		CV_b = 10%				

[a]I-1 = irrigation applied at planting and 24 days after seeding (DS), I-2 = irrigation applied at planting 24 and 52 DS, I-3 = irrigation applied at planting 24, 52, and 68 DS.



1. Percent nitrogen in whole maize plants sampled at 23 days after emergence. IRRI, 1980 wet season.

were applied at 50 and 100 kg N/ha. SCU and SG were applied either all at planting or split with one-half at planting and one-half before interrow cultivation at 30 days after emergence (DE). As a standard for comparison, granular urea was drilled between maize rows at 0, 50, and 100 kg N/ha in a 1/2-1/2 split. Maize was seeded in 50-cm rows and thinned to a final population of 50,000 plants/ha.

Agronomic attributes and grain yield as influenced by fertilizer rate, nitrogen source, and application methods are summarized in Table 17.

Percent nitrogen of whole plants sampled 23 DE are shown in Figure 1. None of the treatments were within the nitrogen sufficiency range of 3.5 to 5.0% N at 23 DE. All tissues sampled at 45 DE had nitrogen levels of all treatments within the range of 1.5 to 1.9%, which was well below the sufficiency range. At silking, only the plants fertilized with granular urea at 100 and 150 kg N/ha fell within the critical limits of nitrogen sufficiency (Fig. 2).

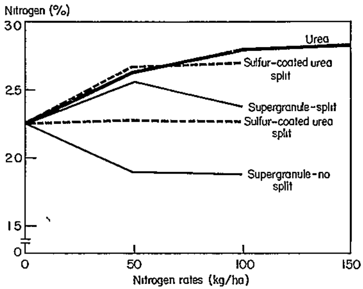
The dry matter yields in Table 17 show general increases with increased nitrogen rates. Total dry matter increase per unit increment of nitrogen applied was higher in plots fertilized with granular urea than in plots receiving SCU. Dry matter yield responses were similar for plots receiving non-split SG and split granular urea.

Average grain yield during the wet season trial was considerably lower than during the dry season trial. The low yields were attributed mainly to excess water during early growth stages. A total of 666 mm rain between emergence and 24 DE caused intermittent flooding during early vegetative growth. The plants turned yellowish and were stunted, regardless of fertilizer treatment. The treatment with no fertilizer was most severely affected and those with the high nitrogen rate as granular urea and SG were least affected. The low tissue nitrogen percentages at 23 and 45 DE were symptomatic of the excess water conditions, indicating either that plant roots were affected and could not extract nitrogen or that nitrogen was not available, or both.

Table 17. Effect of fertilizer rate, nitrogen source, and method of application on dry matter and grain yield of maize[a]. IRRI, 1980 wet season.

Treatments			Dry matter at harvest (t/ha)	Grain yield at 15 5% moisture content (t/ha)
Nitrogen source[b]	Rate (kg/ha)	Application method[c]		
Control			2 0 c	0.63 d
SG	50	S	2.6 abc	1.40 c
SG	100	S	2.5 abc	1 90 b
SG	50	NS	2 6 abc	1.17 c
SG	100	NS	3 0 ab	1 40 c
SCU	50	S	2.3 bc	1.09 cd
SCU	100	S	2.3 bc	1.39 c
SCU	50	NS	2.8 abc	1 31 c
SCU	100	NS	2.4 abc	1.40 c
U	50	S	2 2 bc	1.25 c
U	100	S	2.9 ab	1.94 b
U	150	S	3.2 a	2 53 a
		S x	0.26	0.16
		CV (%)	21	23

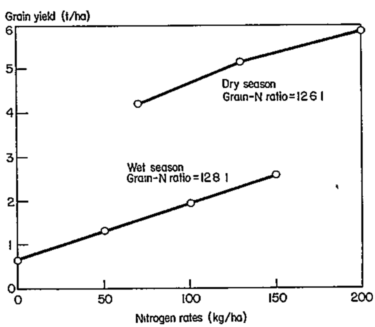
[a]Separation of means in a column by Duncan's multiple range test at the 5% level [b]SG = supergranule, SCU = sulfur-coated urea, U = granular urea. [c]S = split application, NS = no split application.



2. Percent nitrogen in maize leaves sampled at silking. IRRI, 1980 wet season.

Grain yields from plots fertilized with the same rates of split granular urea and SG applications were similar. Splitting the N application obviously improved the efficiency of urea and SG, but not of SCU. The lower yields of plots fertilized with SCU regardless of application method suggest that little of the second application was available to the crop.

The main grain yield responses to split application of granular urea for the dry and wet season trials are shown in Figure 3. The grain-nitrogen ratios are considerably lower than ratios of 25:1 to 30:1 reported by others. The similarity of the ratio of grain yield to applied granular urea nitrogen in both experiments suggests either that soil nitrogen availability was affected by wetness, or that the basal nitrogen applications were not effectively used in either season (i.e., the responses were only from the topdressed portion of the split), or both. The low efficiency of the no-split methods, regardless of nitrogen source, suggested that most of the basally applied nitrogen material became unavailable through leaching, denitrification, or immobilization, or some combination of these processes.



3. Grain-to-nitrogen ratio of maize hybrids grown in distinct seasons. IRRI, 1980.

Limited irrigation applications on mungbean. An experiment late in the dry season tested the effects of small quantities of water applied through plastic piping over the mungbean row at selected crop development stages. The main plots were irrigated according to a factorial arrangement of application dates: no water applied, water at 16 DE only, water at 31 DE only, and water at both 16 and 31 DE. The equivalent of 11 mm of water was applied on each irrigation day. Mungbean varieties MG50-10A(Y) and Dau Mo were planted in subplots.

Varietal differences were clearly manifested by parameters such as plant height and grain yield, but no interaction between irrigation and variety was detected.

Throughout the growing season, the water table was more than 1 m deep, but only a few plants developed main roots that extended deeper than 20 cm. Irrigation did not stimulate root growth, nor did it affect the number of pods per plant or the number of seeds per pod. Plant height, number of flower clusters, and total grain yield were significantly affected by irrigation (Table 18). A partition

Table 18. Plant height, number of flower clusters, and grain yield of mungbean as affected by irrigation.[a] IRRI, 1980 dry season.

Irrigation treatment	At first priming (58 DE)		Mean grain yield, (kg/ha), 12% moisture content
	Mean plant ht (cm)	Flower clusters (no.)	
None	37 ab	3.9 ab	459 bc
Watering 16 DE	34 b	3.5 b	384 c
Watering 31 DE	41 a	3.9 ab	626 a
Watering 16 & 31 DE	37 ab	4.0 a	546 ab
CV (%)	12	9	24

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DE = days after emergence.

of the main plot sum of squares indicated that application 16 DE did not significantly affect grain yield but application 31 DE significantly increased yield by 150 kg/ha. There was no interaction between applications 16 and 31 DE. The results suggest that timely applications of small quantities of irrigation water can have an important impact on the production of mungbean grown during the dry season after rice.

Soybean management studies. Soybean management studies were initiated with a long-term objective of improving soybean performance in the postrice (postwet season) environment. Research focused on identification of cultivar characteristics that affect yield ability in the postrice environment and determination of nitrogen fertilizer and inoculant responses.

Soybean was planted near the end of the 1979 wet season (late October) and harvest was early in the dry season (late January or early February) in two contrasting environments. Pangasinan, Philippines, represented areas with dry postrice environments, in which the wet season ceases abruptly. Laguna, Philippines, represented areas with wet postrice environments, in which there are sporadic rains after the rice season. The Pangasinan experiments were in farmers' fields at 16° N latitude, 8-m elevation; Laguna experiments were at IRRI at 14° N latitude, 15-m elevation. The Pangasinan fields had no known history of soybean cultivation, whereas soybean had been grown frequently in tests in the Laguna fields. The surface soil characteristics of the fields are summarized in Table 19.

Weather at the two sites differed during the growing season. The mean daily maximum and minimum temperatures (31.9 and 20.0° C) in Pangasinan were correspondingly hotter and cooler than in Laguna (29.4 and 21.9° C), indicating greater cloudiness and wetter conditions in Laguna. During the growing season, Pangasinan received less rainfall (136 mm) than Laguna (251 mm). Mean daily solar radiation was 401 cal/cm^2 per day at Laguna; the information was not determined for Pangasinan. Mean day lengths during the growing season were 11.6 hours at Pangasinan and 11.7 hours at Laguna.

Soybean cultivar adaptation studies. Because of a complex relationship between genotype, environment, and yield, the results from variety trials conducted at many sites and seasons within the cropping systems program have generally been inconclusive. A soybean cultivar adaptation study examined the effects of environment on crop attributes and the effects of those attributes on yield, under the hypothesis that at least part of the difficulty in reconciling yield levels and yield rankings among cultivars grown under different environments is due to differences in expression of important phenologic and morphologic attributes in these environments. A secondary objective was to test factor analysis as a technique that could be used to improve data interpretation on a larger scale study.

Table 19. Surface soil characteristics of experiment fields in Pangasinan and Laguna Provinces, Philippines, 1976-80.

	Pangasinan	Laguna
pH	6.8	6.4
Total nitrogen (%)	0.09	0.13
Carbon-nitrogen ratio	9.4	8.6
Olsen phosphorus (ppm)	10	24
Cation exchange capacity (meq/100 g ads)	50.3	33 0
Exchangeable potassium (meq/100 g)	0.28	0.96
Exchangeable magnesium (meq/100 g)	9.6	8.8
Exchangeable calcium (meq/100 g)	40 6	17.9
Particle size (%)		
Clay	43	42
Silt	47	42
Sand	10	16

The theoretical basis for the study was that when *p* genotypes are planted in *m* environments, the resultant array of yields (Y) is determined by the interactions of genetic attributes and environmental co-attributes, which determine phenotypic attributes, and by the interactions of phenotypic attributes and environmental co-attributes, which determine grain yield:

G_{pxl} — *p* genotypes with *l* plant attributes

En_{nxm} — *m* environments of *n* attributes

Eg_{lxm} — *m* environments of *l* attributes that are co-attributes for phenotypic expression: *l* is a subset of *n*

P_{pxq} — *p* phenotypes with *q* plant attributes that determine yield; *q* is a subset of *n*

Ey_{qxm} — *m* environment of *q* attributes which are co-attributes for yield; *q* is a subset of *n*

$$\underset{pxm}{Y} \text{ — yields from } p \text{ cultivars in } m \text{ environments.}$$

$$\underset{pxm}{P} = \underset{pxl}{G} \times \underset{lxm}{Eg}$$

$$\underset{pxm}{Y} = \underset{pxq}{P} \times \underset{qxm}{Ey}$$

Interactions between a) genetic attributes and a subset of environmental co-attributes that determine final phenotypic expression, and between b) phenotypic attributes and a subset of environmental co-attributes, result in difference in variety yield levels and rankings over years and sites. If a series of common varieties are grown in two environments, under the assumption that environment does not influence phenotypic expression, an attribute determined on all varieties within one site should be highly correlated with values for the same attribute at the other site. If a data reduction procedure is used to derive independent composite attributes from measurements of many real attributes, the inter-correlations between environments calculated from the composite attributes should approach an identity matrix as shown in Table 20. Under an additional assumption that environmental attributes do not affect yields by interacting with phenotype, the composite attributes found to be significant by regression analysis should be the same for both environments.

Pangasinan experiments were planted in a farmer's field 16 and 31 October 1979 after the harvest of a rainfed wetland rice crop. In Laguna, a single experiment was planted 20 October on an IRRI field after a weedy fallow during wet season. The 8 cultivars Clark 63, L-114, Multivar 80, Shishi, SJ-1, SL-6, TK-5, and UPLSY2 were common to all experiments. ORBA was the ninth cultivar in Laguna and the 16 October Pangasinan experiment, and Jupiter was the ninth cultivar in the 31 October Pangasinan experiment. Most of these varieties had been or are currently recommended in one or more countries in Southeast Asia.

In all experiments, basal applications of 15 kg N/ha (ammonium sulfate) and 30 kg P_2O_5/ha (ordinary superphosphate) were made at planting by even drilling along the seed furrows. Seeds were inoculated with rhizobium strain CB1809. Plants were thinned to 12 plants/linear meter for a final density of 300,000 plants/ha in Laguna and the second Pangasinan experiment. Because of poor emergence in the first Pangasinan experiment, plants were not thinned.

At IRRI, one sprinkler irrigation was provided during the seed formation stages. At Pangasinan, one light flood irrigation was given to the first and third replications of the first planting, but the irrigation source went dry before the second and fourth replications were irrigated. The second Pangasinan experiment received no irrigation.

In all experiments, a randomized complete block design with four replications was used. Each plot consisted of 15 rows.

Data on the crop characteristics listed in Table 21 were recorded for the analysis. Factor analysis identified patterns of association among phenological and morphological attributes. The objective was to reduce the 14 real attributes to 4 or 5 factors that could be interpreted agronomically and designated as composite attributes. For each experiment, factors were interpreted agronomically on the basis of the pattern of loadings of the 14 attributes. Once interpreted the factors were designated as a composite attribute on the basis of the group of morphological or phenological traits most clearly expressed in the factor. Following interpretation of the factors, factor scores were computed and used as independent variables in a regression analysis of soybean yield variability.

• *Laguna.* In Laguna, 4 factors accounting for 83% of the total variance were retained. The factor loading matrix is shown in Table 22. Because of its high loadings on nodes at harvest, pod-bearing

Table 20. Intercorrelation pattern of composite attributes assuming no interaction between genotype and environment. IRRI, 1980.

Composite attribute from environment 2	Intercorrelation pattern: Composite attributes from environment 1			
	CA_1	CA_2	CA_3	CA_4
CA_1	1	0	0	0
CA_2	0	1	0	0
CA_3	0	0	1	0
CA_4	0	0	0	1

The response of yield to composite attributes assuming no interaction between phenotype and environment:

Environment 1
$Y = a_1 + b\ CA_1 + cCA_2 + dCA_3$

Environment 2
$Y = a_2 + b\ CA_1 + cCA_2 + dCA_3$

Table 21. Variables and mnemonic codes included in the factor analysis of each experiment. 1980.

Variable[a]	Mnemonic code
100-seed wt	S100WT
Dry matter nodules per plant at R1	DMNR1
Dry matter nodule per plant at R5	DMNR5
Plant ht at R1	HTR1
Increase height from R1 to R8	INCHT
Days to R1	DAYSR1
Days from R5 to R8	DAYS5TO8
Days from R1 to R3	DAYS1TO3
Days from R3 to R5	DAYS3TO5
Number of nodes per plant at harvest	NODEHARV
Number of pod-bearing nodes per plant	PODBN
Number of pods per plant at harvest	PODHARV
Number of filled pods per plant at harvest	FIPODHARV
Number of seeds per pod at harvest	SNPODHARV

[a]R1 = beginning bloom, R3 = beginning of pod, R5 = beginning of seed, R8 = full maturity.

nodes at harvest, pods at harvest, and filled pods at harvest, factor 1 was regarded as a composite attribute expressing a fruiting site characteristic. Because the loadings were negative, the factor had a reverse polarity, i.e., low attribute values result in high factor scores. Factor 2, which was dominated by reproductive period height increase, days from R5 (beginning of seed) to R8 (full maturity), and seed per pod, was regarded as a composite attribute representing pod-filling potential, or alternatively, the degree of indeterminacy. Because of the high loadings on height at R1(beginning bloom) and days to R1, factor 3 was regarded as a composite attribute representing vegetative growth. Within the varieties tested it appeared that cultivars with heavy vegetative growth had short pod-setting periods (days between R3 [beginning of pod] and R5) and small seeds. Because of high loadings on days from R1 to R3 and R3 to R5 and modest loadings on days from R5 to R8, factor 4 was interpreted as a composite attribute representing the pattern of reproductive growth phases.

• *Pangasinan (first experiment).* In the first experiment at Pangasinan 5 factors accounting for 82% of the total variance were retained. The factor loading matrix is shown in Table 23. Factor 1, which had high loadings for nodes at harvest,

Table 22. Factor loadings and commonalities of 14 variables on 4 obliquely rotated factors derived from data on 9 soybean cultivars, Laguna (Philippines) experiment. Composite attributes corresponding to each factor are given at the bottom of the table.

Variable	Loadings[a]				Commonalities h^2
	Factor 1	Factor 2	Factor 3	Factor 4	
S100WT	−0.202	−0 422	<u>−0.784</u>	−0.150	0.63
DMNR1	−0.102	0.057	<u>0.683</u>	0.463	0.72
DMNR5	<u>−0 579</u>	−0.219	0.146	−0.118	.0.47
INCHT	−0.074	<u>0.923</u>	0.229	0.146	0.86
DAYSR1	−0.224	−0.080	<u>0.842</u>	0 065	0.93
DAYS5TO8	−0.220	<u>0.721</u>	0.087	−0.420	0.93
DAYS1TO3	−0.092	0.066	−0.275	<u>−0.911</u>	0.94
DAYS3TO5	−0.077	−0.125	<u>−0.670</u>	<u>0.639</u>	0.85
NODEHARV	<u>−0.799</u>	−0.083	0.243	−0.013	0.85
PODBN	<u>−0.945</u>	−0.081	0 031	0.008	0.91
PODHARV	<u>−0.871</u>	0.233	0.090	0.110	0.96
FIPODHARV	<u>−0.908</u>	0.360	−0.274	0.154	0.89
SNPODHARV	0 262	<u>0.761</u>	−0.137	−0.265	0.81
HTR1	−0.326	−0.191	<u>0.699</u>	−0.151	0.85
Cumulative variance (%)	40	61	73	83	
Composite attribute designation[b]	FS	PF	VGP	RGP	

[a]Underlined loadings indicate values large enough to be considered as characterizing the factor in an agronomic sense. [b]FS = fruiting site, PF = pod-filling potential, VGP = vegetative growth phase, RGP = reproductive growth phase.

Table 23. Factor loadings and commonalities of 14 variables on 5 obliquely rotated factors derived from data on 9 soybean cultivars in the first Pangasinan (Philippines) experiment. Composite attributes corresponding to each factor are given at the bottom of the table.

Variable	Loadings[a] Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Commonalities h^2
S100WT	0.117	−0 932	0.036	0.204	0 149	0.84
DMNR1	0.314	0.611	0.317	0 336	0.164	0.84
DMNR5	0.057	−0 116	0.036	0.894	0.021	0.78
INCHT	−0 202	−0.042	0 013	0 866	0.037	0.74
DAYSR1	0.153	0.191	0.575	0.178	0 603	0 85
DAYS5TO8	0.103	−0.847	0.171	0.056	0.312	0.85
DAYS1TO3	0.114	−0 048	0 672	0.394	0.337	0.80
DAYS3TO5	0.105	0.238	0.880	0.167	0.163	0.92
NODEHARV	0 758	0.087	0 458	0.013	0 172	0.87
PODBN	0 795	0 136	0.225	0.248	0 356	0 84
PODHARV	0.960	−0.085	0.107	0 007	0.140	0 93
FIPODHARV	0.937	−0.177	0 144	0.093	0.160	0 94
SNPODHARV	0.426	−0 348	0.282	0.269	0.148	0.51
HTRI	0.096	−0.021	0.039	0.140	0.865	0 79
Cumulative variance (%)	26	46	62	74	82	
Composite attribute designation[b]	FS	PF	PPFG	INDT	VGP	

[a]Underlined loadings indicate values large enough to be considered as characterizing the factor in an agronomic sense. [b]FS = fruiting site, PF = pod-filling potential, PPFG = pre-pod filling growth duration, INDT = indeterminacy, VGP = vegetative growth phase

number of pod-bearing nodes, pods and field pods, was regarded as a composite attribute expressing a fruiting site characteristic. Factor 2 was regarded as a composite attribute representing a pod-filling potential because of high loadings on days from R5 to R8 and 100-seed weight. Nodule dry weight at R1 was modestly associated with this factor. Factor 3 was regarded as a composite attribute representing a pre-pod filling growth duration pattern because of high loadings on days to R1 and days from R1 to R3 and R3 to R5. Factor 4 was regarded as a composite attribute reflecting degree of indeterminacy based on high loading on height increase during the reproductive period and an intermediate loading on days from R1 to R3. This factor was also highly associated with nodule dry weight at R5. Factor 5 was associated with days to R1 and height at R1 and therefore was regarded as a composite attribute for vegetative growth.

• *Pangasinan (second experiment).* For the second experiment in Pangasinan four factors accounting for 75% of the total variance were retained. The factor loading matrix is shown in Table 24. Factor 1 was regarded as a composite attribute expressing a fruiting site characteristic. In addition to high loadings on nodes at harvest, pod bearing, number of pods and filled pods, factor 1 also had a modest association with height at R1. Because of high loadings on 100-seed weight and days from R5 to R8, factor 2 was regarded as a composite attribute representing pod-filling potential. Alternatively this factor could be regarded as representing late nitrogen status or nodulation potential because of the strong association with nodule dry weight at R5. Factor 3 was regarded as an attribute expressing pod-setting potential because of the high loadings on days from R3 to R5 and number of seeds per pod. Because of a high loading on nodule dry weight at R1, factor 3 may also be interpreted as nitrogen nutrition attribute. Factor 4 was regarded as an attribute reflecting degree of indeterminacy because of high loadings on reproductive period height increase and days from R1 to R3.

A composite attribute for pod-set was recognized only in this experiment.

Across the 3 experiments, it is clear that 4 or 5 composite attributes (factors) accounted for most of the variability observed among the 14 real attributes included in the analysis. Of the compo-

Table 24. Factor loadings and commonalities of 14 variables on 4 obliquely rotated factors derived from data on 9 soybean cultivars in the second Pangasinan (Philippines) experiment Composite attributes corresponding to each factor are given at the bottom of the table.

Variable	Loading[a]				Commonalities h^2
	Factor 1	Factor 2	Factor 3	Factor 4	
S100WT	0 194	0.901	0.253	0.103	0.80
DMNR1	0.081	−0 254	−0 680	0.075	0 47
DMNR5	−0.368	0.593	0 046	−0 293	0.63
INCHT	−0 303	0 020	−0.060	0 757	0.60
DAYSR1	−0 804	−0.071	−0 153	−0 388	0.89
DAYS5TO8	−0 128	0 728	−0 252	0.303	0.80
DAYS1TO3	0.488	0.236	−0.151	0 643	0 81
DAYS3TO5	−0 242	0 086	−0 625	0 207	0.49
NODEHARV	−0 972	−0.208	−0.107	0 224	0 88
PODBN	−0.962	0 042	0.016	0.057	0.93
PODHARV	−0 891	0 111	0 133	0 108	0.86
FIPODHARV	−0.876	0.129	0 186	0 126	0 86
SNPODHARV	0 442	0.139	−0.675	−0 152	0.77
HTRI	−0.531	0 408	−0 187	−0 315	0 70
Cumulative variance (%)	39	55	67	75	
Composite attribute designation[b]	FS	PF	PS	INDT	

[a]Underlined loadings indicate values large enough to be considered as characterizing the factor in an agronomic sense. [b]FS = fruiting site, PF = pod-filling potential, PS = pod-setting potential, INDT = indeterminacy

Table 25 Intercorrelations among composite attributes[a] within the Laguna and Pangasinan experiments, Philippines, 1980.

Composite attribute	Intercorrelations				
	Laguna experiment				
	FS	PF	VGP	RGP	
FS	1 000	−0 104	−0 399	0 085	
PF		1 000	−0 089	−0.197	
VGP			1 000	−0 010	
RGP				1 000	
	First Pangasinan experiment				
	FS	PF	PPFG	INDT	VGP
FS	1 000	−0 047	−0 091	0 115	−0 059
PF		1 000	0 032	0 304	−0 011
PPFG			1.000	−0 093	−0 066
INDT				1 000	−0 090
VGP					1.000
	Second Pangasinan experiment				
	FS	PF	PS	INDT	
FS	1.000	−0.154	−0 097	0.137	
PF		1 000	−0.191	0 095	
PS			1.000	0 131	
INDT				1 000	

[a]FS = fruiting site, PF = pod-filling potential, VGP = vegetative growth phase, RGP = reproductive growth phase, PPFG = pre-pod filling growth duration, INDT = indeterminacy, PS = pod setting

site attributes, the one representing the number of fruiting sites was most important on the basis of percentage. The composite attribute representing the pod-filling period was second in importance. Fruiting site and pod-filling attributes were consistently extracted as the first and second factors, and jointly they accounted for 61% of the total variance in the Laguna experiment, 46% first in the first Pangasinan experiment, and 55% in the second.

Correlation coefficients from among the composite attributes within each experiment are presented in Table 25. No coefficient was statistically significant. Among the Laguna composite attributes, however, fruiting site (FS) was moderately correlated with vegetative growth phase (VGP). Among the first Pangasinan experiment composite attributes, pod-filling potential (PF) was moderately correlated with indeterminacy (INDT). The relatively low levels of correlation and few cases where even moderate correlations were found suggest that the oblique rotation aided interpretation but did not severely diminish the orthogonality among factors extracted from within each experiment.

Table 26 Intercorrelations of composite attributes[a] extracted from the Laguna and first Pangasinan experiments, and the Pangasinan first and second experiments, Philippines, 1980.

	Intercorrelations				
	FS	PF	PPFG	INDT	VGP
Laguna experiment			*First Pangasinan experiment*		
FS	−0.739*	−0 110	0 217	0 171	−0 034
PF	−0 042	−0.196	0 085	0 053	0 073
VGP	−0 060	0 496	−0 368	0.033	−0 152
RGP	0 085	0.516	0 668*	0 062	−0 139
Second Pangasinan experiment			*First Pangasinan experiment*		
FS	−0.564	−0 296	0 163	0.200	0 257
RF	−0 370	−0 846**	−0 006	0 113	−0.089
PS	0 262	−0 398	−0.435	0.169	0 063
INDT	−0 034	−0 095	−0 072	0 324	0 114

[a]FS = fruiting site, PF = pod-filling potential, VGP = vegetative growth phase, RGP = reproductive growth phase, PS = pod setting, INDT = indeterminacy, PPFG = pre-pod filling growth duration

Correlation coefficients between composite attributes recognized in the Laguna and first Pangasinan experiments are shown in Table 26. In these two experiments, the same nine cultivars were grown. FS from Laguna and FS from the first Pangasinan planting were strongly correlated, although their polarities were opposite and therefore the correlation was negative. The comparatively strong correlations between reproductive growth phase (RGP) from the Laguna experiment and PF and pre-pod filling growth duration (PPFG) from the first Pangasinan experiment suggest that the RGP composite attribute from Laguna extracted many traits extracted in two attributes in the first Pangasinan experiment. The PF composite attributes in these two experiments, however, appeared to have little in common except a high loading on days from R5 to R8.

The lack of a strong correlation pattern between composite attributes regarded as agronomically similar suggests that in Laguna and Pangasinan environmental co-attributes that affected phenotypic expression were not similar. Environment-induced alterations of many phenological and morphological attributes were obtained.

Because the substitution of Jupiter for ORBA in the second Pangasinan experiment may have resulted in changes in the patterns of loadings on the extracted factors, factors were extracted from the first Pangasinan experiment data with ORBA deleted and from the second Pangasinan experiment with Jupiter deleted. In both experiments, deletion of the varieties changed the order in which some factors were extracted, but the factor loadings were only slightly changed and the agronomic interpretations were not altered. The similarities indicate that the analyses were not very sensitive to the presence or absence of the deleted varieties, and that correlations between composite attributes derived from all nine varieties, as shown in Table 26, is valid for comparative purposes. Although the PD composite attributes from both experiments were strongly correlated and the FS, PPFG/PS and INDT composite attributes extracted from the experiments showed tendencies toward higher correlations with each other than with different composite attributes, the pattern of the correlations was not strong. The weak correlations among many attributes were estimated to arise from slight weather differences between the two growing periods, from differences between Jupiter and ORBA, from interactions between varieties and irrigation water in the first experiment, and from experimental error. The relative contributions of these factors on attribute expression cannot be determined from this study.

Correlation coefficients between composite attributes and grain and dry matter yields are shown in Table 27. The pattern of correlation coefficients between the composite attributes and grain and dry matter yields were similar within each Pangasinan experiment. The pattern in the Laguna experiment showed differences, mainly in FS and VGP. The lack of a close association between grain and dry matter yield in the Laguna experiment might have resulted from a rather favorable moisture regime, which permitted full expression of VGP under prevailing photoperiod and temperature regime.

Table 27 Correlation coefficients between composite attributes[a] extracted from the Laguna and Pangasinan (Philippines) experiments and grain and dry matter yield 1980.

Variable[b]	Correlation coefficient				
	Los Baños experiment				
	FS	PF	VGP	RGP	
Yield	0 400*	−0 122	−0 759*	0 261	
TOTDMH	−0 603**	0 213	0.129	−0 088	
	First Pangasinan experiment				
	FS	PF	PPFG	INDT	VGP
Yield	0 311*	−0.393*	−0 209	0 299*	0 365*
TOTDMH	0 240	−0 326*	−0 219	0.261	0.423*
	Second Pangasinan experiment				
	FS	PF	PS	INDT	
Yield	−0.545**	0 749**	−0 038	0.141	
TOTDMH	−0.562**	0.746**	−0 030	0.109	

[a]FS = fruiting site, PF = pod-filling potential, VGP = vegetative growth phase, RGP = reproductive growth phase, PPFG = pre-pod filling growth duration, INDT = indeterminacy, PS = pod setting [b]Yield = seed yield, TOTDMH = total dry matter yield at harvest

Growth in both Pangasinan experiments was severely affected by moisture deficits, regardless of variety. Mean dry matter yields across all varieties were 3.4 t/ha for Laguna, and 1.9 and 1.7 t/ha for the first and second Pangasinan experiments.

To determine the relative contributions of the composite attributes to grain yields, regression models were formulated with yield as a dependent variable and factor scores, final plant population, and squared and interaction terms as independent variables.

For each experiment, an analysis of variance on yields, using a standard classification model, is shown in the upper portion of Table 28. The comparatively high error mean squares in the Pangasinan experiments presumably arose from variable plant density not controlled by blocking. To determine the relative contributions of the composite attributes of seed yield variability, factor scores were computed for each composite attribute (factor), and used in a regression analysis with seed yield as the dependent variable. In the first regression model (Model I), factor scores and plant populations (FINALPOP) in linear and quadratic forms and in all possible interaction terms were candidates for stepwise selection. The regression statistics for the models are listed in Table 29. As expected, no term involving FINALPOP entered the model in the Laguna analysis because plant density was well controlled experimentally. FINALPOP entered as linear and interaction terms in both Pangasinan analyses. In Model II, the linear, quadratic, and interaction terms found significant in Model I plus dummy variables for replication were included in the regression model.

As shown in Table 28, the extra MS from the replication dummy variables (Reg II/Reg I) was significant only in the first Pangasinan analysis, where irrigation application on two replications

Table 28. Partitioned sum of squares, coefficients of variation (CV), and coefficients of determination (R^2) from the Laguna and first and second Pangasinan (Philippines) experiments, 1980.

Source	Laguna		First Pangasinan		Second Pangasinan	
	df	MS	df	MS	df	MS
Classification Model[a]						
Replication	3	7241	3	1300516	3	129508
Variety	8	380806**	8	266466ns	8	367677**
Residual	24	10747	24	135830	24	28828
CV (%)		8		35		21
R^2		92		65		83
Regression Model I						
Reg I	4	605018**	4	1556940**	6	599922**
Residual	31	29227	31	98885	29	14561
CV (%)		13		30		15
R^2		74		67		89
Regression Model II						
Reg II	7	349077**	7	996155**	9	401770**
Reg II/Reg I	3	7823ns	3	248440*	3	5467ns
Residual	28	31520	28	82861	26	15610
CV (%)		13		28		15
R^2		74		75		89

[a]Analysis of variance using standard two-way classification model: $Y = \mu + r_i + v_j + e_{ij}$.

Table 29. Regression statistics for Models I and II, Laguna and first and second Pangasinan experiments, Philippines, 1980[a]

Variable[b]	Model I			Model II		
	Regression coefficient	Standard error	F-value	Regression coefficient	Standard error	F-value
Los Baños						
Intercept	1299	—	—	1330	59 3	—
Rep Dummy 1	—	—	—	−39 3	84 6	0.2
2	—	—	—	−17 7	84.3	0 0
3	—	—	—	−68.7	84 2	0.7
FS	−12.7	9.3	1 9	−13.4	9.67	1 9
VGP	−68.7	14.4	22.7**	−69.7	15.1	21 3**
RGP	51 6	15.5	11 1**	52 1	16 2	10.4**
FS*RGP	−9 42	5.1	3.4*	−9 26	5 49	2.9
Pangasinan (first experiment)						
Intercept	110 9	—	—	−39.9	180 8	—
Rep Dummy 1	—	—	—	459 2	160.5	8 2**
2	—	—	—	66 3	137 7	0 2
3	—	—	—	181.4	170 5	1.1
FINALPOP	3 22	0 650	24 8**	3 03	0.654	21 4**
FINALPOP*PF	−0.481	0.095	25.5**	−0 310	0 115	7 2**
FS*PF	10.60	6.86	2 4	6 18	6.64	0 9
INDT*INDT	32 65	8 96	13.3**	34.56	8 56	16 3**
Pangasinan (second experiment)						
Intercept	238 1	—	—	325 1	167 72	—
Rep Dummy 1	—	—	—	−63 8	67 6	0 9
2	—	—	—	−42 15	62 3	0 5
3	—	—	—	−8 53	63 0	0.0
FINALPOP	3.28	0.90	13 3**	2 99	0 98	9 3**
FS	−64.3	13.9	21 3**	−69 4	16 7	5 9*
FINALPOP²	−0 00392	0 001	7 7**	−0 00365	0 0015	9.1**
FINALPOP*FS	0.119	0.036	10 6**	0.134	0.044	109 6**
FINALPOP*PF	0 390	0.034	129 7**	0.396	0.037	3 6+
FS*FS	−1.85	0.84	4 9*	−1 75	0.917	17.2**

[a]Significant at the 0 10 (+), 0 05 (*), and 0 01 (**) levels [b]FS = fruiting site, VGP = vegetative growth phase, RGP = reproductive growth phase, FINALPOP = final population, PF = pod filling, IND = indeterminacy

probably caused major replication effects.

The regression models for Laguna accounted for 80% of the variance explained by the classification model. The extra SS for the replication dummy variables in Model II was similar to the replications MS in the classification model, suggesting that replications removed the same minor sources of variation in both models.

In the analysis of the first Pangasinan experiment data, Model II explained 15% more of the total SS than the classification model, but the extra MS for the replication dummy variables in Model II was much less than the replication MS from the classification model, suggesting that Model II variables extracted considerable yield variation among replications in addition to variation arising from varieties. In both Pangasinan analyses, the replication sum of squares in the classification model analysis of variance was estimated to be removing much of the same variability removed by final population in the regression models.

The independent variables that were important in the first model were also found to be significant in Model II, with the exception of the FS*PF interaction in the first Pangasinan experiment.

To determine the contributions of the composite attributes, interpretational equations were obtained by setting FINALPOP to its mean value (Table 30). Mean plant populations per 11.6 m^2 were 336 for the Laguna experiment, 252 for the first Pangasinan experiment, and 308 for the second.

In Laguna, composite attributes FS, VGP, and

Table 30 Interpretational equations derived from Model I, with final population set to experimental means in both Pangasinan equations. IRRI, 1980.

Laguna
$\hat{Y} = 1299 - 12.7FS - 68.7VGP + 51.6RGP - 9.42FS*RGP$

Pangasinan (1st)
$\hat{Y} = 958 - 78\ 1PF + 6\ 2FS*PF + 34.6INDT^2$

Pangasinan (2d)
$\hat{Y} = 875 - 27\ 6FS + 120\ 1PF - 1\ 85FS^2$

RGP, and the FS*RGP interaction were significant variables at 20% or lower probability levels. Of the four, VGP alone explained 59% of the total variation. Because the regression coefficient for VGP was negative, varieties among the test group with long vegetative growth durations (and also short pod-set periods and low seed weights) had low yields. RGP explained an additional 10% of the variation when added to the model. Because the regression coefficients for RGP were positive, varieties with short flowering periods (days from R1 to R3) and long pod-set periods (days from R3 to R5) had comparatively high yields.

FS had a comparatively minor influence on yield, but it formed an important interaction with RGP. The polarity of FS was reversed; therefore, the coefficient showed that as the number of fruiting sites increased at a positive RGP value, yield increased. As the pod-set period (days from R3 to R5) lengthened and the flowering period (days from R1 to R3) shortened (i.e., as RGP became increasingly positive), the number of fruiting sites became more important, as shown by the FS*RGP term. The reverse was true where RGP was low (negative).

In the analysis of the first Pangasinan planting, FINALPOP, FINALPOP*PF, PF*FS, and $INDT^2$ were important explanatory variables. FINALPOP*PF alone accounted for 51% of the variability. Because of the negative regression coefficient and the reversed polarity of PF, the analyses show that varieties with high-pod filling potential (long pod-filling period, large seed and large numbers of seeds per pod) had high negative factor scores and high yields. The contribution of PF increased as FINALPOP increased. Where FS was negative (i.e., where there were few nodes and pods), the contribution of a long pod-filling period increased as shown by the PF*FS interaction. Conversely, where the number of fruiting sites was high the contribution of a long pod-filling period diminished. This interaction may have arisen because the water requirement of plants with a large number of fruiting sites may have been too high to be supported by slow extraction of water from the soil late in the growing season, and as a result, small varieties with few fruiting sites but with long pod-filling periods yielded more than large varieties with many fruiting sites but long pod-filling periods. The quadratic term for INDT is difficult to interpret agronomically. Inspection of the data showed that high yielding varieties were found with very high and very low factor scores for INDT, suggesting that the lowest yielding varieties had intermediate plant height increases during the reproductive phase and average nodule dry weight at R5. Therefore, no important causal interpretation is given to INDT.

In the analysis of the second Pangasinan experiment, FINALPOP, FS, $FINALPOP^2$, FINALPOP*FS, FINALPOP*PF, and FS^2 were important explanatory variables. The FINALPOP*PF interaction contributed most to the explanation of yield variability. As in the first Pangasinan experiment, PF contributed more to yield as FINALPOP increased, at least within the range of observations. High yields were obtained with high populations of varieties that had high pod-filling potential. The higher populations may have resulted from better inherent seedling emergence rates, or differences in vigor resulting from dissimilar conditions during seed development or during storage or both. The linear and quadratic coefficients for FS regression showed that as fruiting sites increased, yields increased but at a diminishing rate.

On the basis of the contributions of composite attributes to grain yield, the Laguna experiment clearly differed from either Pangasinan experiment in that the vegetative growth and pod-set duration or flowering duration or both (RGP) composite attributes were important in this experiment alone. The vegetative growth attribute was negatively associated with yield and the pod-set duration (or flowering duration) attribute was positively (negatively) associated with yield. Whereas VGP and RGP were regarded as the dominant causes of yield differences in the Laguna experiment, the PF attribute was regarded as the dominant cause of yield differences in both Pangasinan experiments. Although the same nine varieties were used in the Laguna and the first Pangasinan experiments, environmental factors obviously interacted with crop characteristics and caused seed yields to be affected by different sets of crop attributes in those two experiments. Environmental effects were not nearly as great between the two Pangasinan experiments as they were between the Laguna and the first Pangasinan experiment. There was, however, one difference among varieties in the Pangasinan experiments, and plant population, which interacted strongly with the PF composite attribute, was more limiting in the first Pangasinan experiment than in the second.

The influence of nodulation is not clear from this analysis. Nodule dry weight at R5 was associated with composite attributes in the Laguna experiment (in FS) and the second Pangasinan experiment (in PF) in such a manner that higher nodule dry weights were associated with higher yields. In the first Pangasinan experiment, however, both high and low nodule weights were associated with higher yields. In the first Pangasinan experiment, however, both high and low nodule weights were associated (through INDT) with yield increases, but INDT was regarded as being spuriously associated with yield. Nodulation at R1 was associated with composite attributes in such a manner that as nodule dry weight increased, yield decreased. In the second Pangasinan experiment, the composite attribute extracting nodule dry weight at R1 was not significantly associated with yield changes.

Nitrogen fertilizer and inoculant application studies. Nitrogen fertilizer and inoculant application studies determined the effects of nitrogen fertilizers and methods of inoculation on soybean seed yield and on nodulation of crops grown in fields that differed in history of soybean cultivation. Four experiments were conducted, two each in Pangasinan and Laguna provinces. The soil and weather conditions were described previously.

- *Experiment 1 (Pangasinan).* Two varieties (UPLSY2 and L114) were used as main plot treatments, and six factorial combinations of basally applied nitrogen fertilizer (0, 20, and 80 kg N/ha) and topdressed nitrogen fertilizer (0 and 40 kg N/ha) were used as subplot treatments in a split-split-plot design. Basal nitrogen (ammonium sulfate) applications were placed in the seed furrow, and topdressings were broadcast at 28 days after planting. The subplot was inoculated with *Rhizobium japonicum* (strain CB1809) at a rate of 100 g inoculant/11.5 kg seed. The other sub-subplot was not inoculated.

- *Experiment 2 (Pangasinan).* Two varieties (UPLSY2 and ORBA) were planted as main plot treatments and 2 basal nitrogen fertilizer rates (0 and 20 kg N/ha) were used as subplot treatments in a split-split-plot design. Factorial combinations of two strains (CB1809 and S38) and two inoculation rates (a standard rate and six times the standard rate) were used as four sub-subplot treatments. A fifth sub-subplot, left uninoculated, was used as a control. The standard rate was identical to that used in experiment 1. To obtain even distribution, the furrow-applied inoculant was mixed with slightly moist sand (passing 2 mm sieve) at a dry sand-peat inoculant ratio of 30:1.

- *Experiment 3 (Laguna).* The 6 factorial treatment combinations of 2 varieties (Clark 63 and Improved Pelican) and 3 basal N fertilizer applications (0, 25, and 50 kg N/ha) were used as main plot treatments of a split-plot design. The seed sown in one subplot was inoculated and that in the other was not. The same inoculant strain and application methods used in experiment 1 were used in experiment 3, but experiment 3 was irrigated.

- *Experiment 4 (Laguna).* Experiment 4 was identical to experiment 2 in experimental and treatment design except that variety L114 was planted in place of ORBA, and it was irrigated.

Nodulation and nitrogen yield: experiment 1. Analysis of variance in nitrogen yield at R5 indicated that both basal nitrogen application and inoculation significantly increased nitrogen yield. Over the range tested, the nitrogen yield increase was essentially linear at a ratio of 0.21 kg N yield/kg applied N. Inoculation increased nitrogen yield by 6.1 kg N/ha. Inoculation significantly increased nodule number at R5, but basal nitrogen applications significantly depressed nodulation as indicated by a significant basal nitrogen-inoculation interaction. Table 31 shows the mean number of nodules/5 plants for the basal nitrogen fertilizer inoculation treatment combinations. A basal application of 80 kg N/ha depressed nodulation to less than 10% of the nodulation obtained when basal nitrogen was not applied. Where seeds were not inoculated, nodulation was almost nil. Although not statistically significant, the number of

Table 31. Nodules from inoculated and uninoculated soybean at 3 basal nitrogen fertilizer rates. Experiment 1, Pangasinan, Philippines, 1980.

	Nodules (mean no /5 plants)		
	0 kg N/ha	20 kg N/ha	80 kg N/ha
Uninoculated	0 1	0.2	0.1
Inoculated	14.1	5.2	1 0

nodules on UPLSY2 was only 12% of the nodules on L114. Under the hot, dry conditions in which this experiment was planted and the low native *R. japonicum* population, nodulation was extremely variable and therefore, despite being significant, the results were interpreted as reflecting general trends rather than determinations of high precision.

Nodulation and nitrogen yield: experiment 2. A summary analysis of variance showing significance levels of treatment effects and first-order interactions at the sub-subplot level on six attributes is given in Table 32. Among the 6 attributes, a basal nitrogen significantly affected only percent nitrogen at the subplot level. At 35 DS, inoculation clearly affected all 6 attributes. Among the inoculation treatments, the method factor was dominant, although several minor interactions were observed. Mean number of nodules, nodule weight, and N_2-equivalent C_2H_2 reduction from uninoculated (C), seed-inoculated (S), seed- and furrow-inoculated (SF) treatments on UPLSY2 and ORBA soybean are shown in Figure 4. Compared to the check treatment, the SF treatment increased nodule number by more than 340%, nodule weight by 250%, N_2-equivalent C_2H_2 reduction by 275%, and N yield by 60%.

Unlike the 60% reduction in experiment 1, the depressive effect on nodule number of the basal nitrogen application of 20 kg/ha where inoculant had been used in this experiment was comparatively minor (25%) and insignificant. Where inoculant had not been applied, no depression was observed in response to a basal nitrogen treatment. Significant variety-inoculation and variety-strain interactions were obtained on number of nodules.

Compared with UPLSY2, ORBA had a slightly greater nodule number increase when inoculant was applied; however, the difference was less than 1 nodule/plant. On ORBA, the number of nodules from application of strain CB1809 increased by 90% over the number from strain S38, but on UPLSY2 the number of nodules from both strains was essentially equal. Over all treatments, the mean number of nodules on ORBA was 90% higher than on UPLSY2.

In inoculated treatments, percent nitrogen was significantly lower where basal nitrogen treatments were applied. Where inoculant was not applied, however, a basal nitrogen treatment increased the percentage.

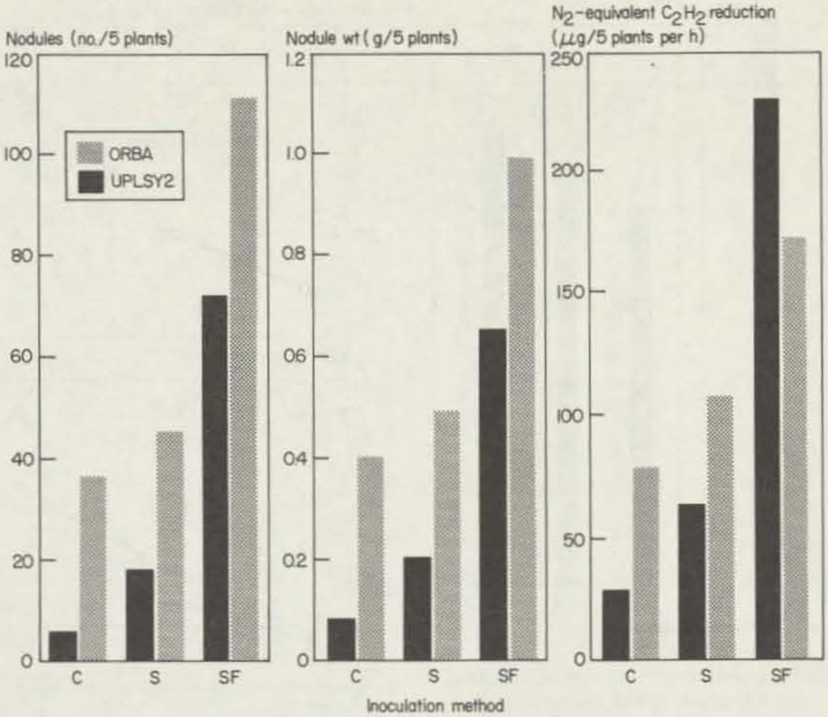
At 49 DS, about the same pattern of treatment effects was found on nodule number and weights, and on N_2 equivalent C_2H_2 reduction; however, the interactions of variety with other treatments diminished. As shown in Figure 5, nodule size between 35 and 49 DS increased for both varieties, but at a greater rate for UPLSY2. Where inoculant had been applied to the seed and furrow, nodule size increased by 84% in UPLSY2 and 41% in ORBA. Corresponding increases were only 33% and 15% where no inoculation or seed inoculation was applied.

Nitrogen concentration declined between 35 and

Table 32 Significant levels of mean squares of treatment effects and first-order interactions at the sub-subplot level of experiment 2 on attributes determined at 35 and 49 days after planting. Pangasinan, Philippines, 1980.

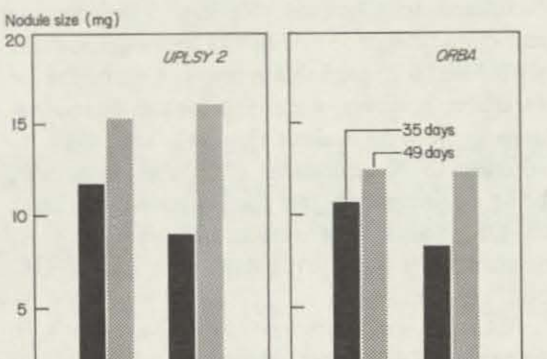
Source	df	Significance[a] of crop attribute[b]: 35 days: Nodule no.	35 days: Nodule wt	35 days: C_2H_2 reduction	35 days: Nitrogen[c] (%)	49 days: Nodule wt	49 days: Nitrogen (%)
Inoculation[d]	4						
Inoculated vs uninoculated (C)	1	**	**	**	**	*	**
Method (M)	1	**	**	**	**	*	*
Strain (S)	1				+		
M × S	1						
Variety (V) × C	1	*		**			
V × M	1						
V × S	1	*					
Basal N (B) × C	1				+		
B × M	1						
B × S	1						

[a]Significant at the 0.10 (+), 0.05 (*), and 0.01 (**) levels. [b]For each sampling time, determinations for all attributes were made from a 5-plant sample taken from each sub-subplot. [c]Determined on a subsample from the entire aboveground portion of the 5-plant sample. [d]To partition the 4 df for sub-subplot treatments, 1 df was used to compare the inoculated seed to all treatments that received inoculation. The remaining 3 df were partitioned as main effects of inoculant methods and strains and their interactions



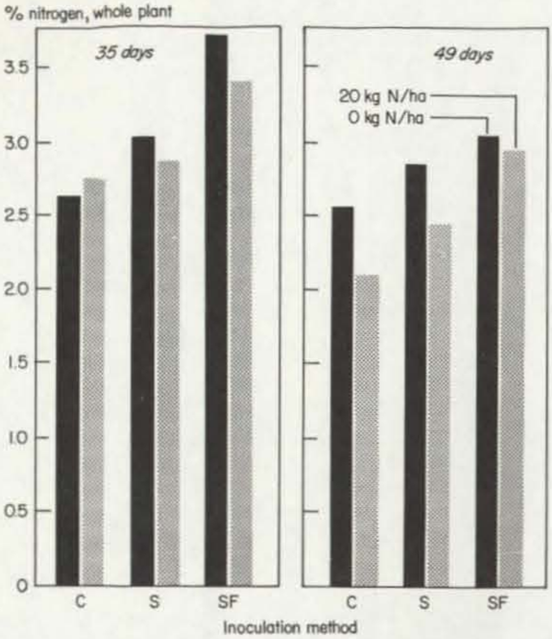
4. Number of nodules, nodule weight, and N_2-equivalent C_2H_2 reduction of UPLSY2 and ORBA at 35 days after transplanting as affected by method of *R. japonicum* inoculation. C = uninoculated, S = seed inoculated, SF = seed and furrow inoculated at a combined rate of 6× that of S. Experiment 2, Pangasinan, Philippines, 1980.

49 DS for all treatments, but the decline was relatively greater where a 20 kg N/ha basal nitrogen treatment was applied to inoculated or seed-inoculated plants (Fig. 6). At 35 DS, nitrogen yields were uniformly greater where 20 kg N/ha basal nitrogen was applied, but at 49 DS, nitrogen yields from a 20 kg N/ha basal nitrogen application exceeded nitrogen yields from a 0 kg N/ha treatment only where seed- and furrow-inoculation had been used (Fig. 7).

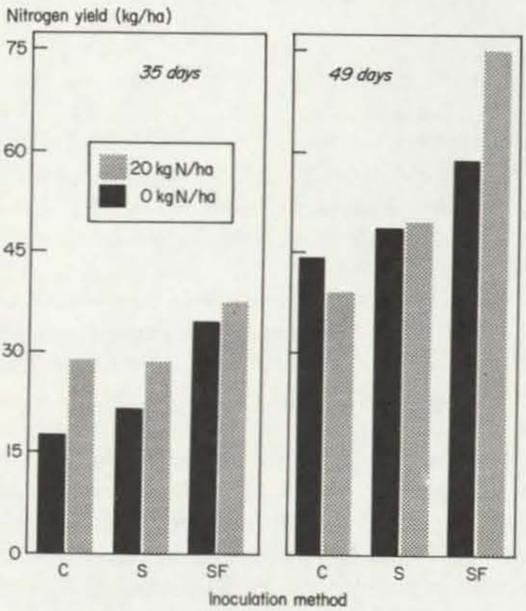


5. Nodule size of UPLSY2 and ORBA soybean, 35 days and 49 days after planting, at initially low and high numbers of nodules. L = plants receiving no inoculation or seed inoculation, H = plants receiving both seed inoculation and furrow inoculation. Experiment 2, Pangasinan, Philippines, 1980.

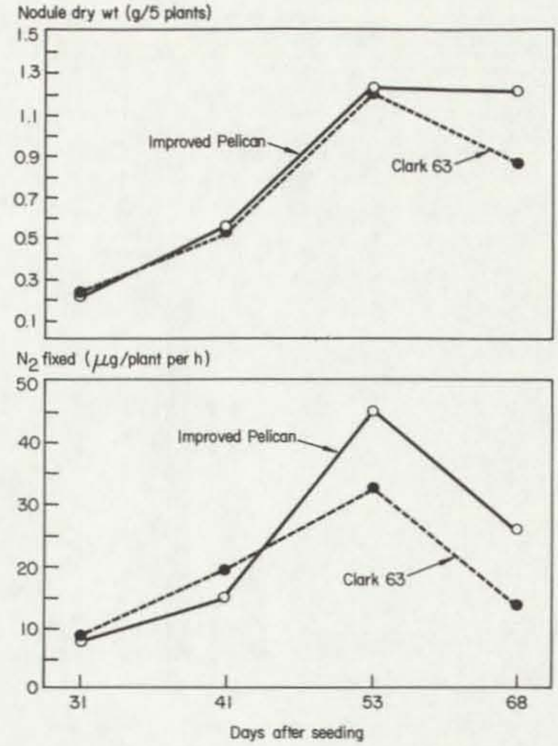
Nodulation and nitrogen yield: experiment 3. Basal nitrogen applications significantly influenced nitrogen yield at R5. Over the range tested, the nitrogen yield increased essentially linearly at a ratio of 0.67 kg:1 kg applied nitrogen. Inoculation did not increase nitrogen yield significantly, nor was nodulation significantly affected by either basal nitrogen or inoculation treatments. Nodulation was significantly affected by variety. The number of nodules was 20/plant on Clark 63 but exceeded 40/plant on Improved Pelican. Almost all nodules were small, especially on Improved Pelican. At R5, mean weight per nodule was 7.3 mg on Clark 63 but only 5.2 on Improved Pelican. As shown in Figure 8, nodule weight per plant differed



6. Effect of basal nitrogen applications and method of *R. japonicum* inoculation on % nitrogen at 35 and 49 days after planting. C = uninoculated, S = seed inoculated, SF = seed and furrow inoculated at a combined rate of 6x that of S. Experiment 2, Pangasinan, Philippines, 1980.



7. Effect of basal nitrogen applications and method of *R. japonicum* inoculation on nitrogen yield at 35 and 49 days after planting. C = uninoculated, S = seed inoculated, SF = seed and furrow inoculated at a combined rate of 6x that of S. Experiment 2, Pangasinan, Philippines, 1980.



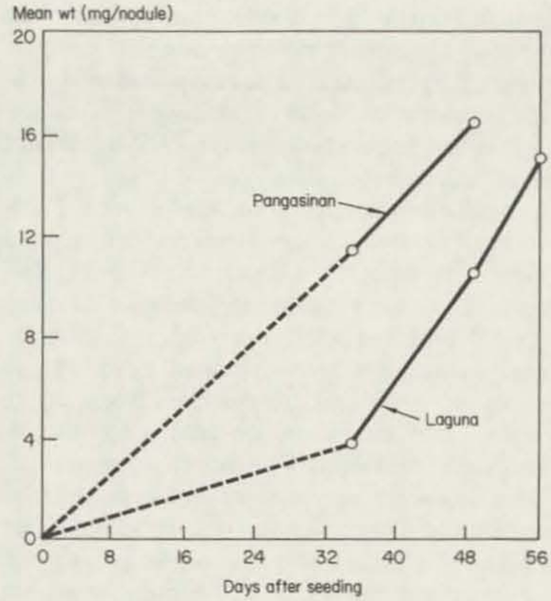
8. Nodule dry weight on N_2-equivalent C_2H_2 fixation rate at 4 growth stages of 2 soybean varieties. Experiment 2, Pangasinan, Philippines, 1980.

only slightly through the first 53 DS, but the weight on Improved Pelican was maintained to 68 DS. At 53 and 68 DS, higher N_2-equivalent C_2H_2 reduction rates were found on Improved Pelican when compared to Clark 63. Varietal differences in reduction rates at 53 and 68 DS were significant at the 0.1 and 0.05 probability levels. Coefficients of variation, however, were high for the determinations at both 53 and 68 DS (44% and 68%). In addition to N_2-equivalent C_2H_2 reduction rates being significantly higher for Improved Pelican at 68 DS, nodule dry weight and nitrogen yield determined for the same date were also significantly higher.

Nodulation and nitrogen yield: experiment 4. In Experiment 4, neither nitrogen application nor inoculation increased the number of nodules per plant or the weight of nodules sampled at 35, 42, or 56 DS. Significant varietal differences were found in number of nodules at the 56 DS sampling, but not at the 35 DS. By 56 DS, the nodules on L114 were profuse, increasing by 95% over the number observed at 35 DS. In all determinations, nodule weight/5 plants was greater for L114 than for UPLSY2, but the weight per nodule did not differ between varieties within sampling dates. During this 21-day interval, the number of UPLSY2 increased by only 29%. At 35 DS, mean weight per nodule was 3.4 mg and increased to 14.8 mg by 56 DS. Because plant sizes were irregular due to an uneven crop stand, nitrogen-yield and C_2H_2 reduction rates were not determined.

Contrasts between the experiments conducted at the two sites were apparent. In the Pangasinan experiments, soybean was responsive to inoculation. In Laguna, no significant inoculation response was obtained probably because that province has a much higher native rhizobial population. At 35 DS, for example, the mean number of nodules per plant from the uninoculated, zero nitrogen, UPLSY2 treatment in experiment 4 (Laguna) was 18.6, but for the same treatment in experiment 2 (Pangasinan), the number per plant was only 1.0. The rates of nodule development in the two sites also differed as illustrated in Figure 9. The slower initial growth rate in Laguna was due perhaps to the division of limited assimilates among a greater number of nodules. Additionally, a more favorable supply of soil nitrogen in Laguna, resulting from moister surface soils and higher total soil nitrogen, may have suppressed early nodule development. Although the constant nodule growth rate between planting and 49 DS in Pangasinan is apparent, given the limited number of sampling dates, crop growth limitations imposed by moisture deficits at that site may have precluded an increase in nodule development rate after 35 DS.

Nitrogen yield differences between the two sites were also substantial. Nitrogen yield at R5 from the uninoculated zero nitrogen treatment was 33.5 kg N/ha in experiment 1 (Pangasinan) and 74.4 kg N/ha in experiment 3 (Laguna); moreover, the nitrogen yield:basal nitrogen was substantially higher in experiment 3 (0.67:1 vs 0.21:1). The nitrogen yield differences in the uninoculated, zero nitrogen treatments reflect differences in soil nitrogen availability and N_2 fixation. Given the moister Laguna environment, soil nitrogen would be more readily available, and of course, the much denser native rhizobial population in Laguna would contribute substantially to nitrogen yield. The difference in the nitrogen yield-basal nitrogen ratios is perhaps related to soil moisture near the surface via effects



9. Mean weight per nodule on UPLSY2 determined at selected days after seeding. Experiments 2 (Pangasinan) and 4 (Laguna), Philippines, 1980.

on nitrification and nitrate uptake. In the study of soybean variety adaptation described previously, the moisture content of the surface 20 cm soil at R1 of UPLSY2 was 47% (weight basis) in Laguna, but only 24% in Pangasinan.

In these experiments, basal nitrogen applications were important factors contributing to early vegetative development as illustrated by leaf area index (LAI) determinations. In Pangasinan, LAIs at 0 and 80 kg N/ha were 0.9 and 1.4 at R1. By R5, the LAIs for the corresponding treatments had increased to 2.4 and 3.6. In Laguna, basal nitrogen applications contributed to significant but less pronounced LAI increases. The differences in early LAI increases apparently contributed to seed yield increases from basal nitrogen treatments.

Whereas many small nodules formed early and developed rapidly after 35 DS and apparently contributed to nitrogen yield at Laguna, low infection by native rhizobia in Pangasinan clearly limited nitrogen yield as demonstrated in both experiments 1 and 2. Although seed inoculation contributed to an apparent nitrogen yield increase of 7.5 kg/ha (av of experiments 1 and 2) at R5, combined seed and furrow inoculation in experiment 2 increased nitrogen yield by 26.7 kg N/ha at the same growth stage, demonstrating a substantial benefit from the high inoculant rate applied to the furrow. The impact of furrow inoculation on nitrogen supply to the crop was supported by significant increases in number of nodules per plant, total nodule weight per plant, and rate of N_2-equivalent C_2H_2 reduction per plant.

Basal nitrogen application in experiment 2 uniformly increased nitrogen yields determined at 35 DS for all inoculation treatments. Minor differences in nitrogen yields (determined at 49 DS) were found from 0 and 20 kg N/ha basal applications on uninoculated and seed-inoculated treatments, in comparison with differences from 0 and 20 kg N/ha basal treatments on seed- and furrow-inoculated treatments. This pattern suggested that, where basal nitrogen was applied but a furrow-application of inoculant was not provided, the rate of nitrogen accumulation did not keep pace with dry matter accumulation as the crop went from flowering to beginning seed. The patterns of N_2-equivalent C_2H_2 reduction and the percent nitrogen in plant tissue also supported this interpretation.

With the exception of UPLSY2, no distinct patterns of variety interactions with nitrogen fertilizer or inoculant treatments were detected in any of the experiments. In the three experiments in which UPLSY2 was included, it produced fewer nodules and lower nodule weight per plant than the variety with which it was paired. Data showed a tendency for UPLSY2 to develop fewer nodules than ORBA and L114, regardless of inoculation treatment and the population of native *R. japonicum*.

There was only meager evidence of differences in infectiveness between the two *R. japonicum* strains compared in experiments 2 and 4. Compared with CB1809 in experiment 2, S38 was more infective on ORBA. Both strains infected UPLSY2 equally well, but to a lesser degree than on ORBA. There was no evidence, however, that the greater nodulation on ORBA caused an increase in N_2 fixation or that either strain was a more efficient N_2 fixer.

Yield components and seed and dry matter yields: experiment 1. The significance levels of treatment effects and interactions in Table 33 indicate that in experiment 1, basal nitrogen applications significantly affected filled pods per plant, seed weight, dry matter yield at R5 and seed yield. Basal nitrogen applications also significantly increased leaf area development. A topdressing of 40 kg N/ha at 28 DS affected filled pods per plant, seeds per pod, and seed weight. Seed yields and filled pods per plant corresponding to all combinations of basal and topdressed nitrogen applications are shown in Figure 10. Although the interaction was not significant, the only seed yield responses to topdressing occurred where basal nitrogen was not applied.

A linear response of seed weight to basal nitrogen application (17 mg/100 seeds per kg applied N/ha) was found over the nitrogen range tested. The response to 40 kg N/ha, topdressed at 28 DS, was equivalent to 11 mg/100 seeds per kg applied N/ha.

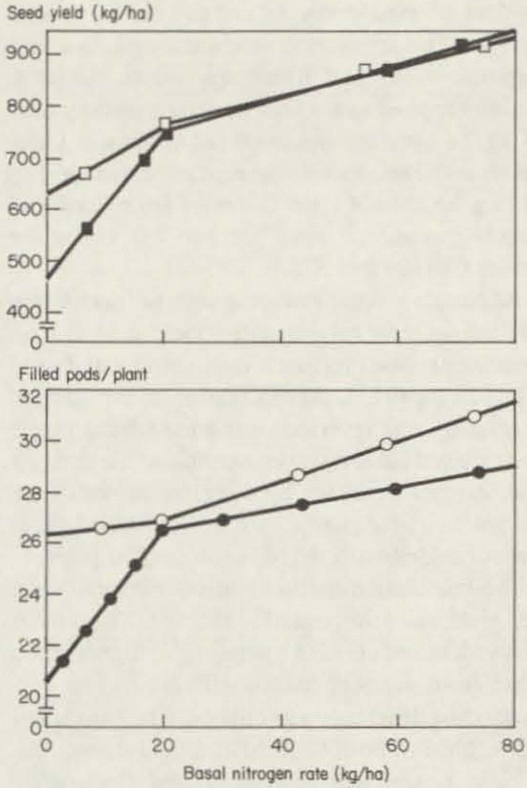
Although basal and topdressed nitrogen significantly increased seeds per pod, the number of seeds per pod in the lowest and highest basal-topdressing combinations were within 3% of the mean number of seeds per pod over the experiment.

Inoculation increased seed weight significantly

Table 33. Significance levels of treatment effect and first-order interaction mean squares at sub- and sub-subplot levels. Experiment 1, Pangasinan, Philippines, 1980.

Source	df	Significance[a] of crop attribute				
		Dry matter yield[b]	Seed yield[c]	Filled pods/plant	No. of seeds/pod	Wt of 100 seeds
Basal N (B)	2	**	**	**		**
Topdressed N (T)	1			**	**	*
B × T	2			*	*	
Variety (V) × B	2	*				
V × T	1					
Inoculation (I)	1	**	+			**
V × I	1		+			*
B × I	2		+			
T × I	1				*	

[a]Significant at the 0.10 (+), 0.05 (*), and 0.01 (**) levels. [b]Dry matter yield/plant at beginning of seed. [c]Seed yield/ha at 14% moisture content.



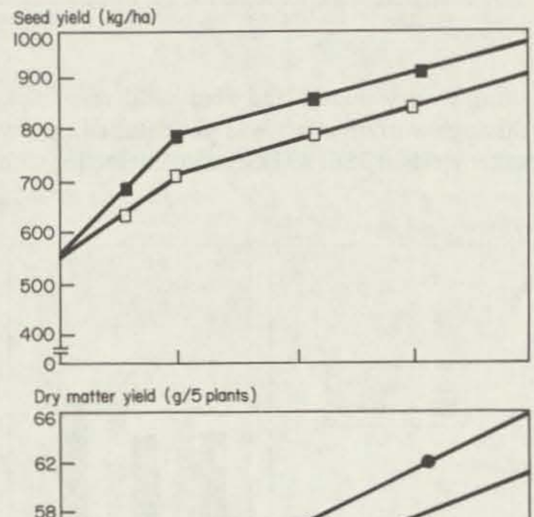
10. Seed yield (■) and filled pods (●) as affected by 40 kg N/ha, topdressed at 28 days after planting (□○) and basal nitrogen rates. Experiment 1, Pangasinan, Philippines, 1980.

but interacted with variety. The data in Table 34, however, suggest that basal nitrogen applications and variety were more important determinants of seed weight than inoculation or the inoculation-variety interaction. The basal nitrogen inoculation-variety interaction on seed weight was significant, but the major contribution to the interaction was the low response in inoculated L114 and a high response in inoculated UPLSY2 to a basal application of 20 kg N/ha. Inoculation also significantly increased dry matter yield and seed yield, but increases were minor. Dry matter and seed yields corresponding to combinations of basal nitrogen applications and inoculation treatments are shown in Figure 11. Responses to inoculation occurred only where basal nitrogen was applied. The significant variety-inoculation interaction for seed yield arose from the comparatively greater response of L114 to inoculation. The yield difference of uninoculated and inoculated UPLSY2 was only 19 kg/ha whereas the inoculation response for L114 was 80 kg/ha.

Table 34. Seed weight of UPLSY2 and L114 soybean as affected by basal nitrogen application and inoculation. Experiment 1, Pangasinan, Philippines, 1980.

Treatment	100-seed wt (g)		
	0 N	20 kg N/ha	80 kg N/ha
		UPLSY2	
Uninoculated	12.3	12.7	13.6
Inoculated	12.5	13.5	13.9
		L114	
Uninoculated	9.8	10.3	11.5
Inoculated	11.2	11.1	12.2

Yield components and seed and dry matter yields: experiment 2. As indicated by the significance levels in Table 35, basal nitrogen applications caused significant responses in dry matter yields determined at 35 DS, 49 DS, and harvest, and in seed yield. Of the comparisons within the inoculation treatments, method of application was a consistent and highly significant factor contri-



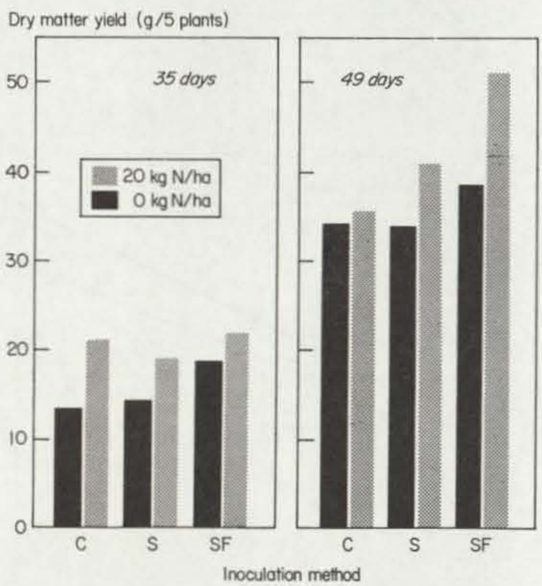
11. Seed yield (□) and dry matter (○) at R5 as affected by seed inoculation with *R. japonicum* (■●) and basal nitrogen rates Experiment 1, Pangasinan, Philippines, 1980.

Table 35. Significance levels of treatment effect and first-order interaction mean squares at sub- and sub-subplot levels. Experiment 2, Pangasinan, Philippines, 1980.

Source	df	Significance[a] of crop attribute			
		Dry matter yield[b]			Seed yield[c]
		5 WP	7 WP	Harvest	
Basal N (B)	1	*	**	+	+
Variety (V) × B	1				
Inoculation[d]	4				
Inoculated vs uninoculated (C)	1		**	**	*
Method (M)	1	**	**	**	**
Strain (S)	1			**	*
M × S	1				
V × C	1				
V × M	1				
V × S	1				
B × C	1	*	*		
B × M	1				
B × S	1				+

[a]Significant at the 0.10 (+), 0.05 (*), and 0.01 (**) levels. Dry matter yield per plant for determinations at 5 and 6 weeks after planting (WP); per unit area for determination at harvest. [c]Seed yield/ha. [d]To partition the 4 df for sub-subplot treatments, 1 df was used to compare the uninoculated seed to all treatments that received inoculation. The remaining 3 df were partitioned as main effects of inoculant methods and strains and their interaction.

buting to dry matter and seed yield responses. Although a strain effect was not detected on dry matter yields at 35 or 49 DS, strain interacting with method affected seed yield and dry matter yield at harvest. The interaction was attributed to a low response in strain CB1809 applied to the seed. CB1809 applied to the seed increased yield by only 96 kg/ha over the uninoculated treatment yield, but strain S38 applied to the seed increased yield by 247 kg/ha. Mean yield increases from seed and furrow inoculation were 518 and 438 kg/ha for strains CB1809 and S38.



12. Dry matter yield at 35 and 49 days after planting as affected by basal fertilizer 20 kg N/ha and method of *R. japonicum* inoculation. C = uninoculated, S = seed inoculated, SF = seed and furrow inoculated at a combined rate of 6x that of S. Experiment 2, Pangasinan, Philippines, 1980.

Although a significant response to inoculation was not detected on dry matter yield at 35 DS, an inoculation-basal nitrogen interaction was found (Fig. 12). By 49 DS, the inoculation-basal nitrogen interaction was reversed — the inoculated plants that received basal nitrogen outyielded the unfertilized, inoculated plants by a greater amount than the uninoculated plants that received basal nitrogen outyielded unfertilized, uninoculated plants.

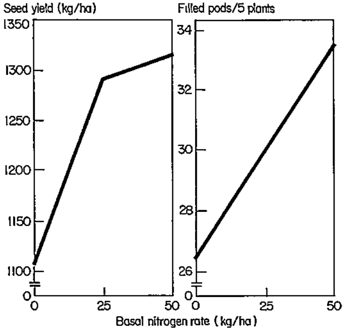
The inoculation method-variety interaction on seed yield was pronounced (Table 36). Yields from seed-inoculated ORBA were 43% higher than those from seed-inoculated UPLSY2. The corresponding difference was only 4% when inoculant was applied to both the seed and the furrow.

Yield components and seed and dry matter yields: experiment 3. Basal nitrogen applications resulted in significant increases in dry matter yield at R5, in seed yield, and in filled pods per plant. The response of seed yield to basal nitrogen was linear over the range tested, but almost 90% of the filled pod response was from the first 25 kg N

Table 36. Effect of basal nitrogen application on seed yield of UPLSY2 and ORBA soybean and method of inoculation with 2 *R. japonicum* strains. Experiment 2, Pangasinan, Philippines, 1980.

Strain	Method[a]	Seed yield (kg/ha)	
		0 N	20 kg N/ha
		UPLSY2	
None	—	682	745
CB1809	S	553	797
	SF	1250	1172
S38	S	779	880
	SF	1139	1212
		ORBA	
None	—	764	775
CB1809	S	910	1086
	SF	1143	1470
S38	S	1114	1181
	SF	1080	1286

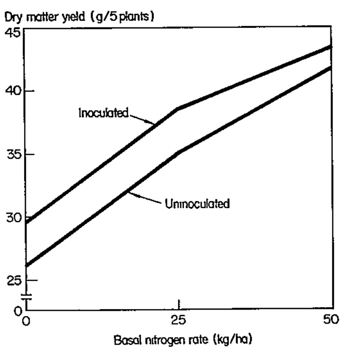
[a]S = inoculant applied to the seed, SF = inoculant applied to the seed and the furrow.



13. Effect of basal nitrogen rate on seed yield and filled pods/5 plants Experiment 3, Laguna, Philippines, 1980.

increment of basal nitrogen (Fig. 13). R5 dry matter yield was also significantly increased by seed inoculation (Fig. 14), but by only 8%; the apparent positive effect of inoculation was not reflected in a seed yield increase or in increases in any of the yield components determined.

The number of seeds per pod and seed weight were significantly affected by varieties. Clark 63 had fewer seeds per pod (1.89) than Improved Pelican (2.01), but the 100-seed weight of Clark 63



14. Effect of basal nitrogen rate and seed inoculation on dry matter yield at beginning of seed. Experiment 3, Laguna, Philippines, 1980.

(11.4 g vs 10.3 g) was greater.

From this series of inoculation and nitrogen-fertilizer experiments, the conclusion was that nitrogen-fertilizer management for soybean should not differ greatly in environmental situations represented by the two sites..

Soybean varieties were observed to differ in their tendency to nodulate, regardless of the level of native rhizobia in the soil or the rate of inoculation. Nodulation tendency can perhaps be considered in soybean breeding programs that have the postrice environment as the target for new cultivars.

PLANT PROTECTION

Cropping Systems Components of the Entomology and Plant Pathology Departments

Effect of planting time and tillage method on cowpea insects (*Entomology*). The effect of planting dates (November and December) and tillage methods (zero and high)on the incidence of cowpea insects and their chemical insect control were studied during the 1979-80 crop season at Iloilo. Because establishing a cowpea crop in rice stubble by the broadcast method resulted in uneven stands in previous tests, seeds were dibble-seeded to ensure an even stand.

The recommended insect control practice of 4 sprays (0.25 kg a.i. monocrotophos/ha 2 and 12 days after crop emergence (DE) and 0.75 kg a.i. carbaryl/ha 25 and 35 DE) were compared with complete protection and an untreated check.

The November and December plantings were severely affected by bean fly, thrips, aphid, and pod borer *Maruca testulalis*, and had yield losses of 73-93% (Table 37). The yields of the November planting were twice those of December, which reflected drought stress of the December planting, even in zero tillage. Previous studies had shown rice stubble to significantly reduce populations of preflowering insects. The effect of stubble on the preflowering insect pests was inconsistent over the two planting 1979-80 dates and given the high insect pressure lower insecticide usage cannot be justified. Compared with complete protection, the recommended insect control practice was suboptimal in the November planting. The preflowering protection in the recommended practice was adequate, and the problem was due to the postflowering insecticide carbaryl, which did not adequately

Table 37. Effect of planting time and tillage method on development of an insect control recommendation for EG2 cowpea planted after rainfed wetland rice.[a] Oton, Iloilo, Philippines, 1979-80.

Treatment	Bean fly-infested plants[b] (%) 12 DE		Bean fly-infested plants[b] (%) 25 DE		Thrips[c] (no./25 leaf buds) 25 DE		Aphid infestation[d] (grade) 50 DE		Yield[e] (t/ha)	
	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT
				November planting						
Complete protection[f]	7 a	3 a	5 a	10 a	0 a	7 a	1 a	1 a	1 00 a	0.80 a
Recommended practice[g]	15 ab	16 a	25 a	17 a	0 a	14 a	1 a	1 a	0 50 b	0.58 a
Untreated	34 b	62 b	73 b	100 b	1 a	12 a	2 a	4 b	0 20 c	0 22 b
				December planting						
Complete protection[f]	1 a	5 a	1 a	4 a	6 a	7 a	1 a	1 a	0.43 a	0 44 a
Recommended practice[g]	8 a	11 a	3 a	17 a	10 ab	8 a	1 a	2 a	0.51 a	0 37 a
Untreated	78 b	100 b	81 b	92 b	18 b	16 a	5 b	5 b	0 03 b	0.09 b

[a]Av of 4 replications (fields) Separation of means in a column within each month of planting by Duncan's multiple range test at the 5% level. DE = days after crop emergence, ZT = zero tillage (seeds dibbled into standing rice stubble 15 cm high), HT = high tillage (plowed and harrowed). [b]*Ophiomyia phaseoli.* 25-plant sample dissected [c]*Thrips palmi:* 25-leaf bud sample. [d]*Aphis craccivora* 1-9 scale per plant 1 = no aphids, 3 = adults, 5 = several small colonies, 7 = many distinct colonies, 9 = many indistinct coalesced colonies. [e]20-m² sample area [f]0.5 kg a.i. monocrotophos (Azodrin 168 EC)/ha 2, 9, 16 DE; 0 03 kg a.i. decamethrin (Decis 2 5 EC)/ha 25, 35, 45 DE. [g]0 25 kg a i. monocrotophos/ha 2, 12 DE; 0.75 kg a.i. carbaryl (Sevin 85 WP)/ha 25, 35 DE

control *M. testulalis.*

Effect of planting time and tillage method on mungbean insects (*Entomology*). A mungbean study similar to the cowpea study in Iloilo was established in Pangasinan in the 1979-80 dry season. Three (October, November, December) planting dates (after rainfed wetland rice) compared insect pest incidence and insecticide requirements. Mungbean was established by seeding in plow furrows opened between rows of rice stubble and the effect of rice stubble density on preflowering insect pests was compared with high tillage.

Bean fly and *Heliothis armigera* pod borer showed no definite trend in terms of seasonality although in previous years, their populations progressively increased with later plantings (Table 38). Thrips, flea beetle, and leafminer populations were highest in the October planting and progressively decreased in later plantings. In contrast leafhopper and aphid populations became higher in the later plantings.

Yields were consistent over planting dates and tillage methods, but yield losses from insects progressively decreased with planting month — Novem-

Table 38. Effect of planting time and tillage method on development of an insect control recommendation for CES1D-21 mungbean planted after rainfed wetland rice.[a] Manaoag, Pangasinan, Philippines, 1979-80.

Treatment	Bean fly-infested plants[b] (%) 25 DE		Flea beetle[c] (no. holes/25 plants) 14 DE		Thrips[d] (no./25 leaf-bud tips) 25 DE		Yield[i] (t/ha)	
	MT	HT	MT	HT	MT	HT	MT	HT
				October planting				
Complete protection[j]	40 a	36 a	4 a	4 a	9 a	12 ab	1.10 a	1.04 a
Recommended practice[k]	42 a	46 a	7 b	6 b	11 a	8 a	0.52 b	0 43 b
Untreated	43 a	48 a	27 c	26 c	12 a	22 b	0.13 c	0.15 b
				November planting				
Complete protection[j]	1 a	1 a	2 a	2 a	5 a	8 a	0 92 a	1.20 a
Recommended practice[k]	1 a	2 a	2 a	3 a	5 a	5 a	0.75 a	1 07 a
Untreated	14 b	22 b	8 b	8 b	6 a	7 a	0.28 b	0.37 b
				December planting				
Complete protection[j]	1 a	12 a	0.3 a	0 a	4 a	2 a	1.04 a	1 22 a
Recommended practice[k]	3 a	10 a	2 b	2 b	2 a	1 a	0.63 b	0 82 b
Untreated	9 a	40 b	6 c	6 c	2 a	6 b	0.48 b	0.48 c

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Table 38. CONTINUED

Treatment	Leafhopper[c] (no./25 plants) 25 DE		Aphid[f] infestation (grade) 25 DE		Leafminer[g] tunnels (no./25 plants) 25 DE		*Heliothis*[h] larvae (no /25 plants) 45 DE		Yield[i] (t/ha)	
	MT	HT	MT	HT	MT	HT	MT	HT	MT	HT
					October planting					
Complete protection[j]	0 a	0 a	0 0 a	0.0 a	1 a	1 a	0 3 a	0 a	1 10 a	1.04 a
Recommended practice[k]	0 3 a	0 3 a	0.0 a	0 0 a	6 b	4 b	6 b	4 b	0 52 b	0 43 b
Untreated	2 b	10 b	0.5 a	2.3 b	22 c	22 c	14 c	9 c	0.13 c	0.15 b
					November planting					
Complete protection[j]	0 a	0 a	0.0 a	0 0 a	1 a	0 3 a	0.3 a	0 a	0 92 a	1.20 a
Recommended practice[k]	1 b	2 b	0.3 a	0.0 a	4 b	4 b	2 b	2 b	0 75 a	1.07 a
Untreated	2 c	9 c	0.7 a	3 0 b	11 c	11 c	8 c	9 c	0.28 b	0 37 b
					December planting					
Complete protection[j]	0 a	0 a	0 0 a	0.0 a	0 a	0 a	0 a	0 a	1 04 a	1 22 a
Recommended practice[k]	1 b	0 a	0 0 a	0 0 a	3 b	2 b	0 a	0 a	0 63 b	0 82 b
Untreated	2 c	18 b	0 8 a	3.5 b	10 c	8 c	11 b	13 b	0 48 b	0 48 c

[a]Av of 4 replications (fields)/monthly planting DE = days after crop emergence, MT = minimum tillage, HT = high tillage. Separation of means in a column within each month by Duncan's multiple range test ($P = 0.05$) [b]*Ophiomyia phaseoli:* 25-plant sample. [c]*Medythia suturalis:* 25-plant sample. [d]*Thrips palmi:* 25 leaf-bud sample. [e]*Amrasca biguttula.* 25-plant sample. [f]*Aphis craccivora:* rating scale 1-9 on per-plant basis: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many indistinct coalesced colonies. [g]*Stomopteryx subsecivella·* 25-plant sample [h]*Heliothis armigera:* 25-plant sample [i]20-m^2 sample. [j]0 5 kg a.i. monocrotophos (Azodrin 168 EC)/ha, 2, 9, 16 DE; 0.03 kg a.i. decamethrin (Decis 2.5 EC)/ha 25, 35, 45 DE. [k]0 25 kg a.i. monocrotophos/ha 2, 12 DE; 0 75 kg a.i. carbaryl (Sevin 85 WP)/ha 25, 35 DE.

ber (87%), October (70%), December (58%). This is in marked contrast with previous years' trials in which December plantings had extremely high yield losses. The difference between years was attributed to a relatively low *Heliothis* population on the December 1979 planting.

The mungbean variety used (CES 1D-21) was observed to be less resistant to powdery mildew than in past years. Powdery mildew incidence was greatest in the December planting. Because no fungicide was sprayed on the plots, the December yields were lower than their potential.

Compared with high tillage the effect of rice stubble (minimum tillage) in reducing preflowering insect pests was greatest with leafhoppers and aphids. Less consistent results occurred with bean fly and thrips over the monthly plantings. Leafminer and flea beetle were neutral in the presence

Table 39. Incidence on crops of diseases caused by *Sclerotium rolfsii* isolated from various hosts. IRRI, 1980.

Source of isolate	Disease incidence or severity[a]					
	Rice[b]		Sorghum	Mungbean	Cowpea	Peanut
	Dryland	Wetland				
			Preemergence damping-off (%)			
Cowpea	87 b	87 b	77 b	98 a	97 a	18 b
Peanut	98 a	98 a	79 ab	99 a	100 a	33 a
Mungbean	95 ab	95 ab	71 b	100 a	100 a	35 a
Rice	99 a	99 a	91 a	99 a	100 a	48 a
			Postemergence seedling infection(%)			
Cowpea	0	0	0	24 b	57 b	78 b
Peanut	0	0	0	97 a	100 a	100 a
Mungbean	0	0	0	97 a	100 a	100 a
Rice	0	0	0	99 a	96 a	97 b
			Infection of mature plants (%)			
Cowpea	38 b	38 a	6 a	97 a	33 b	89 a
Peanut	42 b	55 a	7 a	100 a	100 a	96 a
Mungbean	62 a	48 a	7 a	100 a	100 a	96 a
Rice	39 b	50 a	7 a	100 a	89 b	100 a

[a]Means of 3 replications. Within each disease, separation of means in a column by Duncan's multiple range test at the 5% level. [b]Tested on seedlings.

of stubble.

The recommended insect control practice gave significantly lower yields than complete control in October and December plantings. The recommended practice was as good as complete control in the 1978-79 trials. The 1979-80 results indicate that the recommendations should be retested.

Pathological relationship of diseases to crops *(Plant Pathology).* The rice stem rot pathogen *Helminthosporium sigmoideum* var. *irregulare* inoculum placed in the soil affected only slightly emergence of rice, sorghum, mungbean, cowpea, and peanut. After emergence of these crops, no infection was observed. Infection on mature rice plants

Table 40 Effect of chemical control of powdery mildew at 2 growth stages on grain yield of mungbean planted after rice[a] Pangasinan, Philippines, 1980.

Site	Fungicide[b] (g/liter H_2O)	Disease severity[c]		Yield (t/ha)	Yield increase (%) over check
		Vegetative	Flowering		
Pao	Thiophanate methyl (70% WP)				
	0 31	2 2 a	2.0 a	2 32 a	70
	Benomyl (50% WP)				
	0 30	2 1 a	1 7 a	2 38 a	75
	0.15	2.3 a	1.8 a	2.27 a	66
	Check	6.9 b	7.8 b	1.37 b	0 or —
Lipit	Thiophanate methyl (70% WP)				
	0.31	3.2 a	2 2 a	1.47 a	57
	Benomyl (50% WP)				
	0.30	3.0 a	2 4 a	1.36 a	45
	0.15	3.2 a	2.2 a	1 22 ab	30
	Check	7 9 b	7 9 b	0 93 b	0 or —

[a]Within each locality, separation of means in a column by Duncan's multiple range test at the 5% level [b]Applied as foliar spray 2 weeks before reading. Thiophanate methyl cost $2 90/120 g and benomyl, $6.70/100 g [c]0 = no infection, 1 = 1 to 5% leaf area infection, 9 = over 75%.

Table 41. Effect of chemical control of powdery mildew on grain yield of 2 mungbean varieties planted after rice.[a] Iloilo, Philippines, 1980.

Site	Fungicide[b] (g/liter H_2O)	Disease severity[c]				Yield			
		MG 50-10A		CES X-10		MG 50-10A		CES X-10	
		Flowering	Pod-forming	Flowering	Pod-forming	t/ha	%[d]	t/ha	%[d]
Rizal	Thiophanate methyl (70% WP)								
	0 31	3 5 a	2.0 a	2.3 a	1.4 a	0 35 a	150	0.39 ab	11
	Benomyl (50% WP)								
	0.30	3 3 a	1.9 a	2.4 a	1.3 a	0.28 ab	100	0.47 a	34
	0 15	3.6 a	2.2 a	2.4 a	1.6 a	0.26 b	86	0.45 a	29
	Check	5.4 b	3 0 b	3.5 b	2.7 b	0 14 c	0	0.35 b	0
Napnapan	Thiophanate methyl (70% WP)								
	0 31	4.4 a	3 3 a	2 0 ab	0 8 a	0.55 a	77	0.62 ab	19
	Benomyl (50% WP)								
	0.30	5.3 ab	3.5 a	1.6 a	1.1 a	0 44 ab	42	0.76 a	46
	0.15	6.1 b	3 1 a	3.1 b	1 0 a	0.44 ab	42	0.70 a	35
	Check	8.2 c	4.4 b	5.0 c	2.3 b	0.31 b	0	0.52 b	0
Cordova	Thiophanate methyl (70% WP)								
	0 31	6.0 a	4.0 b	7.0 ab	2.5 a	0.57 a	27	0.65 a	0
	Benomyl (50% WP)								
	0.30	6.5 a	3 1 ab	6 0 b	2.7 ab	0.54 a	20	0.71 a	9
	0.15	6.1 a	2 7 a	6.0 b	2.8 ab	0.51 a	13	0.74 a	14
	Check	8.0 b	5 8 c	7.6 a	3.9 b	0 45 a	0	0.65 a	0

[a]Within each site, separation of means in a column by Duncan's multiple range test at the 5% level [b]Applied twice as foliar spray 2 weeks before reading [c]Rated on a scale of 0-9, where 0 = no infection, 1 = 1 to 5% leaf area infected, 9 = over 75% [d]Over check.

Table 42 Effect of seed treatment with *Trichoderma* sp. isolated from dryland rice fields on the incidence on 2 legume crops of damping-off caused by *Rhizoctonia solani* and *Sclerotium rolfsii* in wetland soil. IRRI, 1980.

Treatment	Preemergence damping-off[a] (%)	
	Mungbean	Cowpea
	Sclerotium damping-off	
Trichoderma	6.00 ± 7 2	17.33 ± 5 8
Vitavax 300	0.67 ± 1.1	2.67 ± 1.1
Untreated	29 33 ± 1 1	40.00 ± 31.4
	Rhizoctonia damping-off	
Trichoderma	28 67 ± 11.7	17 33 ± 9.4
Terra-Coat L-205	12.67 ± 4.6	7 33 ± 5.0
Untreated	47 33 ± 40.8	18.67 ± 17.0

[a]Data taken 14 days after sowing.

in dryland and wetland plots was noted. On the other hand, *Sclerotium rolfsii* affected rice and other crops before and after emergence (Table 39).

Chemical control of powdery mildew of mungbean *(Plant Pathology).* The efficacy of benomyl and thiophanate methyl on powdery mildew of mungbean was tested at two cropping system sites in Pangasinan and five sites in Iloilo.

At Pangasinan, foliar sprays 22 and 36 DE significantly reduced disease severity 2 weeks after each application (Table 40).

At three Iloilo sites the effect on mungbean yield of thiophanate methyl and benomyl against powdery mildew was also evident (Table 41). In Iloilo CES X-10 appeared to be more resistant to powdery mildew than MG 50-10A as shown by the lower disease severity rating. The effect of chemical control on yield of CES X-10, although significant, was less than on MG 50-10A.

Microbial activity on sclerotia-producing pathogens of legumes (*Plant Pathology*). In a preliminary survey of wetland paddies fungi potentially antagonistic to certain sclerotia-producing pathogens — *Sclerotium rolfsii* and *Rhizoctonia solani* — were seldom isolated from plant debris or soil after rice. A *Trichoderma* sp. was, however, frequently isolated from plant residues in dryland rice fields. The *Trichoderma* sp. was capable of minimizing the incidence of preemergence damping-off of legumes caused by *S. rolfsii* or *R. solani* in the greenhouse. The saprophyte appeared to be more effective on *S. rolfsii* than on *R. solani,* especially on cowpea (Table 42). Infestation with the saprophyte adversely affected the pathogens' survival (Table 43).

The *Trichoderma* sp. had a higher cellulolysis adequacy index (3.4) than both *R. solani* (0.66) and *S. rolfsii* (1.64), suggesting that it could decompose organic matter such as rice straw better than the pathogens (Table 44). But because of the relative fast growth rate of *R. solani,* the efficiency of *Trichoderma* sp. to minimize the incidence of legume damping-off initiated by *R. solani* depends on the size of its inoculum and perhaps other sources of nutrients available to the pathogen before infection.

Table 44. Cellulolysis adequacy index (CAI) of *Rhizoctonia solani* and *Sclerotium rolfsii* from component crops, and of *Trichoderma* sp., a saprophytic fungus isolated from dryland rice soil. IRRI, 1980.

Organism	Loss of straw wt[a] (%)	Rate of linear growth (mm/day)	CAI
Rhizoctonia solani from			
Mungbean	29 6	53	0.56
Cowpea	35.4	45	0.79
Maize	35.8	56	0.64
Sorghum	32.7	47	0.69
Rice (dryland)	30.1	48	0.64
Sclerotium rolfsii from			
Rice	22.5	20	1 10
Mungbean	29.7	16	1.84
Cowpea	28 3	16	1.79
Peanut	29.7	16	1.84
Trichoderma sp.	34.6	10	3.40

[a]Based on control, 7 weeks after incubation.

Table 43. Influence of a *Trichoderma* sp. isolated from IRRI dryland rice fields on the survival of *Sclerotium rolfsii* and *Rhizoctonia solani,* the causal agents of legume damping-off in dryland fields. IRRI, 1980.

Treatment[a]	Sclerotia in soil (no./100 g wet wt)	Recovery from crop debris in soil[b] (%)		
		S. rolfsii	*R. solani*	*Trichoderma*
Trichoderma alone	0.0	0.0	0.0	72.6 ± 6.4
S rolfsii alone	27.0 ± 14 6	48.6 ± 8.5	0 0	0.0
S. rolfsii + *Trichoderma*	20.7 ± 16.5	1.1 ± 1 0	0.0	9.5 ± 1.1
R. solani alone	9.5 ± 1 7	0.0	32.9 ± 10.5	0.0
R solani + *Trichoderma*	1 7 ± 1 3	0.0	3.5 ± 1.8	77.5 ± 18.7

[a]The inoculum was incorporated in dryland soil autoclaved for 3 days before sowing of mungbean and cowpea. [b]Based on isolation of mycelium growth from plant residues in 500 g of wet weight soil per replication. Replicated 3 times.

Table 45. Effect of fungicide application on relationship between main rice crop infection of stem rot and ratoon crop development IRRI, 1980.

Benomyl-thiram[a] application at	Main crop		Ratoon crop				
			Tillers (no./hill)		Lodging		Yield (t/ha)
	Stem rot (%)	Yield (t/ha)	Basal	Nodal	Tillers (no.)	With stem rot (%)	
Seed	84	8.1	10.1	8.1	66	57	1.3
Maximum tillering	86	7.8	12.0	6.4	57	51	1.4
Grain filling	83	7.7	10 5	6.2	41	67	1.3
Seed + maximum tillering	80	6.7	11.5	5 6	91	45	1.5
Seed + grain filling	59	7 4	12.2	8.8	83	39	1.6
Maximum tillering + grain filling	61	7.5	12.0	8 5	58	36	1 6
All three stages	60	8.3	11.4	10.0	42	14	1.8
Check	85	7 3	10 2	7.0	119	86	1 2

[a]1 g/liter H_2O.

Ratoon rice diseases (*Plant Pathology*). When the main crop of IR32 was treated with benomyl-thiram, the severity of stem rot caused by *Helminthosporium sigmoidea* var. *irregulare* was generally less than that in untreated plants (Table 45). The ratoonability of the main crop was also improved by the treatment although the increase in ratoon tillers was not significant. Lodging and stem rot of ratoon tillers decreased.

Yellow dwarf was observed on the ratoon crop but not on the main crop. The incidence of sheath blight increased on the ratoon crop. Other major diseases to which IR32 was resistant were not noted on the ratoon rice.

CULTIVAR TESTING

Multiple Cropping Department

Elite lines and cultivars from the screening program of the University of the Philippines' Institute of Plant Breeding at Los Baños were used in 1980 cultivar tests. Dryland crop cultivars were selections from materials from the breeding programs of the Asian Vegetable Research and Development Center (AVRDC), International Institute of Tropical Agriculture (IITA), International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), and national programs in the Philippines, Thailand, Burma, and Indonesia. The rice cultivars were all from IRRI. The trials were in dryland and wetland fields at high and zero tillage levels at IRRI and at the cropping systems research sites in Oton (Iloilo) and Manaoag (Pangasinan).

Rice. In the 1980 wet season, 17 promising early-maturing and 17 medium-maturing selections were dry-seeded in rainfed wetland fields at IRRI. Among the early-maturing selections, IR13204-3-3-3-2 and IR19743-25-2-2 yielded 4.0 and 3.8 t/ha. IR50 and IR36 ranked sixth and ninth with 3.5 and 3.3 t/ha.

The earliest-maturing selection was IR19724-67-3, which was harvested 86 days after seeding. However, it had the lowest yield (2.3 t/ha) and was tallest (83 cm). IR13204-3-3-3-2 had relatively more filled grains per panicle than IR50 and IR36, but fewer productive tillers.

Among the medium-maturing selections, IR15318-2-2-2-2 yielded 5.3 t/ha. IR54 yielded 3.8 t/ha and matured in 117 days. IR42 ranked second with 4.9 t/ha and matured in 133 days. The high yielding entries were generally taller than the low yielding ones.

Mungbean. *Dry season trials.* In the 1979-80 dry season, 14 mungbean cultivars were evaluated after wetland rice with zero tillage at IRRI and with zero and high tillage at Iloilo and Pangasinan.

With zero tillage, CES 1D-21, EG MG 174-3, and CES X-10 yielded highest (av 1.2 t/ha) at IRRI. A high average yield (1.1 t/ha) in the trial was attributed to good growing conditions, particularly rainfall and solar radiation, that prevailed throughout the crop period.

At Iloilo, a high average yield (1.5 t/ha) was also obtained with zero tillage. CES 1T-2 and CES 14 yielded 1.9 t/ha. Both varieties outyielded CES 1D-21, which ranked 12th with 1.5 t/ha. The yield differences were due to powdery mildew, to which CES 1D-21 did not show the tolerance shown at

IRRI and Pangasinan.

The Pangasinan trials suffered from drought during the critical growth stages of the crop and thus gave a low average yield (0.7 t/ha). CES 14, CES X-10, CES 1T-2, and CES 1D-21 were the top yielders in the Pangasinan test. With high tillage, the most promising cultivars in Pangasinan were CES 1T-2 and CES 14 with 0.8 and 0.7 t/ha. They also had highest yields with zero tillage. The high-tillage planting in Pangasinan was established later than zero tillage because wetness of the field hindered tillage. The crop had low yield because it depended solely on the low rainfall after planting.

Wet season trials. During the 1980 wet season, 11 mungbean cultivars were also evaluated with high tillage before wetland rice at IRRI, Iloilo, and Pangasinan to verify the 1979 wet season tests. The trials verified the profitability of growing mungbean before wetland rice. The most promising cultivars for a crop before rice were CES J-2Y, M350, EG MG 174-3, MG 50-10A (Y), and CES 1D-21. Those cultivars have growth duration of less than 70 days.

Cowpea. In the 1978-79 dry season, 13 indeterminate cowpea cultivars were evaluated with zero tillage after wetland rice at IRRI, Iloilo, and Pangasinan. The same entries were also tested in high tillage wetland fields in Iloilo and Pangasinan.

With zero tillage in IRRI, three entries outyielded EG #2 in dry bean and green pod production. The top dry bean yielders were All Season, Vita 3, and TVx-289-4G with 1.3, 1.2, and 1.2 t/ha. They were also the top producers of green pods —8.9, 7.1, and 5.6 t/ha. In addition they exhibited the best tolerance for fungus diseases, especially Fusarium stem and root rot. In Iloilo, the average yield of all cultivars was 1 t/ha. In Pangasinan, the trials suffered from drought after planting. TVx-6-4H and EG #2 had highest yields (0.8 and 0.7 t/ha) of dry beans.

With high tillage, yield levels in the Iloilo and Pangasinan trials were lower than those with zero tillage because of reduced stand of crop caused by lack of moisture after planting. Average yields of trials in Iloilo and Pangasinan were 0.6 and 0.4 t/ha.

Two uniform cultivar trials from IITA were tested on IRRI upland fields under high tillage. Among the indeterminate cultivars, Vita 4 and TVx-2949-03D were the top yielders with 2 t dry beans/ha. EG #2, the check variety, had a yield of 1.6 t/ha. Average yield of all cultivars was 1.8 t/ha. All the determinate cultivars yielded less than 1 t/ha. TVx-1836-015J was highest yielder with 0.9 t/ha.

Bush sitao. Eleven promising cultivars of bush sitao were evaluated with high tillage before wetland rice and zero tillage after wetland rice at IRRI.

In the test before rice, BS_4 (MP × 21), BS_2 (MP × 21), and Los Baños Bush Sitao #1 had highest yields of 10.2, 8.3 and 6.6 green pods/ha. Those are determinate cultivars with an average growth duration of 75 days. In addition, they possess smooth pods, a character highly preferred by consumers.

After rice, 8 bush sitao cultivars had a green pod yield of more than 7 t/ha. Los Baños Bush Sitao #1 and UPLB BS_2 had the highest yields (8.5 and 8.3 t/ha). They also yielded 0.8 and 0.9 t dry beans/ha.

Soybean. In the 1979-80 dry season, nine promising soybean cultivars were evaluated with zero tillage after wetland rice at IRRI. Ten cultivars were tested in wetland fields with zero and high tillage in Iloilo and Pangasinan.

With zero tillage at IRRI, lines 50106-4-7 and 40142-0-54 gave the highest yield of 0.6 and 0.5 t/ha. The trial was planted 5 December 1979. Yields were low for all cultivars because of moisture stress during the onset of the reproductive stage of the crop. Photoperiod sensitivity of most of the entries also contributed to low yield.

At Iloilo and Pangasinan, the trials suffered from excess moisture during the early seedling stage, and damping-off of seedlings reduced plant stand. At Iloilo, UPLB SY-2 and Clark 63 gave the highest yields (0.4 t/ha). At Pangasinan, 2120, a selection from AVRDC, gave the highest yields of 1.2 t/ha with zero tillage and 1 t/ha with high tillage. It matured in 84 days but had the tallest plants (93 cm) and lowest seed weight (6 g/100 seeds).

Peanut. Initial testing of peanut cultivars was in wetland fields with zero tillage at IRRI during the 1979-80 dry season. The trial was planted in a clay loam soil by dibbling the seeds at the base of the rice stubble after harvest of a puddled transplanted rice. Average yield of 10 cultivars was more than 1 t/ha. The most promising entries were CES 103, Acc 12, Kidang, P1 18200, and M-10 with yields of 1.5 to 1.3 t/ha.

In Iloilo and Pangasinan, trials were in wetland fields with high tillage. CES 102 and F334-33 were the highest yielders in Iloilo with 1.1 t/ha. Other promising entries were UPLB PN 2 and Acc 12, which yielded 1 t/ha. In Pangasinan the trial failed because of severe drought.

Maize. Twelve maize cultivars were evaluated with zero tillage in a wetland field at IRRI during the 1979-80 dry season.

Prolific DMR Comp. 1, Prolific DMR Comp. 2, and Early DMR Comp. #1 were the top yielders with 2.4, 2.3, and 2.5 t shelled grains/ha. All three cultivars matured in 98 days and yielded an average of 2.4 t/ha.

In Iloilo and Pangasinan, no trials were established after rice because previous results showed the nonadaptability of most of the cultivars now available.

Sorghum. In the 1979-80 dry season, elite lines, varieties, and hybrids were evaluated with zero tillage in wetland fields at IRRI, and with zero and high tillage in Iloilo and Pangasinan.

At IRRI, CS 226 gave the highest yield (3.7 t/ha). CS 225 ranked second with a yield of 3.1 t/ha. Both lines matured in 100 days. UPLB SG-5 ranked fifth with 2.7 t/ha. No yield data were obtained from Pioneer Hybrid 8417 because of heavy bird damage.

In Iloilo, the highest yields with zero tillage were from IS 2940 (2.9 t/ha) and Pioneer Hybrid 8417 (2.7 t/ha).

In Pangasinan, the promising entries with zero tillage were D67-4, CS 217, CS 182, and UPLB SG-5, which yielded 2.7, 2.5, 2.3, and 2.3 t/ha. UPLB SG-5 yielded 2.7 t/ha in a 1979 trial.

With the high tillage, CS 232 and CS 225 yielded more than 5 t/ha in Iloilo. Both matured in 97 days. Yield was almost 80% higher from high tillage than from zero tillage.

In Pangasinan, cultivars tested with high tillage had only 2% yield advantage over those with zero tillage. IS 2940 and UPLB SG-5 had highest yields of 2.5 and 2.3 t/ha. Average yield of all entries at both tillage levels was 2 t/ha.

Sweet potato. Eleven sweet potato cultivars were tested with zero tillage after wetland rice at IRRI, Iloilo, and Pangasinan.

Three cultivars yielded more than 20 t marketable tubers/ha at IRRI. The highest yielding entries were Minuras, Kinabakab, and Japan × $US_1 - 10$ with 23.4, 20.5, and 20.1 t/ha. The high yields were attributed to sufficient moisture and high solar radiation throughout the growing period. BNAS 51, the recommended variety for cropping pattern testing, yielded 16 t/ha.

In Iloilo, a local variety outyielded all introduced cultivars with 19.7 t marketable tubers/ha. The low yield (av 10 t/ha) of the introduced cultivars was caused by damage of planting materials during transport and a 4-day delay in trial establishment.

In Pangasinan, Kinabakab gave the highest yield of marketable tubers with 11.4 t/ha. Next highest were Catanduanes, Tinipay, and Minuras with 11.1, 10.6, and 10.1 t/ha. BNAS 51 yielded only 3.2 t/ha. Low yields in Pangasinan were caused by weevils.

Sesame. Seven sesame cultivars from Thailand were evaluated with high tillage in dryland fields during the 1979-80 dry season at IRRI. The most promising entries were Nakornsawan, TK 3, and Pitsanulok with seed yields of 1.2, 0.9, and 0.8 t/ha. Those cultivars exhibited good seedling vigor.

Chickpea. A dryland yield trial of 16 chickpea cultivars from ICRISAT was conducted with high tillage during the 1979-80 dry season at IRRI. Accessions 78073, 78031, 78043, and 5003 were the highest yielders (0.8-0.7 t/ha). Accessions 4951, 552, and 4918 had early maturity and the twin-podded characteristic.

Black gram. Five black gram cultivars from Thailand were tested with high tillage in dryland fields during the 1979-80 dry season at IRRI. Yield levels were low for all cultivars because of rust disease. Average yield of the entries was only 0.4 t/ha.

Cropping systems program

Preproduction evaluation

Rice Production Training and Research Department

A cooperative applied research project with the Philippine Council for Agriculture and Resources Research (PCARR) and the Ministry of Agriculture continued during 1980. An azolla trial and a nitrogen fertilizer efficiency trial were added.

Varieties for direct seeding in dry soil. Three IRRI varieties and seven promising selections were direct-seeded in dry soil at five sites in four Philippine provinces (Table 1). Only in Pampanga did any selection (IR19743-25-2-2) significantly outyield IR36.

Herbicide trials. Three herbicides and five herbicide combinations were evaluated on IR36 direct-seeded in dry soil at four sites in the Philippines.

All herbicide treatments gave rice yields significantly greater than those in the unweeded control (Table 2). At Malasiqui (Pangasinan) and Apalit (Pampanga), a combination preemergence application of thiobencarb (2.0 kg a.i./ha) and oxadiazon (0.25 kg a.i./ha) resulted in rice yields significantly higher than from plots hand-weeded twice (15 and 35 days after emergence [DE]). At the three other sites, none of the herbicide treatments gave rice yields significantly different from those of the

Table 1. Grain yield of 3 varieties and 7 promising selections direct-seeded in the dry soil at the start of the rainy season at 5 sites in 4 provinces in the Philippines, 1980 wet season.

Variety or selection	Yields[a] (t/ha)				
	Malasiqui, Pangasinan	Koronadal, South Cotabato	Zamboanga del Sur: Pagadian	Zamboanga del Sur: Dumalinao[b]	Macabebe, Pampanga
IR36	3.8 a	5.3 a	5.9 a	2.4 b	4.2 b
IR50	4.8 a	1.7 c	4.6 ab	1 3 bc	5.4 ab
IR52	4.4 a	3.9 bcd	2.0 c	3.8 a	4.0 b
IR9209-181-3-5	3.7 a	2.7 de	4.1 b	0.8 c	4.9 ab
IR9209-249-1-2-3-2	4.1 a	5.2 ab	4.7 ab	1.0 c	4.8 ab
IR9752-2-1-2-1	3.5 a	5 1 abc	5 2 ab	2.0 bc	4.5 b
IR13419-22-1	0.7 a	3.1 d	5 0 ab	2 6 ab	5.3 ab
IR19729-5-1-1	3.3 a	3 7 cd	4 6 ab	0.6 c	4 5 b
IR19743-25-2-2	4 4 a	3 3 d	5.4 ab	0 9 c	6.1 a
IR19746-28-2-2	4.2 a	3.8 cd	5.3 ab	0.8 c	4.8 ab

[a]Mean of 3 replications Separation of means by Duncan's multiple range test at the 5% level. [b]Heavy rat damage reduced yields.

Table 2. Effect of weed control treatments on grain yield of IR36 direct-seeded in dry soil at 4 sites in the Philippines, 1980 wet season.

Treatment	Time of application[a]	Rate of application (kg a i./ha)	Grain yield[b] (t/ha)				Toxicity rating[d]
			Malasiqui, Pangasinan	Apalit,[c] Pampanga	Norala, South Cotabato	IRRI, Laguna	
Butachlor	Pre-E	2.0	3.9 bc	1.6 bc	4.5 a	4.4 a	2.3
Pendimethalin	Pre-E	2 0	3.5 bc	2.0 ab	4.0 a	4.1 ab	3.6
Oxadiazon	Pre-E	0.75	4.0 bc	1.9 ab	4.4 a	4.5 a	2.7
Butachlor + oxadiazon	Pre-E	1.5 + 0.25	3.9 bc	1.8 abc	4.6 a	4.0 ab	3.8
Pendimethalin + oxadiazon	7-10 DE	1.5 + 0.25	3 2 bcd	2.2 ab	4.2 a	3.4 ab	3.0
Pendimethalin + propanil	7-10 DE	1.5 + 1.5	2 3 d	1.7 bc	3.8 a	3.1 b	3 8
Thiobencarb + oxadiazon	Pre-E	2.0 + 0 25	5.2 a	2.8 a	4.2 a	4.0 ab	2.8
Thiobencarb + propanil	7-10 DE	2.5 + 1.25	2.9 cd	2.4 ab	3.8 a	3 9 ab	4.3
Unweeded control	—	—	0.6 e	0.8 c	2.0 b	2.0 c	0
Hand-weeded control (2x)	15, 35 DE	—	4.2 b	2.1 ab	4.8 a	4.4 a	0

[a]Pre-E = preemergence, DE = days after rice emergence. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. [c]Trial site yields were affected by floods during typhoons. [d]0 = no injury, similar to unweeded and hand-weeded plots; 10 = all plants killed.

Table 3. Grain yield of IR36 at 4 methods of nitrogen fertilizer application, transplanted in wetland irrigated farmers' fields at 11 sites in 7 provinces in the Philippines, 1980 wet season.

Method of applica-tion[a]	Yields[b] (t/ha)										
	Pangasinan		Pampanga		Iloilo	South Cotabato		North Cotabato		Zamboanga del Sur	Laguna
	Catablan, Urdaneta	Torre Neog, Mangatarem	Sucad, Apalit	Sampaloc, Apalit	Nambog Oton	Magsaysay, Koronadal	Poblacion, Norala	Kalaisan, Kidapawan	Saguing, Makilala	Tawagan Sur, Pagadian	IRRI
PC	6.1 a	4.8 b	5.3 a	4.9 a	6.5 a	5.4 a	4.8 a	2.8 a	2.8 a	4.5 a	5.0 a
PS	5.3 a	4.8 b	5.3 a	5.3 a	6.1 a	5.3 a	4.6 a	2.9 a	2.4 ab	4.7 a	5.1 a
SG	6.0 a	5.6 a	4.9 a	4.1 b	6.0 a	5.5 a	4.8 a	2.5 a	2.7 a	4.6 a	5.3 a
SP	5.4 a	5.3 ab	5.0 a	4.0 b	5.7 a	5.3 a	4.5 a	2.6 a	2.5 ab	4.5 a	5.4 a
Check	4.0 b	5.0 ab	4.5 a	3.0 c	4.9 b	3.9 b	3.5 b	2.4 a	1.7 b	4.3 a	4.8 a

[a]Rate is 60 kg N/ha. PC = all nitrogen fertilizer applied basal in the plow sole, using the IRRI-designed handtractor-drawn plow sole applicator. PS = all nitrogen fertilizer applied basal, hand-drilled in the plow sole, using the carabao-drawn native plow. SG = nitrogen supergranules applied at the center of every 4 hills 1 day after transplanting (DT). SP = nitrogen fertilizer applied in 2 split applications, 40 kg N/ha basal before final harrowing + 20 kg N/ha topdressed at 25-30 DT. Check = control plot, no fertilizer applied. [b]Means of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 4. Grain yield of IR36 in an azolla-treated plot and at 5 best-split nitrogen levels in irrigated-transplanted fields at 9 sites in 5 provinces in the Philippines, 1980 wet season.

Treatment[a]	Yield[b] (t/ha)								
	Pangasinan		Pampanga		Pampanga	North Cotabato		Zamboanga del Sur	Laguna
	Catablan, Urdaneta	Torre Neog, Mangatarem	Sucad, Apalit	Sulipan, Apalit	Saplad David Macabebe	Kalaisan, Kidapawan	Singao, Kidapawan	Tiguma, Pagadian	IRRI
AZ	3.4 c	4.2 b	4.3 a	4.1 a	3.6 ab	3.8 a	5.9 a	3.6 b	5.0 a
BS 40	4.5 b	4.4 ab	4.7 a	4.2 a	3.7 ab	3.7 a	5.1 b	4.4 a	4.7 a
BS 60	4.2 bc	5.0 a	5.0 a	4.2 a	3.9 abc	4.1 a	4.5 b	4.1 ab	5.2 a
BS 80	4.2 bc	4.8 ab	5.0 a	4.6 a	4.3 ab	3.9 a	4.4 b	4.0 ab	5.0 a
BS 100	5.5 a	4.7 ab	4.2 a	4.8 a	4.5 a	3.4 a	5.0 b	4.5 a	5.4 a
Check	3.8 bc	4.1 b	4.2 a	4.0 a	3.3 b	3.5 a	5.0 b	4.2 ab	3.7 b

[a]AZ = azolla inoculation at 2 and 12 days after transplanting and incorporation 10 days later. BS 40 = basal: 30-20-20, topdressing: 10-0-0 (TD). BS 60 = basal: 45-20-20, TD: 15-0-0. BS 80 = basal: 60-20-20, TD: 20-0-0. BS 100 = basal: 80-20-20, TD: 20-0-0. Check = basal: 0-20-20, TD: 0-0-0. [b]Means of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

hand-weeded treatment. All herbicides were toxic to rice to some degree; butachlor at 2 kg a.i./ha was least toxic.

Nitrogen fertilizer efficiency. Nitrogen fertilizer efficiency trials were planted in farmers' fields at 11 sites (Table 3). Eight sites had no difference in crop yields among the four methods of nitrogen fertilizer tested. Supergranules (SG) proved superior to both plow-sole application methods (PS) and (PC) in Mangatarem, Pangasinan. The reverse was seen in Apalit, Pampanga. At most sites there were no significant differences among treatments.

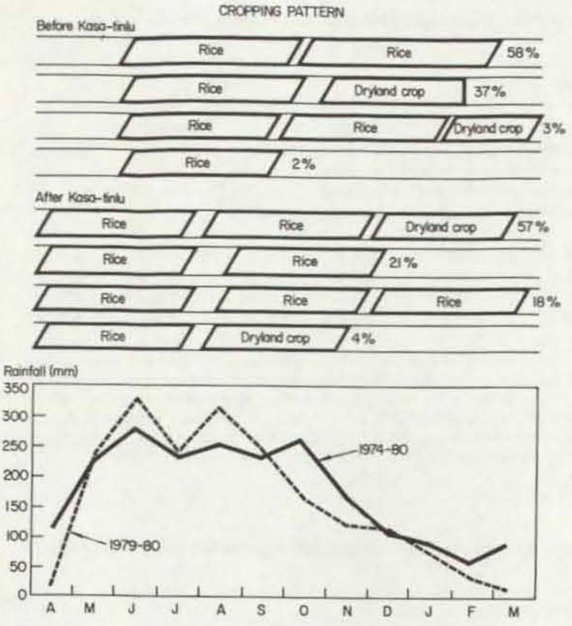
Azolla trials. Azolla applied research trials were at 9 sites (Table 4). At IRRI, Azolla and all nitrogen treatments gave significantly higher yields than the check. Only at Singao, North Cotabato, did the azolla-treated plots give significantly higher yields than any other treatment. Results of the trials during the wet season showed no general trend.

PILOT PRODUCTION PROGRAMS

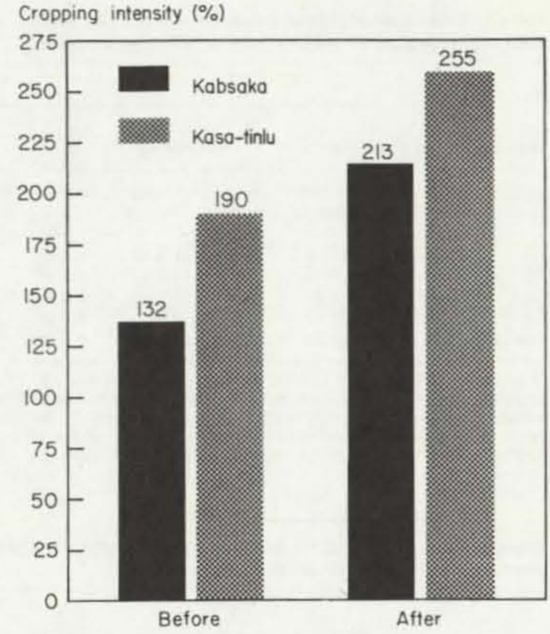
During 1980, five pilot programs were in progress in the Philippines.

Kabsaka. During 1980, the Kabsaka pilot production program in Iloilo became a full-scale production program. The Philippine Government obtained a World Bank loan to fund a province-wide development project, based on the promising results of previous years. Kabsaka technology was extended to other provinces in the region.

Kasa-tinlu. The Kasa-tinlu pilot production



1. Cropping pattern changes of 74 farmers before and after Kasa-tinlu, plotted against the average annual rainfall distribution. South Cotabato, Philippines, 1980.



2. Cropping intensity changes following implementation of Kabsaka and Kasa-tinlu pilot production programs. Philippines, 1980.

program in South Cotabato was evaluated. Seventy-four Kasa-tinlu farmers in Norala were surveyed to determine the impact of the program on cropping patterns adopted, cropping intensity, crop yields, and capital asset accumulation.

Cropping patterns. Before Kasa-tinlu, the most common cropping pattern was rice − rice (58%) — 37% of the respondents grew only one rice crop, followed by a dryland crop. After the program, the major cropping patterns were rice − rice − dryland crop (57%), rice − rice (21%), and rice − rice − rice (18%) (Fig. 1).

It was also found that the method of establishing the first rice crop changed dramatically from transplanting to dry seeding (Table 5). As a result of the shift in cropping pattern and crop establishment method, the cropping intensity increased from 190% to 255% after implementation of Kasa-tinlu. This was a comparatively higher intensity than that obtained after Kabsaka (Fig. 2).

Yield. Farmers' yields for 2 rice crops increased from 8.6 to 9.3 t/ha (Table 6).

Table 5. Rice establishment for 74 farmers with various cropping patterns[a] before and after Kasa-tinlu. South Cotabato, Philippines, 1980.

Before Kasa-tinlu		After Kasa-tinlu	
Cropping patterns	Area planted (%)	Cropping patterns	Area planted (%)
Rice — rice		Rice – rice – DC	
TPR–WSR	43	DSR–WSR–DC	49
WSR–WSR	8	DSR–TPR–DC	8
TPR–TPR	7		
Rice — dryland crop (DC)		Rice – rice	
TPR–DC	29	DSR–WSR	17
WSR–DC	8	DSR–TPR	4
Rice — rice — DC		Rice – rice – rice	
TPR–WSR–DC	2	DSR–WSR–WSR	9
TPR–TPR–DC	2	DSR–TPR–WSR	5
		DSR–TPR–TPR	2
		DSR–WSR–TPR	2
Rice–fallow		Rice – DC	
TPR–fallow	2	DSR–DC	4

[a]TPR = transplanted rice, WSR = wet-seeded rice, DC = dryland crop.

Table 6. Mean yields[a] obtained from pilot extension phase of Kasa-tinlu program, South Cotabato, Philippines, crop year 1978-80.

Year	Yield (t/ha)		
	First crop	Second crop	Total
1978	4.6	4.0	8.6
1979	4.7	4.3	9.0
1980	4.8	4.5	9.3

[a]Source: BAEx, Koronadal, South Cotabato.

Table 7. Farm capital assets acquired by 58 farmers in Kasa-tinlu, South Cotabato, Philippines, 1979-80.

Item	3 or more years in Kasa-tinlu (n = 31)		2 years in Kasa-tinlu (n = 27)	
	Farmers reporting (%)	Units (no.)	Farmers reporting (%)	Units (no.)
Four-wheel tractor	—	—	4	1
Irrigation pump	10	3	7	2
Thresher	3	1	7	2
Carabao	35	14	37	14
Plow	32	12	30	12
Harrow	29	9	22	6
Sprayer	35	12	26	7
Cart	19	6	19	5
Shovel	77	28	63	23
Scythe	90	101	89	62
Rice mill	—	—	4	1
Dryer	13	8	16	4
Farmland	—	—	7	2[a]

[a]3-ha farm.

Capital assets accumulation. High-value farm investments (4-wheel tractor, irrigation water pump, thresher) were acquired by a few farmers after implementation of Kasa-tinlu. Medium-value items (carabao) were more commonly acquired by farmers. Small farm items like plow, harrow, sprayer, shovel and scythe, were common in the list of farmers' acquired assets (Table 7).

Among household assets, radio-cassette (stereo) dominated the farmers' list (Table 8). Priority among farmers' investments was house repair (improvement) (Table 9).

Other programs. A rice − dryland crop pattern formed the basis of a program — code-named *Manbilayka* for Pangasinan, Central Luzon. Yields of Manbilayka participants' dry-seeded rice crops averaged 3.25 t/ha. Poor control of weeds and a drought at flowering time affected rice yields.

In Zamboanga del Sur and North Cotabato, new pilot production programs to grow two rainfed wetland rice crops — code-named *Zamdugani* and *Matisayon* — started.

Table 8. Household assets acquired after the Kasa-tinlu program, South Cotabato, Philippines, 1979-80.

Item	3 or more years in Kasa-tinlu (n = 31)		2 years in Kasa-tinlu (n = 27)	
	Farmers reporting (%)	Units (no.)	Farmers reporting (%)	Units (no.)
Radio-cassette (stereo)	58	18	33	9
Gas stove	10	3	15	4
Living-dining set	19	7	19	5
Refrigerator	—	—	4	1
Tricycle	—	—	7	3
Others[a]	—	—	4	2

[a]Electric fan, steam cooker.

Table 9. House improvement made by farmers in the Kasa-tinlu program, South Cotabato, Philippines, 1979-80.

Item[a]	Years in Kasa-tinlu (no.)	
	3 or more (n = 31)	2 (n = 27)
Farmers reporting (%)	17	11
Total value ($)	4818	6413
Av value per farmer ($)	283	583

[a]Values converted to US$ at the rate of US$1 = ₱7.5

Cropping systems program

Asian Cropping Systems Network

Multiple Cropping Department

THE ASIAN CROPPING SYSTEMS NETWORK

Twenty-six operational research sites were included in the Asian Cropping Systems Network in 1980 (Table 1). In addition, national programs in Bangladesh, Burma, Indonesia, Philippines, Sri Lanka, and Thailand have formed national cropping systems networks. The number of sites rose from 55 in 1979 to 98 in 1980. China and Vietnam expressed their desire to join the network and collaborative work will begin in 1981.

NETWORK ACTIVITIES

Most activities at the network sites focused on the design and testing of cropping patterns, and research in related component technologies such as varietal testing, fertilizer studies, and pest control. A number of sites started multilocational testing and pilot production programs. The developments stimulated collaborative work on methodological problems related to the extrapolation of technologies developed at sites and their transfer to wider groups of farmers.

Lack of dryland crop varieties and related technologies for prerice and postrice environments was identified as a major constraint to developing more productive cropping patterns in rice-based systems.

Highlights of the activities in the network sites follow:

Bangladesh. The Bangladesh Rice Research Institute (BRRI) cropping systems program collaborates with a number of other agencies to provide technical and material inputs to 24 research sites in addition to 4 BRRI sites. The first annual review meeting of the BRRI-coordinated network was held in June 1980.

Table 1. Asian Cropping Systems Network research sites, 1980.

Country	Year program was initiated	Sites (no.)	Sites (no.) in network
Bangladesh	1976	28	3
Burma	1980	7	3
India	1980	1	1
Indonesia	1974	23	3
Korea	1977	3	3
Malaysia	1977	2	2
Nepal	1977	6	2
Philippines	1974	15	2
Sri Lanka	1976	7	3
Thailand	1975	6	4
Total		98	26

A survey of farmers' cropping patterns conducted in Bangladesh showed that more than 70% of the rainfed farms had double- or triple-cropping systems; more than 80% with irrigation had double- or triple-cropping systems.

At the rainfed Bhogra site a Chandina – BR4 pattern gave the highest yield (9.4 t/ha). The highest net return ($852/ha) came from the BR3 – Chinigura (a local high-quality rice) pattern, followed by Chandina – BR4 ($772/ha), which was developed by the BRRI cropping systems program.

At the Dandkandi site farmers' dominant patterns were deepwater rice (DWR) – wheat (43%), DWR – potato (18%), and DWR – mustard (14%). The average yield of deepwater rice ranged from 2.4 to 3 t/ha; Ari Raj and Vitali Bajal had yields of 3 t/ha.

Burma. Seven cropping systems research sites are operated by the national cropping systems working group of Burma, which was set up by the Agricultural Development Corporation and includes scientists from the Agricultural Research Institute. Three sites are included in the Asian network.

Shwelaungkyun is in Wakema Township in the delta area where the annual rainfall averages 2,388 mm and tidal flooding occurs. The predominant farmers' pattern is premonsoon jute sown in early March with pump irrigation, followed by transplanted rice in August. Rice is harvested in November and immediately followed with the sowing of either blackgram, maize, peanut, cowpea, or early sesame. Proposed new patterns are rice – pea / bean, rice – sunflower, rice – sesame, and jute – rice using improved varieties.

Sedawgyi is in the dry zone of Central Burma. It is served by irrigation and is on a flat topography between the Shan Plateau and Irrawaddy river. Rains start in March and end in October; average annual rainfall is 850 mm. There is usually a dry spell in July. Two soil types predominate — a heavy-textured dark clay and a loamy soil with crumb structure.

The major crop in the area is rice, usually sown in May or June. The patterns being tested are rice – grain legumes, rice – maize, and rice – sorghum.

Pyinmana (Yezin) is midway between Rangoon and Mandalay near the foot of the Shan plateau. About 6,500 ha in the area is irrigated; the rest is rainfed. Rains, which start in early May and end in October, are often erratic. Average annual rainfall is 1,415 mm. Temperatures are low (about 18° C) in December and January.

In irrigated areas the farmers' pattern is early sesame sown in March followed by transplanted rice in July. In rainfed areas, green maize and blackgram are sown in May and harvested in July and followed by transplanted rice in August. Sometimes peanut is sown after harvest of rice in October or early November.

Proposed patterns for irrigated areas are, sesame – rice, sesame – rice – grain legumes, sesame – rice – sunflower, and sesame – rice – maize or sorghum. For the rainfed areas, the proposed patterns are rice – maize or sorghum, rice – sunflower, and rice – chickpea. In all patterns the rice is established in June or early July.

India. In India, the collaborating institution is the Indian Council of Agricultural Research (ICAR). The site included in the Asian network is Ranchi, Bihar. It is a rainfed site with a short rainy season and soils with low water retention capacity.

Land in the site was classified into high, intermediate, and low elevation, and different cropping patterns are developed for each land class. Research activities at the site involved the participation of staff from the Ranchi Agricultural College (affiliated with the Rajendra Agricultural University). The agricultural engineering group is an important component. It has developed simple and inexpensive machinery for tillage and dryland crop establishment.

Indonesia. The Central Research Institute for Agriculture in Indonesia participates in the Asian network and has greatly expanded cropping systems research activities in the country. The national cropping systems network operates research sites in irrigated, rainfed, and tidal swamp ricelands as well as on the fragile upland soils of Sumatra, Kalimantan, and Sulawesi.

The cropping systems research is done within a farming systems framework with important crop-livestock interactions explicitly taken into account. Research into the intensive *sorjan* systems of raised beds and furrows has started at Sukoharjo, Central Java.

Asian network research is at three sites.

Madura includes dryland, rainfed wetland at low elevation, and rainfed wetland at high elevation. It receives more than 200 mm rainfall for 3 months and less than 100 mm for 5 months. The main constraint in all land categories has been low soil fertility. Higher rates of fertilizer application and band placement of phosphate with seed have given considerable yield increases. Dry-seeded rice (*gogorancah*) produces higher yields and net returns than transplanted rice in the two wetland land categories. Dry-seeded rice – maize + peanut had higher net returns than farmers' or other experimental patterns.

Tajau Pecah (Kalimantan) has had results similar to those obtained in upland areas of Sumatra. The most promising pattern with medium input is maize + dryland rice with cassava relay-planted into maize rows 30 days after planting and later cowpea replacing rice as an intercrop with cassava.

Barambai (tidal swamp site — Kalimantan) has its hydrology affected by rainfall and by tides. The fragile nature of these potentially acid sulfate soils requires long-term management strategies.

Adaptation of the furrow-bed (*sorjan*) system, to circumvent flooding for dryland crops and insufficient water for wetland rice, has proved to be important. The main problem is to determine the relative proportion of bed to furrow for different water regimes. The experimental patterns of intercropping maize + upland rice + cassava as raised beds and double-cropping rice in the furrow beds have shown promise.

Republic of Korea. The Office of Rural Development collaborates in the Asian network. Sites at Suweon, Iri, and Milyang represent temperate rice environments with good irrigation and drainage facilities.

An unusual cold spell during summer 1980 affected rice production throughout Korea and lowered overall production by an estimated 40%. Low air temperatures, insufficient sunshine hours, and heavy rainfall during mitosis to flowering stage (late July to early August) induced high sterility in rice, with the adverse effects being more pronounced in Tongil-type varieties than in the japonicas.

In Suweon, highest net incomes were obtained from the rice – wheat pattern followed by the rice – barley. In Milyang, the highest net income was from sweet maize – rice. The highest rice yields, however, came from the rice – potato pattern because the early planted rice (1 April) escaped the low temperatures. At Iri, the single-rice-crop pattern gave highest net returns, followed by pea – rice and wheat – rice. The cold temperatures had less effects on rice yields in Iri than on those elsewhere.

Nepal. The collaborating agency in Nepal is the Department of Agriculture. The integrated cereals project of the department, supported by the International Agricultural Development Service, has research at six sites.

By the end of 1980, at least three complete cycles of the predominant rice – and maize-based cropping patterns had been evaluated at five sites. A pilot production program was initiated in the spring of 1980 at Pumdi Bhumdi, a hill site near Pokhra. Similar programs were initiated in winter 1980 at Lele, Khandbari, and Chann Jahari.

Results of cropping pattern and component technology trials generally confirmed results obtained in past years. On the plains at Parsa, rice varieties Janki, Sabitri, and Laxmi yielded more than 3.5 t/ha in the first rainfed crop; the local varieties averaged 1.4 t/ha. The rice variety IET1444 was seen to be suitable for lowlands with medium or low production potential where soils are light-textured with low water-retention capacity.

In irrigated areas in Parsa, the improved varieties Chandina, Durgh, and Laxmi (av maturity, 120-125 days) had yields ranging from 3 to 4.2 t/ha. Local varieties averaged 1-2 t/ha when planted as the first crop. A variety suitable for planting as a second crop is yet to be found; the best available is Massuli, which yielded about 2 t/ha.

Philippines. In 1980 IRRI operated one cropping systems research site at Tuguegarao, Cagayan Valley, Philippines, where it cooperated with the Cagayan Integrated Agricultural Development Program and the Philippine Council for Agriculture and Resources Research (PCARR).

The Philippine national program substantially expanded cropping systems research activities in 1980. In addition to the research at the World Bank-assisted settlement sites at Agusan, Bukidnon, and Capiz, cropping systems research was initiated in eight provinces. Surveys for cropping pattern design were made in selected areas.

A national program to intensify crop production on 60,000 ha of rainfed rice in Iloilo was launched, using research results from earlier research activities. Plans also went ahead to develop production programs in the three settlement sites that have completed 2-3 years of research. Recommendations for suitable varieties and other component technologies for single crops were developed. UPLRI-5 was found to be the best variety for dryland fields at Bukidnon and Capiz and C171-136 performed best at Agusan. IR36 performed best in wetland paddies at all sites. CES-1D-21 was identified as the best mungbean variety for the sites.

Sri Lanka. A highly successful pilot production was launched in Sri Lanka based on technology developed at the cropping systems research site at Walagambahuwa, a minor-tank-based village. Research at the site is operated by the Department of Agriculture, which is the collaborating agency participating in the Asian network. The site is representative of about 10,000 minor-tank based villages in the dry zone.

Traditionally a farmer's rice is not planted until the tank is full. In the cropping system developed, rice is direct-seeded at the beginning of the rainy season and the tank water is used for supplementary irrigation later, if needed. After harvest of the first rice crop, either a second rice crop or a dryland crop is established, depending on available water in the tank. The system performed well in 1979-80 when rainfall was unusually low.

Close extension-research links facilitated spread of the system to other areas through pilot production programs. At the end of 1980 more than 200 tank-based villages had come into the program and the system was spreading rapidly. Major increases in rice and dryland crop production with consequent increases in farm income and employment took place.

At Katupota, a rainfed wetland site in the intermediate zone, more intensive patterns for different land categories were identified. Those are: rice – rice for the slopes and the valley bottom and rice – dryland crops for the west. A 75-day rice variety developed at the nearby Batalagoda rice breeding station was tested as the second rice crop on the slopes.

At the rainfed Manawari site at Paranthan, a short rainy season and low water-retention capacity of the soils make it extremely difficult to establish two-crop patterns. Research activities on irrigated systems in the area started in 1980 and two crop systems appear feasible.

Thailand. Cropping systems research in Thailand is in collaboration with the Rice Division, Department of Agriculture, at Ubon, PiMai, and a new site at Phrae; with the Technical Division of the Department of Agriculture at Khompangphet; and with Kasetsart University at Bangpae. The Division of Agricultural Economics collaborates with the Rice and Technical Division on the economics component. Four sites are in the Asian network.

Ubon is rainfed wetland with 5 wet months and 7 dry. After tests in 1980, the peanut – rice pattern was identified as the most stable pattern and most acceptable to farmers on fields that can be well-drained. Tinan 9, the recommended variety, must be established by the first week in May. No stable pattern has been identified for the easily flooded bottomlands or the upper paddies, which do not regularly grow a good rice crop.

Green maize was proven to be a high risk crop and mungbean yields were low.

PiMai is rainfed wetland with 1-2 wet months and 7 dry. No stable pattern has been identified. Drought and flooding are major constraints.

Phrae is rainfed wetland with 4 wet months and 6 dry. Research started in 1980. Patterns tested were rice (100 days) – rice, mungbean – rice – sweet maize, mungbean – rice – soybean, and sweet maize – rice – peanut. The 100-day rice performed poorly and a white sesame, which had shown promise in observation trials, will be substituted.

Bangpae is rainfed wetland with 1-2 wet months and 7 dry. The best patterns identified were mungbean – rice – mungbean, sweet maize – rice – mungbean, and glutinous maize – rice – mungbean. Large-scale evaluation of these patterns started in 1980.

CROPPING SYSTEMS CONFERENCE

A cropping systems conference was held at IRRI in March 1980. Developing countries of Asia were represented by participants from Bangladesh, Burma, China, India, Indonesia, Malaysia, Nepal, Korea, Sri Lanka, Thailand, and the Philippines. Progress reports of the country programs in the Asian Cropping Systems Network demonstrated that the site-related, on-farm research methodology was being actively used.

CROPPING SYSTEMS WORKING GROUP

The 9th Working Group meeting held at IRRI, followed the Cropping Systems Conference. The group discussed the experiences of the symposium, future research directions, and training needs.

The 10th Working Group meeting was held in the Republic of Korea in September. Program leaders from eight countries and IRRI attended the meeting. The group discussed progress in national programs, monitoring and reporting of cropping pattern testing, multilocation testing methodologies and country program experiences, pilot production program methodology, role of cropping systems research in farming system projects, and the economic evaluation of component technologies at design and testing. The group decided to intensify efforts to develop methodologies for preproduction evaluation of technologies developed at sites.

TRAINING

The rapid expansion in country programs raised training needs substantially. A major achievement in 1980 was the preparation of a manual on cropping systems research methodology, which elaborates on the methodology developed jointly by IRRI and national program cropping systems researchers. The manual will be published by IRRI in 1981.

The Asian network economics group decided in March to work toward a training manual on basic economic tools. A November meeting developed a draft, which will be evaluated and finalized in 1981.

The 6-month cropping systems training program at IRRI had 42 participants. A special 1-month training program in agricultural economics was held in October with participants (9) from Bangladesh, Burma, Indonesia, Sri Lanka, Thailand, and the Philippines.

Eighteen participants from six countries visited Philippine cropping systems sites in August 1980. They later divided into two groups. One group visited Indonesia and the other visited Nepal to discuss experiences in their national programs and relate those to what they found in the countries visited. The group in Indonesia was joined by five participants from Malaysia, Bangladesh, and the International Agricultural Development Service.

Machinery development and testing

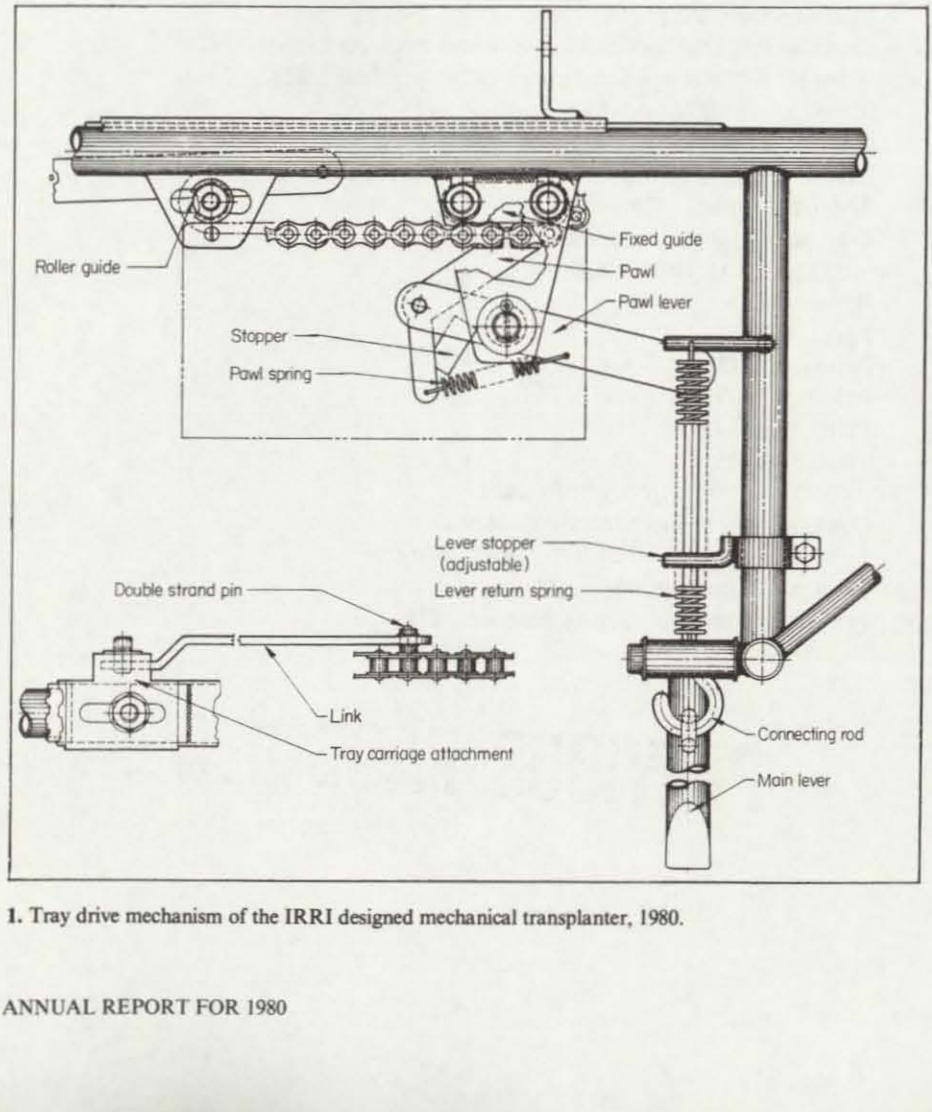
Agricultural Engineering Department

Transplanter. Changes in the design of the tray drive mechanism were made to simplify fabrication and reduce the cost of manufacturing the transplanter. In the new design a specially-shaped pawl, which meshes with the roller chain, is used to drive the chain. The pawl is pinned to one end of a lever whose other end is linked to the main drive lever (Fig. 1). Re-arrangement of the roller guides and the bar guide, with respect to the position of the pawl and lever assembly, eliminated one of the roller guides in the original design. The modification was extensively tested and no failure was observed.

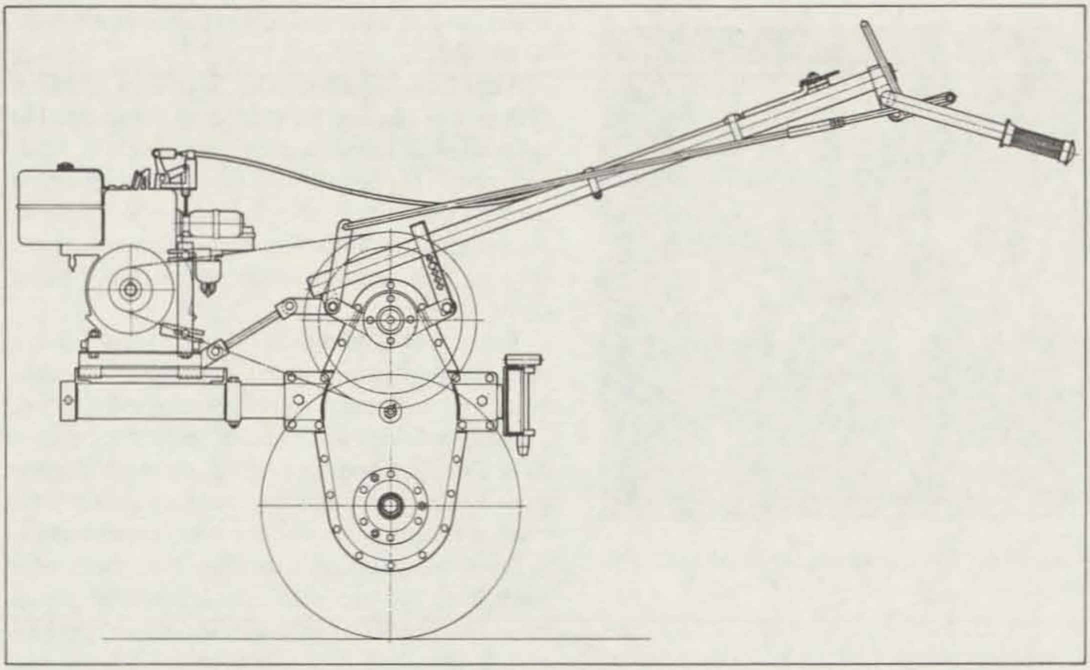
The transplanter was demonstrated in many areas of the Philippines. The design was released during the early part of the year and several local manufacturers have started production.

Two-wheel 3-hp tiller. Development of a 3-hp tiller started. The objective was a simple, low-cost, lightweight power tiller suitable for wetland tillage. An earlier economic study indicated that a 3-hp machine would be cheaper than custom hiring so long as it was operated on a minimum of 6.5/ha per year.

The design and fabrication of the first prototype (Fig. 2) were completed. The tiller weighs 67 kg, believed to be the ideal weight for soft, paddy wetland cultivation. The transmission is a two-step reduction with a total speed ratio of 1:15. Roller chain and sprockets were used throughout. The input and output shafts are mounted on ball bearings, and the intermediate shaft is fixed on the housing. The first drive sprocket and the second step drive sprocket are on a common hub that rotates on a bronze bushing on the intermediate shaft.



1. Tray drive mechanism of the IRRI designed mechanical transplanter, 1980.



2. IRRI-designed 3-hp tiller, 1980.

The split transmission housing is manufactured from 1.5-mm-thick mild steel using simple forming jigs. Double oil seals are provided on each of the axle bearings. The housing provides continuous oil bath lubrication for the bearings, roller chain, and sprockets.

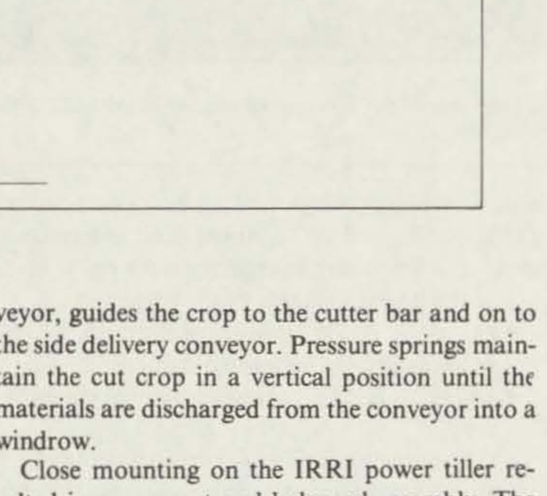
The engine base slides on rails fixed to the main frame. This permits engaging or disengaging of the drive through a toggle system link to a lever attached to the handle. The arrangement eliminates the use of an idler pulley, which shortens belt life.

Dryland and wetland tests were started to determine the durability and suitability of the tractor.

CAAMS-IRRI reaper project. A collaborative project was initiated with the Chinese Academy of Agricultural Mechanization Sciences (CAAMS) to adapt a Chinese-designed reaper-windrower to the IRRI power tiller. A team of three Chinese engineers collaborated in the adaptation.

The reaper is a vertical 1.6-m-wide unit with a side delivery conveyor (Fig. 3). The novel features of the design are the lifting and gathering mechanisms, which consist of an assembly of inclined star wheels and a set of pressure springs. The star wheel, driven by lugs attached to a vertical flat bed conveyor, guides the crop to the cutter bar and on to the side delivery conveyor. Pressure springs maintain the cut crop in a vertical position until the materials are discharged from the conveyor into a windrow.

Close mounting on the IRRI power tiller resulted in a compact and balanced assembly. The



3. The 1.6-m reaper in tests on a farm near IRRI, 1980.

4. Field tests of the 1.0-m reaper attached to the IRRI 3-hp tiller, 1980.

tiller and reaper weigh 240 kg and can operate effectively in mud up to 20 cm deep. At ground speed of 3 km/hour the capacity is 0.5 ha/hour.

Outstanding advantages of the reaper are:

- extremely gentle handling of the crop, which keeps shattering losses to a minimum;
- ability to handle lodged as well as standing crop;
- rice control at all times — rice does not fall free when the reaper is stopped or comes at the end of the field — and
- simple mechanical components that allow manufacture by small indigenous shops.

Changes were made in the original Chinese design to cut cost and simplify manufacture. A belt clutching drive is used instead of two sets of bevel gears and a dog clutch. A sickle guard assembly that can be locally fabricated using standard ledger plates was developed.

Because the 1.6-m reaper was too big for small plots such as those frequently encountered in the Philippines and in other areas of Asia, a 1-m unit was designed for attachment to the 3-hp tiller (Fig. 4). An important feature of the design was the quarter-turn belt drive used in lieu of bevel gears. Most of the other parts developed for the larger machine were used in the smaller unit. The 1-m reaper and tiller weigh 112 kg — which makes it suitable for soft wetland fields. The 1-m reaper has an estimated capacity of 2 ha/day, at 75% field efficiency, and an estimated cost of half as much as the larger reaper.

Axial-flow thresher. The axial-flow thresher (TH-8) was adapted for multicrop threshing. The cylinder was redesigned by replacing the alternative rows of pegteeth with rubber flaps, except at the feed side. The rubber flaps were bolted along the length of the angle bar. The system imparted a rubbing and impact action to materials being threshed.

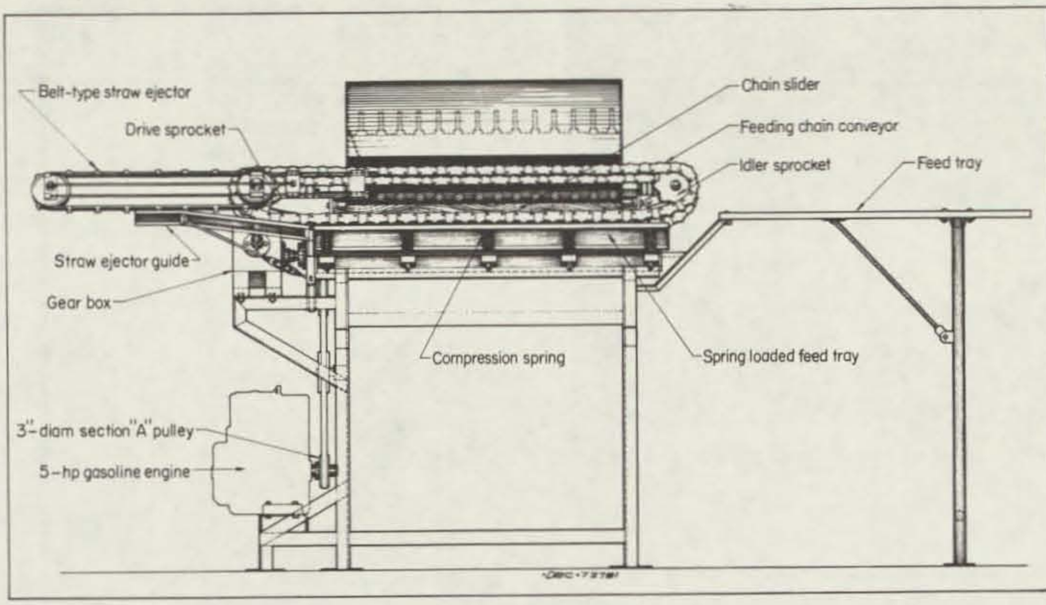
Two concave modifications were tried. First, a steel wire mesh was fastened on top of the concave frame and the concave rods were removed. Second, a perforated sheet was installed under the concave rods. Both methods prevented unthreshed grain from escaping through the concave, but the steel mesh wire appeared to be the best arrangement.

Preliminary test runs with dry mungbean were made with the modified cylinder and steel wire mesh concave. The thresher cylinder was operated at 450 rpm and a capacity of 1.3 t/hour was attained with no indication of machine overloading. Threshing wet mungbean with stalks produced a low capacity of 123 kg/hour, with 66% purity and high grain milling. Work started on a small TH-6 axial-flow thresher with easy adjustment of the cylinder speed, concave type, and various cylinder arrangements to facilitate determination of the optimum design parameters.

Head feed thresher. A basic axial-flow thresher (TH-6) was converted into a head feed thresher (Fig. 5). The regular feed tray was removed and the front section of the thresher redesigned. Belts and pulleys were used to drive the feed conveyor system. The engine was moved back to provide space for the conveyor feed drive. Intermediate shafts were installed to eliminate the use of large pulleys and to provide a 90°-turn in the conveyor feed drive. The main frame was modified by removing a section of the front concave bars and the side walls to provide an opening for passage of the materials during operation.

The conveyor feeder assembly consists of the feed tray and feeder chain assembly with springs to exert a consistent, compressive force. This holds the straw against the feeder chain during the conveying-threshing operations. A sprocket, at the discharge end, drives the conveyor at 28 m/minute.

Preliminary test runs conducted with bundles of rice ranging from 80 to 90 cm long gave an average



5. Portable axial-flow thresher with conveyor feeder. IRRI, 1980.

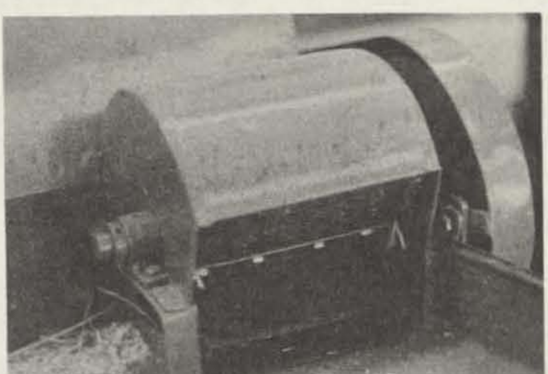
capacity about 57% lower than that of the standard portable axial-flow thresher (TH-6). An unthreshed grain loss of 2.74% and a low output purity of 75% were recorded.

The design will require major changes, such as a wire loop cylinder and a complex drive for the feeder, before it will be satisfactory for head feed threshing.

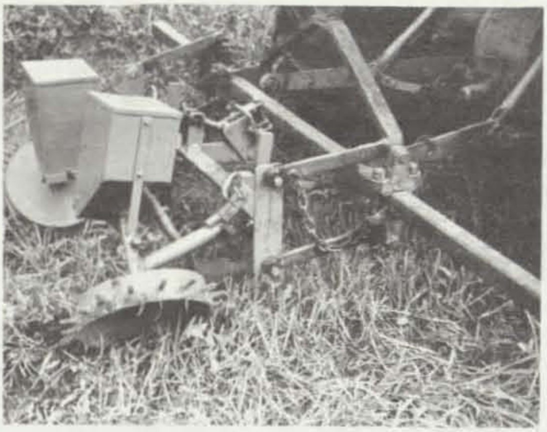
Safety device for axial-flow thresher. The design concept for a safety feed device that can be adapted to different throw-in type threshers was studied. The main objective was to develop a feed mechanism for rice threshers that will minimize the probability of the operator being caught in the threshing cylinder. A secondary objective was to provide a mechanism for regulating the flow of material through the thresher.

The safety feed mechanism consists essentially of a cylinder assembly with two bearings. It is mounted on a rigid frame fastened to the main frame in front of the thresher feed opening (Fig. 6). The feed cylinder assembly is powered by chain and sprocket from the threshing cylinder, with the feed cylinder rotating at 1/5th of the speed of the threshing cylinder. The slow rotation of the feed cylinder and slower feeding of the material reduce the probability of the operator's hand being caught by the cylinder. Because of the slow rotary movement, the backward position, and the flexibility of the rubber flaps of the safety feed cylinder, accidents are not likely to cause more than a few minor bruises. Tests of the modified thresher showed that the capacity was 21% lower than that of the standard thresher. Further modifications will be made to determine whether better performance can be attained.

Inclined seed-plate planter. Preliminary tests were conducted on the inclined seed-plate planter and modifications were made to improve its per-



6. Safety device for IRRI axial-flow thresher, 1980.



7. An IRRI inclined seed-plate planter attached to a 4-wheel tractor, 1980.

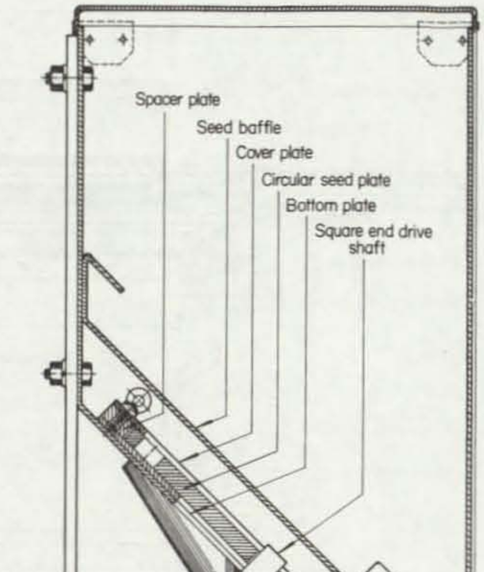
formance and structure. Modified parts include structural supports and metering assembly. The planter was also tried on a four-wheel tractor using an extended tool bar and multiple planting units to take advantage of the additional capacity of the tractor.

A parallelogram hitch attachment adapted from a maize planter was used to attach the planter to a four-wheel tractor (Fig. 7). The planter performed normally on leveled ground but on irregular ground the furrow opener did not penetrate uniformly. This was attributed to the distance of the planter from the rear of the tractor.

The original metering assembly was modified to eliminate milling and leak problems, and to simplify change of seed plates. The modified assembly consists of a bottom plate welded to a plate spacer, and a cover plate fastened by three bolts (Fig. 8). Field tests gave a smooth and gentle metering for a variety of seed size. The arrangement facilitated changing of the seed plate because only two of three bolts holding the cover plate need to be removed.

The new metering assembly can use a wooden seed plate. Wear is prevented by a sheet metal lining on the side of the seed plate that rubs with the surface of the cover plate.

Granular fertilizer applicator (two-wheel tractor attached). A rotating spring-type metering mechanism comprising a coil spring placed inside an L-shaped tube was evaluated as a granular fertilizer applicator. One end of the tube is fixed to the



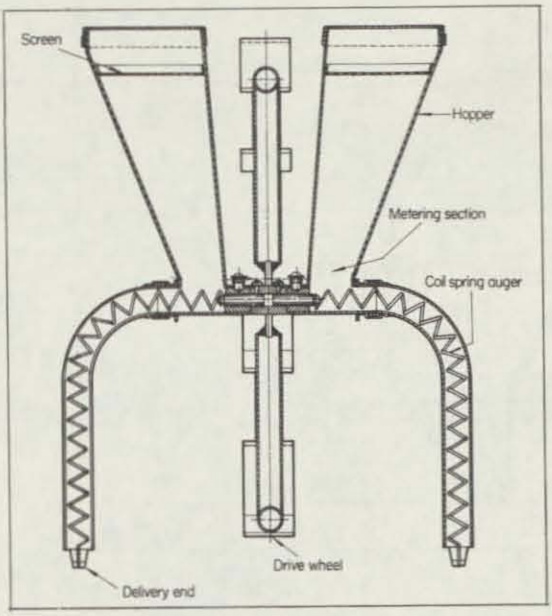
8. Cross section of seed hopper of the inclined seed-plate planter, showing the modified metering system assembly. IRRI, 1980.

hopper and the other end to the discharge (Fig. 9). By rotating the spring, the fertilizer is conveyed from the hopper into the puddled soil. Following the success of the laboratory tests, a 4-row applicator, which can be mounted on a power tiller, was designed and built.

The machine consists of two fertilizer applicators mounted on a main frame (Fig. 10). The drive wheel unit is castered to permit sharp turns during operation. The drive wheels rotate four springs for metering and delivery of fertilizer. The distance between each delivery tube is 40 cm. Wheel diameter is 60 cm and hopper capacity is 1.5 kg urea.

During initial field trials the machine proved extremely maneuverable and provided uniform fertilizer flow. The machine can operate in fairly deep fields.

Granular fertilizer applicator (manually operated). In view of the promising result of the power-



9. Section view of spring auger mechanism. IRRI, 1980.

tiller attached granular fertilizer applicator, an 8-row manually operated applicator was designed to enhance application of fertilizer immediately before transplanting.

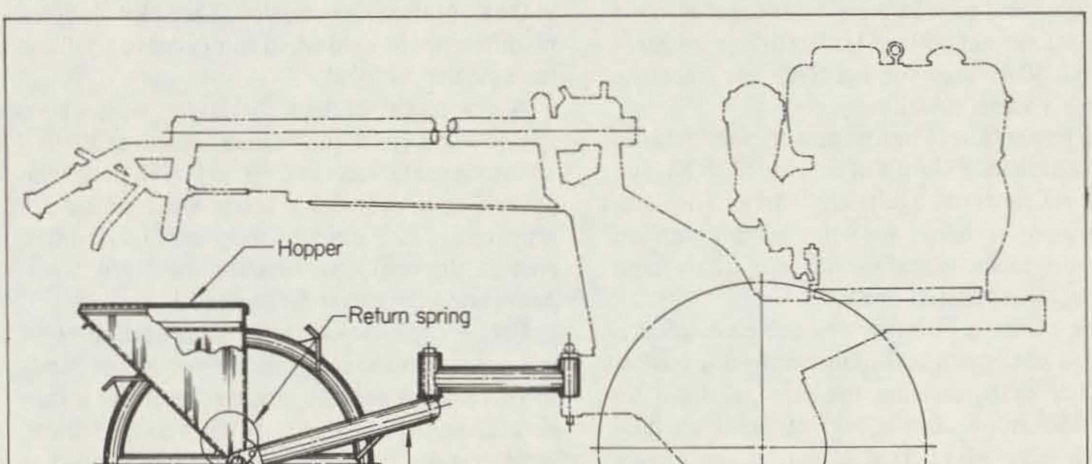
The machine also serves as a row marker when applying the fertilizer between rows. The coil spring auger is driven by ratchet and the rate of injection is controlled by the length of travel of the handle (Fig. 11). The machine weighs only 6 kg and is easily operated in the field.

Initial trials showed promising performance. Field testing is under way.

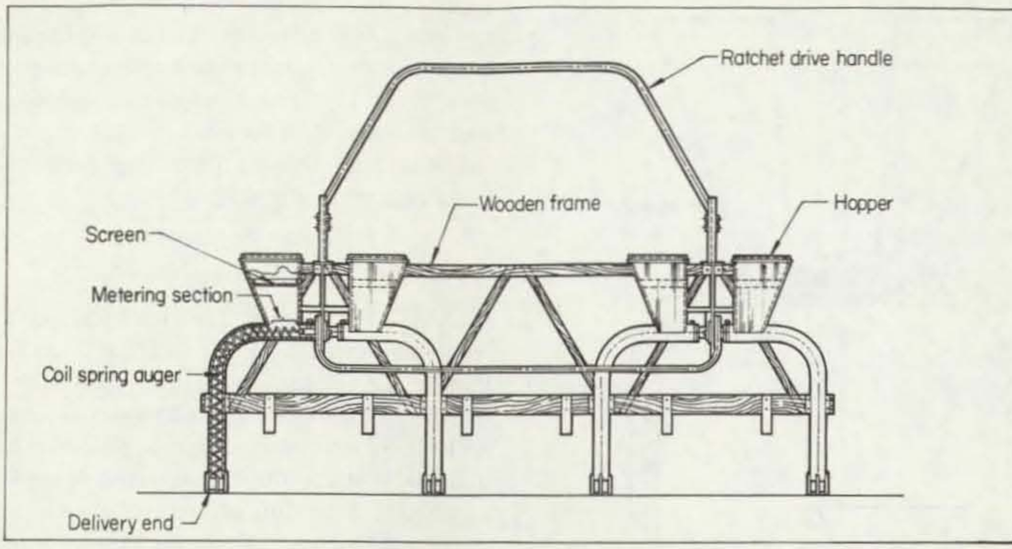
MACHINERY TESTING AND EVALUATION

CAAMS-IRRI reaper. The IRRI Chinese 1.6-m reaper was tested in rice producing areas in Tarlac, Pangasinan, Laguna, and Iloilo Provinces. The reaper capacity was observed to vary from 0.5 to 0.9 ha/hour depending on size of plot, crop condition, and plot condition. Crop losses ranged from 0.1 to 0.9% depending on crop variety and conditions. The machine worked well on transplanted and broadcast-seeded crops, regardless of whether the field was wet or dry.

The main problem observed was transport to distant plots surrounded by immature crops. The reaper and tractor were too heavy to be carried on the levee. Maneuverability of the machine within the plot was also observed to be poor. Assistance was required during the first three circuits of the plot. The machine bogged down easily in deep



10. Fertilizer applicator, attached to a power tiller. IRRI, 1980.



11. Manually operated fertilizer applicator. IRRI, 1980.

mud. A lighter unit with a narrower swath was suggested by farmers.

Kerosene engine for the 6- to 8-hp power tiller. A 6- to 7-hp kerosene engine was mounted on a 6- to 8-hp power tiller and field-tested at Calauan, Laguna. The kerosene engine proved comparable to a gasoline engine in terms of power output. Average fuel consumption was slightly higher — 1.76 liters/hour compared to 1.56 liters/hour for a gasoline engine. At current costs of US$0.66/liter for gasoline and $0.44/liter for kerosene the kerosene engine is a viable substitute.

3-hp power tiller. The first prototype of the 3-hp tillers completed 87 hours of field test at IRRI, and in farmers' fields in Laguna and Tarlac. The lightness, maneuverability, and low fuel consumption of the unit made it ideal for tillage of sandy loam and clay loam wetland fields.

Most effective plowing was achieved using a standard size moldboard plow, with a disc coulter to reduce draft, stabilize the plow, and cut up weeds and stubble. In wet but firm fields, an 18.5-cm-wide cage wheel fixed to run in the furrow improved directional stability and ensured uniform width of the furrow slice. The 3-hp tiller required an average of 13.3 hours to plow a hectare; gasoline consumption averaged 1.15 liters/hour. The use of a standard comb harrow, combined with a pair of 45-cm-wide puddling wheels, was appropriate for harrowing even in soft and deep fields. Harrowing a hectare required an average of 9.45 hours and gasoline consumption was 1.34 liters/hour.

Transplanter applied research. Research on the acceptability to farmers of the IRRI mechanical rice transplanter was conducted in Central Luzon, Western Visayas, Quezon Province, and Mindanao. Farmer-cooperators commented favorably, indicating benefits in time saved and convenience in the transplanting operation. They also observed no difference in yield when compared to seedlings transplanted by hand.

A new model of the transplanter, with 4 rows spaced 30 cm apart, can be used to plant at 30 cm × 10 cm. Some farmers in Central Luzon prefer this pattern as it provides a better environment for growing azolla. Farmer-cooperators find no difference in the operation between the 4-row transplanter and the earlier 5-row model.

Farmers report that seedling production needs more care than the conventional wet-bed or dapog methods. They are also reluctant to accept it fully because of the initial cost of the wooden frames. Modifications in the process are still being studied to minimize or totally avoid the use of wooden frames.

INDUSTRIAL EXTENSION

Industrial extension activities continued in Burma, Egypt, Indonesia, Pakistan, Philippines, and Thailand during 1980.

Burma. Small-scale machine activity in Burma is in cooperation with the No. 1 Base Workshop, Agricultural Mechanization Department (BW/AMD). Most activity focused on the manually operated mechanical transplanter. A prototype machine was demonstrated and an initial order for 6 units was followed by an order for 30 more. Agricultural Research Institute and Applied Research Division personnel received instruction on the double-frame method for producing seedling mats suitable for the transplanter.

After initial testing and adjustments, 25 machines were demonstrated in May for managers from 72 townships. As a result of the demonstration, the Agricultural Mechanization Department produced an additional 100 units and delivered them to the Extension Division of the Agriculture Corporation for use in training and demonstration courses. More than 160 workers were trained in the use of the transplanter and about 160 ha of paddy were transplanted and grown to maturity.

Egypt. Industrial extension work in Egypt is with the Ministry of Agriculture under a cooperative program administered by the University of California. The work concentrated on:

- *Low-lift water pumps.* The IRRI 15-cm and 25-cm pumps were built and tested by 2 companies.
- *Land preparation.* Trials were conducted on the moldboard plow and the power tiller with rotary tilling.
- *Mechanical transplanter.* The transplanter was tested and compared with direct seeding. Heavy clays gave the mechanical transplanter problems. Local artisans had difficulty in maintaining quality in manufacturing.
- *Thresher.* The IRRI thresher was adapted to Egyptian requirements for both rice and wheat. Farmers use their straw as animal feed and require straw to be finely chopped. Considerable modification was indicated to make the machine acceptable to Egyptian farmers.

Indonesia. Offices and a workshop at Pasar Minggu to provide working area for the 29 staff members were completed in early 1980. An attractive display area was included in the building.

A training course for eight engineers of the Subdirektorat Mekanisasi provided the engineers an introduction to IRRI designs.

There was considerable interest in power tillers, threshers, and transplanters developed by IRRI. Demonstrations were held for farmers and several manufacturers produced power tillers and threshers in Kecamatan Lubuk Baseng, Sumatra Barat, Aceh, and North Sumatra. Interest in the IRRI transplanter developed during the year.

Luwu area project. IRRI entered into a project with USAID Indonesia and the Government of Indonesia to test the utility of power tillers in the Luwu district of South Sulawesi where existing resources of man and animals for land clearing and preparation, and for cultivating and harvesting crops are inadequate.

The project will evaluate the efficiency and economics of 2-wheel, locally-built IRRI-type power tillers and compare them with imported Japanese 4-wheel tractors and the traditional human and animal power sources.

Pakistan. The Agricultural Machinery Division (AMD) of the Pakistan Agricultural Research Council was established in 1980. The IRRI-PAK Agricultural Machinery Program assisted in planning and constructing AMD facilities, and in hiring and training AMD's staff.

Design and development work concentrated in multicrop axial-flow threshers. These can thresh wheat, rice, sorghum, soybean, sunflower, and other small grain crops. Two sizes of threshers were developed — one with a 12-hp diesel engine and one for a 40- to 50-hp tractor. The tractor power-takeoff-operated machine generated considerable interest in Pakistan, and seven manufacturers produced the machine commercially. Engineering drawings were sent to manufacturers in India and Egypt.

Other machinery development projects undertaken included the adaptation of a simple 4-wheel, 16-hp Thai tractor to conditions in Pakistan. Efforts were also made to test and evaluate the IRRI transplanter and studies on wheat and paddy harvesting losses were conducted.

Philippines. Intensive technical consultant assistance extended to Springfield Industries, Davao City, was completed. The Industrial Extension staff member assisted in the implementation of the recommendations outlined in the report and later assessed the improvement in productivity and the percentage reduction in manufacturing cost brought about by the recommendations.

Table 1. Current estimated cost[a] of IRRI-designed machines in the Philippines. 1980.

Machine	Direct labor cost[b] (1)	Material cost			Prime cost (5) = (1) + (4)	Manufacturing overhead cost[d] (6)	Total manufacturing cost (7) = (5) + (6)	Approximate selling price[e]
		Fabricated[c] (2)	Purchased (3)	Total (4) = (2) + (3)				
Portable thresher (TH6)	₱ 382.16	₱ 587.49	₱ 467.20	₱1,054.69	₱1,436.85	₱ 428.35	₱1,865.20	₱3,700.00
Portable thresher with osc. screen (TH-7)	745.93	1,043.10	826.81	1,869.91	2,615.84	836.07	3,451.91	6,900.00
Compact axial flow thresher (TH-8)	1,104.80	2,315.04	2,422.43	4,737.47	5,842.27	1,238.31	7,080.58	14,000.00
Manual rice transplanter	279.54	225.67	141.53	367.20	646.74	313.32	960.06	1,900.00
Multicrop upland seeder	544.04	547.22	166.64	713.86	1,257.90	609.79	1,867.69	3,700.00
Axial-flow propeller pump (15 cm)	174.37	318.62	62.68	381.30	555.67	195.44	751.11	1,500.00
One-ton batch dryer (BD1)	421.62	1,569.24	605.17	2,174.41	2,596.03	472.57	3,068.60	6,100.00
Vertical bin batch dryer (BD2)	594.68	1,078.48	550.56	1,629.04	2,223.72	666.52	2,890.27	5,800.00
Rice hull furnace: BD1	91.28	674.95	27.90	702.85	794.13	102.31	896.44	1,800.00
BD2	165.13	993.75	54.69	1,048.44	1,213.57	185.08	1,398.65	2,800.00
10-row liquid injector	169.22	199.37	169.86	369.23	538.45	189.67	728.12	1,500.00
Inclined seed plate planter	169.18	289.49	41.04	330.53	499.71	189.63	689.34	1,400.00
Multihopper row seeder (wetland)	134.45	144.52	36.11	180.63	315.08	150.70	465.78	900.00
Savonious windmill and piston pump	300.68	1,760.16	1,835.79	3,595.95	3,896.63	337.01	4,233.64	8,500.00
Portable grain cleaner	154.58	443.63	224.89	668.52	823.10	173.26	996.36	2,000.00
6- to 8-hp power tiller with steering clutches	526.19	471.31	1,731.01	2,202.32	2,728.51	589.96	3,318.47	6,600.00
Attachments:								
Comb harrow	29.79	33.08	—	33.08	62.87	33.39	96.26	200.00
Moldboard plow	39.84	90.50	15.02	105.52	145.36	44.65	190.01	400.00
Counterweight	2.91	40.26	180.56	220.82	223.73	3.26	226.99	450.00
Dryland cage wheel (1 pair)								
a. cast iron wheel wt	110.27	94.65	309.54	404.19	514.46	128.59	638.05	1,300.00
b. concrete, 10 kg	110.40	94.65	104.64	199.29	309.69	123.74	433.43	900.00
Wetland cage wheel	111.15	193.00	—	193.00	304.15	124.59	428.74	850.00
Grass cutter	123.44	217.63	168.28	385.91	509.35	138.35	647.70	1,300.00
Pump mounting	8.70	45.07	—	45.07	53.77	9.74	63.51	130.00
Trailer	149.56	419.73	517.11	936.84	1,086.84	167.63	1,254.03	2,500.00
Rototiller	252.57	494.70	1,542.05	2,036.75	2,289.32	283.09	2,572.41	5,100.00
Axial-flow pump (25 cm)	138.60	439.70	208.07	647.77	786.37	155.33	941.70	1,900.00

[a]Costs are in Philippine pesos. ₱7.50 = US$1.00 in 1980. [b]₱4.22/m-h. [c]With 15% allowance for scraps and rejected materials. [d]₱4.73/h. [e]Excluding engine cost.

Tryme Agro Industry, Pagadian City, received intensive technical consultant assistance. Young's Metalcraft, a new cooperator in Butuan City, was given assistance with layout, including arrangement of machinery and other facilities in the shop.

A detailed cost analysis of the manufacture and marketing of IRRI-designed machines was made in Davao, Butuan, Bacolod, and Iloilo. Data from the study are being analyzed.

Updated cost estimates of various IRRI-designed machines in the Philippines are shown in Table 1. Production costs were adjusted to reflect increased cost of labor and materials.

Thailand. Production of the IRRI axial-flow thresher continued to increase. About 8,557 threshers have been produced since 1976 with more than 50% of those used on a custom basis. Estimated production for 1980 was 3,650 units.

Sixteen manual transplanters were fabricated and are ready for testing but will face competition from Japanese and Chinese models already in production.

Satisfactory progress was made toward modifying the traditional buffalo plow to plow 50% more area with the same animal power. Testing of the modified plow was in final stages before releasing its plans to manufacturers. Other machines in various stages of testing and development included a plow-sole fertilizer applicator, a small dryland seeder, and a dryland weeder.

ECONOMICS OF MECHANIZATION

Consequences of mechanization. Work continued on the major study of the consequences of mechanization, which was initiated in 1979. Data were collected from two sites in Indonesia and one each in Thailand and the Philippines and some preliminary manual analyses performed.

Philippines. In the Philippines, data collection for the 1979 wet season was completed in February 1980. Data were also collected for the 1980 dry and wet seasons. Data for the 1979 wet season were computerized and manual tabulations done. There was little variation in the demographic characteristics and the average farmholding between mechanized and nonmechanized farms. However, in terms of percent cropped land and yield, the highest values were in the irrigated mechanized farms and the lowest values in the rainfed nonmechanized category (Table 2).

Thailand. The survey of the 1979 wet season crop (286 households) in Thailand was completed. A detailed survey for the 1980 dry season was cancelled because of a drought. However, limited field activities were undertaken to provide a complete, although inadequate data set for the year. Record keeping was continued but limited to farmers who were able to use underground water for irrigation.

Initial data processing was undertaken at the Asian Institute of Technology, Bangkok, and the information sent to Los Baños, for final checking and correcting. Some initial results are shown in Table 3.

West Java, Indonesia. Data for West Java were collected continuously for the 1980 wet and dry seasons. The 1979 data sets were validated at Los Baños. One site supervisor received 6 weeks of training at IRRI during which time he was taught data validation and editing procedures being used.

Two-way tables for the 1979 crop year were generated during the first half of the year. Extensive sets of alternative tables were also developed from the initial data sets. Some of the results are shown in Table 4.

South Sulawesi, Indonesia. The activities in

Table 2. Socioeconomic characteristics by type of farm in 8 villages in Cabanatuan City and Guimba, Nueva Ecija, Philippines, 1979 wet season.

Characteristic	Irrigated farms		Nonirrigated farms	
	Mechanized	Nonmechanized	Mechanized	Nonmechanized
No. in category	151	54	63	54
Av age of household head (yr)	47.0	42.4	42.1	45.4
Av education of household head (yr)	4.4	4.5	5.2	4.6
Av experience in farming (yr)	20.7	18.5	16.2	20.0
Av household composition (no.)	5.8	6.0	5.4	5.4
Av landholding (ha)	2.3	1.9	2.2	2.2
% cropped land	98	91	88	72
Yield (t/ha) of improved rice	3.6	2.5	2.0	1.7

Table 3. Socioeconomic characteristics by type of farm in 7 villages in Don Chedi and U-Thong, Supanburi, Thailand, 1979 wet season.

Characteristic	Irrigated farms			Nonirrigated farms		
	Mechanized	Partially mechanized	Non-mechanized	Mechanized	Partially mechanized	Non-mechanized
No. in category	114	35	7	16	30	33
Av age of household head (yr)	46.9	51.1	49.3	44.2	51.0	47.7
Av education of household head (yr)	3.8	3.3	3.9	3.3	2.9	2.6
Av experience in farming (yr)	27.7	33.2	31.0	24.4	30.5	28.5
Av household composition (no.)	5.4	5.1	5.1	6.1	6.2	6.2
Av landholding (ha)	3.6	3.7	2.4	5.2	7.3	5.6
% cropped land	88	72	75	82	63	64
Yield (t/ha) of improved rice	3.3	2.1	2.9	1.2	3.0	1.4

Table 4. Socioeconomic characteristics by type of farm (all irrigated) in 8 villages in Indramayu and Subang, West Java, Indonesia. 1979 dry season.

Characteristic	Mechanized farms		Nonmechanized farms		
	Tractor owner	Tractor hirer	Animal	Animal and manual	Manual
No. in category	60	60	60	60	60
Av age of household head (yr)	40.5	38.4	37.4	39.5	40.7
Av household composition (no.)	4.7	4.8	4.7	5.0	4.3
Av landholding (ha)	4.8	1.9	1.9	1.5	1.2
% cropped land	100	100	100	100	100
Yield (t/ha) of improved rice	2.9	2.9	2.8	2.6	2.8

Table 5. Socioeconomic characteristics by type of farm in 8 villages in Pinrang, Sidrap, South Sulawesi, 1979 wet season.

Characteristic	Irrigated farms		Nonirrigated farms	
	Mechanized	Nonmechanized	Mechanized	Nonmechanized
No. in category	76	82	48	84
Av age of household head (yr)	38.0	40.0	40.0	40.7
Av education of household head (yr)	3.5	4.6	5.6	4.8
Av experience in farming (yr)	19.1	20.3	20.6	20.3
Av household composition (no.)	5.9	7.1	6.5	6.3
Av landholding (ha)	1.2	1.3	1.6	1.4
Yield (t/ha) of improved rice	1.5	1.1	0.8	0.5

South Sulawesi consisted of completion of data collection for the dry season and a start for the wet season. Data were processed and validated at IRRI, although instructions were prepared in South Sulawesi. The data for 1979 were checked for completeness. Table 5 shows some initial results.

Tube well irrigation in eastern Nepal. A study of the economics of pump irrigation in eastern Nepal was completed in August. A summary of the major characteristics of the sample households is shown in Table 6. Expansion of the area for wheat after the introduction of irrigation increased cropping intensity. There was also a switch from traditional to improved varieties of rice. Differences in average levels of inputs and outputs for pump-irrigated and rainfed samples of improved rice are shown in Table 7. Subsequent analyses suggested that the yield differences were due to a combination of neutral technological change and increased use of inputs.

Tractor contract services. A survey of tractor use and custom hiring was carried out in 13 towns of Nueva Ecija, Philippines. Tabulated data on trac-

Table 6. Socioeconomic characteristics of sample farms in the eastern terai of Nepal, 1980.

Characteristic	Rainfed farms	Pump irrigated farms
Av size of landholding (h)	3.62	4.54
Cropping intensity	118[a]	152
Size of household (no.)	8.43	9.56
Years of schooling of the farmers (yr)	5.04	7.85
Age of the farmer (yr)	39.64	38.83
Percentage area[b] under		
Improved paddy	3.52	23.99
Local paddy	81.46	66.87
Improved wheat	11.52	35.97
Percentage of farmers growing		
Improved paddy	13.04	51.54
Local paddy	91.30	85.56
Improved wheat	28.26	90.72

$$^{a}\text{Cropping intensity} = \frac{\text{gross cropped area in one agricultural year}}{\text{net cultivated area}} \times 100.$$

$$^{b}\text{Percentage area under crop} = \frac{\text{area under crop}}{\text{net cultivated area}} \times 100.$$

Table 7. Differences in average levels of yields, input use, and income per hectare between the pump-irrigated and rainfed improved paddy farms.[a] Eastern terai of Nepal, 1980.

Item	Pump irrigated	Rainfed	Difference
Sample farms (no.)	37	25	
Yield (t/ha)	2.64	1.80	0.83**
Plow unit (days)	37.67	34.35	3.32 ns
Human labor (days)	63.63	39.17	24.46**
Manures and fertilizers[b]	280.74 (299.740)	123.84 (149.456)	156.90**
Plant protection[b]	36.05 (59.960)	30.61 (36.423)	5.44 ns
Total income[b]	2128.28 (725.244)	1524.39 (655.705)	603.89**
Net income[b]	2105.18 (811.988)	1393.85 (674.782)	711.13**

[a]Numbers in parentheses are standard deviation. [b]Input costs and income in Nepalese rupees; US$1 = 12 rupees.

Table 8. Tractor use patterns, by site and by operation, for 150 tractor owners in Nueva Ecija, Philippines, 1980.

Item	2-wheel tractor	4-wheel tractor
Tractor use (h) by site and season		
Wet season	137	432
Own farm	89 (65%)	75 (17%)
Off-farm	48 (35%)	357 (83%)
Dry season	121	414
Own farm	78 (64%)	68 (16%)
Off-farm	43 (36%)	346 (84%)
Total (h)	258	846
Percent use by operation		
Plowing	38	19
Harrowing	42	5
Rototilling	19	65
Cultivating	1	—
Transport/pump	—	3
Threshing	—	8
Total (%)	100	100

[a]Wet season covered May-September; dry season covered October-April.

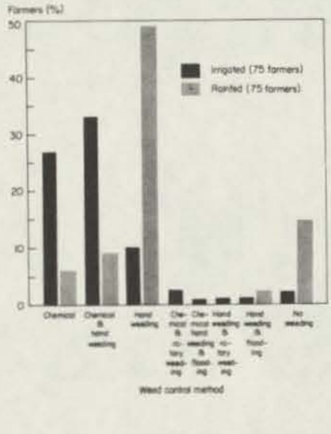
Table 9. Choice of chemical insect control technology in Nueva Ecija, Philippines, 1979.

Control method	Irrigated farm	Rainfed farm
Broadcast granules	14 (20.0)	1 (1.56)
Spray	47 (67.14)	56 (87.50)
Broadcast and spray	9 (12.86)	7 (10.94)
Total	79 (100.0)	64 (100.0)

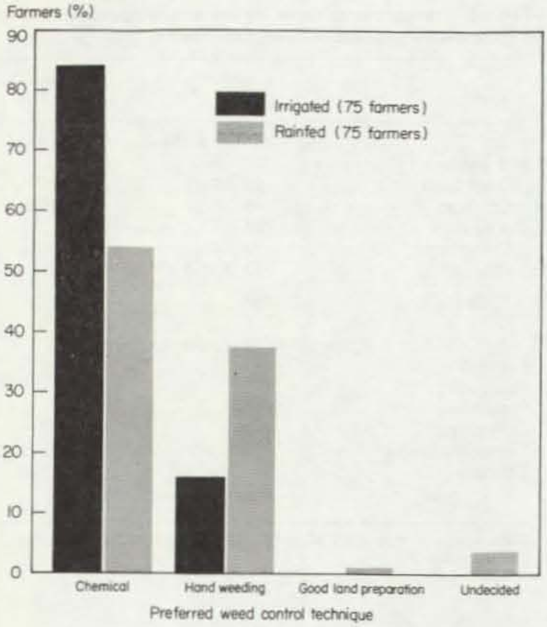
[a]Figures in parentheses show percentage of total number reporting.

tor use (Table 8) indicate differences in the intensity and pattern of tractor use as well as type of use.

Pest control practices and techniques. A summary of the pest control practices and techniques used by irrigated and rainfed farms in Nueva Ecija



12. Frequency distribution of 150 farmers by weed control method. Nueva Ecija, Philippines, 1979.



13. Frequency distribution of 150 farmers by preferred weed control technique. Nueva Ecija, Philippines, 1979.

is shown in Table 9 and Figures 12 and 13. For insect control, most farmers from irrigated and rainfed areas preferred a sprayable chemical, which was more effective and less costly than granular insecticides.

The weed control method used by farmers varied by farm type (Fig. 12). In irrigated areas, liquid and granular herbicides were the most common. In contrast, hand weeding was practiced by about half of the farmers in the rainfed areas. Regardless, however, of farm type, chemical application was the preferred method of weed control.

Associated formal training

IRRI training programs are research and production oriented and fully integrated with the Institute's research activities. The programs include postdoctoral fellowships, MS and PhD degree programs, special nondegree research programs, and training courses supportive of various research and international network activities. During 1980, a total of 384 participants, equivalent to 199.6 person-years, participated in IRRI training.

RESEARCH ORIENTED PROGRAMS

Individuals with a bachelor's degree are designated research scholars, those with a master's degree or its equivalent are called research or postmasteral fellows, and those with PhD degrees are called postdoctoral fellows. During 1980, 217 scientists participated in research training at IRRI for a part of or the whole year — 38 postdoctoral fellows, 89 research fellows, and 90 research scholars from 28 countries (Table 1). Agronomy had the highest number of fellows and scholars, followed by plant breeding, agricultural economics, entomology, and multiple cropping (Table 2).

Among the 179 research fellows and scholars, 44 were PhD students and 88 were master's degree students. Ten were in graduate studies in selected universities in the United States, the Netherlands, and Australia and the rest studied at the University of the Philippines at Los Baños. Forty-six young scientists received nondegree training and gained experience by working with IRRI scientists.

TRAINING COURSES

About 50% of IRRI trainees are in formal 3- to 6-month training courses. In those courses, scientists, production specialists, and extension specialists learn techniques and methodologies of research for their areas of specialization.

Table 1. Distribution by country of IRRI research fellows and scholars, 1980.

Country	Postdoctoral fellows	Research fellows			Research scholars		Total
		PhD	MS	N.D[a]	MS	N.D.[a]	
Bangladesh	2	5	24	1	3	3	38
Philippines	3	6	—	2	16	—	27
India	19	3	1	2	—	—	25
Indonesia	1	3	—	1	6	6	17
China	—	—	—	4	11	2	17
Thailand	—	5	—	—	7	4	16
Sri Lanka	2	1	—	—	6	5	14
Pakistan	1	6	—	1	1	1	10
Korea, Republic of	1	2	3	2	—	—	8
United States	2	4	—	—	1	—	7
Japan	2	—	—	1	—	3	6
Germany, Federal Republic of	2	2	—	2	—	—	6
England	1	1	—	1	—	2	5
Nepal	—	1	—	—	3	1	5
Mexico	—	1	—	—	1	—	2
Vietnam	—	2	—	—	—	—	2
Colombia	—	—	—	—	1	—	1
Egypt	—	—	—	—	—	1	1
Ghana	—	—	—	—	1	—	1
Kenya	—	—	—	—	1	—	1
Malaysia	1	—	—	—	—	—	1
Netherlands	—	1	—	—	—	—	1
Panama	—	1	—	—	—	—	1
Peru	1	—	—	—	—	—	1
Senegal	—	—	—	—	1	—	1
Sudan	—	—	—	—	1	—	1
Surinam	—	—	—	—	—	1	1
Venezuela	—	—	—	—	1	—	1
Total	38	44	28	17	61	29	217

[a]Nondegree.

Table 2. Distribution by department of IRRI research fellows and scholars, 1980.

Department	Postdoctoral fellows	Research fellows			Research scholars		Total
		PhD	MS	N.D.[a]	MS	N.D.[a]	
Agronomy	8	5	4	2	8[b]	3	30
Plant Breeding	4	9[b]	—	2	7	6	28
Agricultural Economics	3	6	5	1	7	1	23
Entomology	5	4	2	—	5[b]	6	22
Multiple Cropping	2	4	6	—	6	2	20
Plant Physiology	3	3[b]	3	4	1	3	17
Agricultural Engineering	1	4[b]	1	2	6	1	15
Soil Chemistry	5	3[b]	3	1	2[b]	2	16
Water Management	1	3	—	—	9[b]	1	14
Plant Pathology	2	1	—	2	7	—	12
Soil Microbiology	4	—	1	1	2	2	10
Chemistry	—	1	—	—	—	1	2
International Rice Testing Program	—	1	—	—	1	—	2
Office of Information Services	—	—	—	1	—	1	2
Rice Production Training and Research	—	—	2	—	—	—	2
Statistics	—	—	1	—	—	—	1
Training Office	—	—	—	1	—	—	1
Total	38	44	28	17	61	29	217

[a]Nondegree. [b]Includes fellows and scholars abroad

Six regular training courses were offered in 1980:

Genetic Evaluation and Utilization	11 February - 30 May 18 August - 5 December
International Network on Soil Fertility and Fertilizer Evaluation for Rice	11 February - 30 May
Rice Production Training Program	10 March - 5 September
Cropping Systems Training Program	8 September - 6 March
Irrigation Water Management Training Program	16 June - 25 July
Agricultural Engineering Course	17-28 March 6-17 October

Table 3 shows the distribution by course and country of the 167 trainees who participated in the 6 courses. Not included are 71 trainees in 2-week Rice Production Training courses 11-22 August and 17-28 November.

SPECIAL COURSES

Special cropping systems training courses in several disciplines were also organized for selected staff of national cooperating institutions. A total of 24 persons from 6 countries received 1-3 months training in cropping systems research methodologies.

A list of individuals who completed their programs in 1980, including their countries and research project areas, follows. An asterisk (*) indicates completion of the MS degree; two asterisks (**) denote completion of the PhD degree during the year.

RESEARCH SCHOLARS

Agricultural Economics

Mercedita Agcaoili.* Philippines. Consumption patterns of farm households.

Jerry Amoloza.* Philippines. The management factor in farm production in Cale, Batangas, Philippines.

Nazrul Islam.* Bangladesh. An economic evaluation of the deep tubewell rehabilitation program at Dhamrai, Bangladesh.

Bert Jagger.* The Netherlands. Some effects on the introduction of an irrigation system on the decision making of small farmers.

Abdul Momen.* The Netherlands. Economics of cropping systems in Manaoag, Pangasinan.

Dibakar Paudyal.* Nepal. The potential of cropping systems research innovation in crop-livestock based farming systems in the Hills of Kaski, Nepal.

Chumsri Poumlak.* Thailand. Optimum technology for different farm types, Khon Kaen Province, Thailand.

Table 3. Distribution by country of participants in various IRRI training courses[a], 1980.

Country	CSTP	GEU	RPTP	INSFFER	IWMT	AEC	Total[b]
Bangladesh	8	9	4	2	—	1	24
Indonesia	6	5	4	2	5	2	24
Philippines	8	3	—	2	10	—	23
China	—	12	—	8	—	2	22
Thailand	7	3	3	2	4	—	19
Malaysia	5	1	3	1	1	—	11
Sri Lanka	2	3	2	1	2	—	10
India	—	—	6	—	—	3	9
Burma	3	3	2	—	—	—	8
Pakistan	—	4	1	2	—	—	7
Nepal	2	—	1	—	—	—	3
Egypt	—	—	—	—	—	2	2
Vietnam	2	—	—	—	—	—	2
Kenya	—	—	1	—	—	—	1
Senegal	—	1	—	—	—	—	1
Uganda	—	—	1	—	—	—	1
Total	43	44	28	20	22	10	167

[a]CSTP = Cropping Systems Training Program, GEU = Genetic Evaluation and Utilization Program, RPTP = Rice Production Training Program, INSFFER = International Network on Soil Fertility and Fertilizer Evaluation for Rice, IWMT = Irrigation Water Management Training, AEC = Agricultural Engineering Course. [b]Excludes participants in 2-week Rice Production Training Course (71 trainees).

Joseph Thattil.* Sri Lanka. Criteria for screening technology prior to field recommendation.

Vichien Vanchainavin.* Thailand. Effect of resource availability on adoption of more intensive cropping patterns in Changwad Ubon, Rathathani, Thailand.

Agricultural Engineering

A. K. M. Haque.* Bangladesh. Field measurement of forces on two-wheel tractor implements.

Mohammad Ilyas.* Pakistan. A response surface analysis of the IRRI axial flow thresher.

Nongluck Jongsuwat.* Thailand. Productivity growth and farm machinery adoption in Thai agriculture.

Frances Kasala.* Data retrieval system for farm mechanization consequences project.

M. R. Khoju.* Nepal. The economics of pump-irrigation in Eastern Nepal.

Virgilio Monge.* Philippines. Analysis of factors affecting the demand for tractor and power tiller services in Nueva Ecija.

Renu Pathnopas.* Thailand. The economics of rice threshing machines in Thailand: A case study of Chachoengsao and Supanburi Province.

Chemistry

Djoko Said Damardjati.* Indonesia. Properties of Indonesian intermediate amylose indica and bulu varieties.

Irrigation Water Management

Wiraphol Chatchawalwong.* Thailand. Agronomic factors limiting dry season cropping of three tank irrigation systems in Northeast Thailand.

Multiple Cropping

Md. Nazrul Islam Rahman.* Bangladesh. Stability of selected mungbean (*Vigna radiata* (L) Wilczek) cultivars evaluated under different growing conditions. (May 1980)

Djuber Pasaribu.* Indonesia. Effect of nitrogen fertilization and inoculation on the performance and yield of soybean.

Anan Polthanee.* Indonesia. The effect of nitrogen fertilizer application method and depth of planting on dry-seeded rice.

Didi Suardi.* Indonesia. Estimation of crop coefficient and other parameters for an evapotranspiration model to evaluate the potential for rice in cropping patterns.

Piroge Suvajinda.* Indonesia. Time of nitrogen application on dry seeded rice grown after mungbean establishment at different tillage levels.

Plant Breeding

Kwak Tae Soon.* Korea. Inheritance of seedling cold tolerance in rice (*Oryza sativa* L.).

Jose Hernandez.* Philippines. Inheritance and allelic relationships of genes governing resistance to the whitebacked planthopper *Sogatella furcifera* (Horvath), in some rice varieties.

Plant Pathology

Rogelio Cabunagan.* Philippines. Adaptability of *Nephotettix virescens* on IR34 and its transmission of rice tungro virus.

Plant Physiology

K. C. Kim.* Korea. Low temperature tolerance of indica-japonica crosses.

Soil Chemistry

Golam Panaullah.* Bangladesh. Effects of the physical and chemical properties of three types of saline soils on the growth, mineral nutrition and yield of three rice varieties.

Statistics

Debi Rudra Narayan Paul.* Bangladesh. Determining labor requirements for cultural operations in crops.

RESEARCH FELLOWS

Agricultural Economics

Marietta Adriano.** Philippines. The impact of an irrigation project on labor intensity and the distribution of income.

Gordon Banta.** U.S.A. Asian cropping systems research: micro-economic evaluation procedures.

James Chapman.** Design and analysis of technology for small farmers: cropping systems research in the Philippines.

Antonio Ledesma.** Philippines. Landless workers and rice farmers: peasant sub-classes under agrarian reform in 2 Philippine villages.

Dennis O'Brien.** U.S.A. Risk and the selection of alternative weed management strategies in Philippine upland rice production.

Donald Sillers.** U.S.A. Measuring risk preferences of rice farmers in Nueva Ecija, Philippines: an experimental approach.

Howard Bouis.** The Netherlands. Rice policies in the Philippines.

Entomology

Fernando Cariño.** Philippines. The role of natural enemies on the population suppression and pest management of rice green leafhoppers.

International Rice Testing Program

M. N. Shrivastava.** India. Genetic divergence and combining ability studies in rice.

Irrigation Water Management

Adul Apinantara.** Thailand. Cooperation and conflict among water users in tank irrigation systems in Northeast Thailand.

Surasak Sritunya.** Thailand. Factors limiting dry season cropping intensity and rice yield in the Nam Phong-Nong Wai irrigation project of Northeast Thailand.

Multiple Cropping

Jakhro Anwar Ali.** Pakistan. Variability of rice yield response to fertilization in a Santa Rita Series in Iloilo in relation to some soil chemical properties.

Francis R. Bolton.** England. Double cropping rainfed rice in Iloilo, Central Philippines.

Plant Breeding

Bambang Suprihatno.** Indonesia. Inheritance of submergence tolerance in rice (*Oryza sativa* L.)

POSTDOCTORAL FELLOWS

Entomology

Dr. P. K. Pathak. India. Development of brown planthopper techniques.

Plant Breeding

Dr. Reynaldo Villareal. Philippines. (a) Evaluation of breeding lines for dry-seeded rice. (b) Evaluation of breeding lines for ratooning ability (AYT & RYT). (c) Evaluation of breeding lines for high protein content, and (d) Coordination of rainfed lowland breeding program.

Soil Microbiology

Dr. Ian Grant. U.S.A. Alga-predator relation in paddy field.

OTHERS

Agricultural Economics

Bert Jagger. The Netherlands. Some effects on the introduction of an irrigation system on the decision making of small farmers.

Abdul Momen. The Netherlands. Economics of cropping systems in Manaoag, Pangasinan.

Dibakar Paudyal. Nepal. The potential of cropping systems research innovation in crop-livestock based farming systems in the hills of Kaski, Nepal.

Agricultural Engineering

Frances Kasala. Thailand. Data retrieval system for farm mechanization consequences project.

Agronomy

U Chit Ohn. Burma. GEU trainee. The improvement of rice drought resistance: A review with emphasis on Burma.

Ir. Sriwidodo. Sri Lanka. GEU trainee. Evaluation of root pulling form as a technique for screening drought resistance in rice.

Nawarat Vaivananda. Thailand. GEU trainee. A simple method to characterize rice root systems in relation to drought resistance.

Entomology

Mohibul Hassan. Bangladesh. Trainee. Varietal resistance screening.

Fazle Rabbi. Bangladesh. Trainee. Insecticide evaluation studies.

Irrigation Water Management

J. R. Colthoff. The Netherlands. Problems of irrigation water management at various stages of farming activities.

Plant Breeding

Wen-Xu Zhang. People's Republic of China. Genetics of photoperiod sensitivity and thermosensitivity and basic vegetative phase in rice.

S. Sahu. India. Germplasm management.

Y. C. Teng. People's Republic of China. Germplasm management.

Ran Chiu Yang. People's Republic of China. (a) Natural outcrossing on cytoplasmic male sterile lines of rice under tropical conditions.

C. L. Li. People's Republic of China. Breeding of perennial habit and well exserted stigmas in male sterile lines for use in hybrid rice.

Plant Pathology

Alicia Albornoz. Cuba. Phage-typing of bacterial blight and kresek isolates at IRRI.

Srisuk Poonpolgul. Thailand. Competitive saprophytic ability of *Sclerotium rolfsii.*

Nahar Anjuman. Bangladesh. Survival of *Sclerotium rolfsii.*

Md. Aminul Haque. Bangladesh. Studies on the pathogenic variability of isolates of *Xanthomonas oryzae.*

Plant Physiology

Wang Yong-rui. People's Republic of China. Growth of large grain sized varieties.

He Chun Ye. People's Republic of China. Salt tolerance by tissue culture.

Li Tai Gui. People's Republic of China. (a) Screening of Chinese varieties for cold tolerance at different growth stages (b) Adaptability of rice cultivars to different temperature patterns (c) Cold tolerance of different varietal types at seedling stage (d) Effect of low temperature on processes leading to seed set (3) Differences between susceptible and resistant varieties when treated with cold water at seedling stage.

Soil Microbiology

Yuichiro Kachi. Japan. N_2 fixation in flooded soil.

Statistics

Weon Sik Hahn. Korea. Germplasm bank computer system.

CROPPING SYSTEMS TRAINING PROGRAM
(8 September 1980-6 March 1981)

Bangladesh

Md. Mustaque Ahmed, Scientific Officer (Agronomy), Regional Agricultural Research Station, B.A.R.I., Ishurdi, Pabna

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Julian L. Albores, Municipal Officer, Ministry of Agriculture, Bansalan, Davao del Sur

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Sri Lanka

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Thailand

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nistration, Kasetsart University, Bangkhen, Bangkok
Thongchai Lomon, Extension Official, Northern Agriculture Extension Region, Chiangmai
Peerasak Pacharanan, Agriculturist, Section of Farm Development Research, Division of Agricultural Economics Research, Office of Agricultural Economics, Bangkhen, Bangkok 9
Panpaka Sradokboa, Agronomist, Ubon Rice Station, Ubonratchathanee
Prawit Tabtim-orn, Agricultural Officer Level 5, Technical Division, Department of Agriculture, Bangkhen, Bangkok
Wonchai Thonsaipetch, Agricultural Officer Level 5, Suphanburi Rice Experiment Station, Suphanburi Province
Viboon Vongmasa, Agricultural Specialist, Agricultural Extension, Mahasarakham Province

Vietnam
Nguyen Van Luat, Researcher, Agricultural Science Institute, Vantien, Hanoi
Nguyen Thuc Nhan, Researcher, Agricultural Science Institute, Hanoi

INTERNATIONAL NETWORK FOR SOIL FERTILITY AND FERTILIZER EVALUATION FOR RICE TRAINING PROGRAM
(15 February-14 June 1980)

Bangladesh
Mohammad Harun-Ar-Rashid, Scientific Officer, Agronomy Division, BRRI, G. P. O. Box 911, Dacca
Abdul Latif Shah, Scientific Officer, Soil Chemistry Division, BRRI, G. P. O. Box 911, Dacca

China
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Zhang Mei Juan, Microbiology Research Associate, Hunan Academy of Agr'l Sciences, Shangsa, Hunan

Indonesia
Hardono, Subject Matter Specialist, Agriculture Service, Denpasar, Indonesia
Muhammad Yunan Rangkuti, Subject Matter Specialist, Medan, North Sumatra

Malaysia
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Pakistan
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Muhammad Rashid Choudhry, Soil Chemist (PARC), Rice Research Institute, Kala-Shah-Kaku

Philippines
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Sri Lanka
Sithy Shifaya Maraikar, Expt. Officer, Div. of Agricultural Chemistry, Central Agricultural Research Institute, Gannoruwa, Peradeniya, Sri Lanka

Thailand
Nanthana Keawshingduang, Agr. Technologist, Rice Division, Dept. of Agriculture, Kong Luang Rice Expt. Station, Pathumathani
Nopharat Muangprasert, Agricultural Technologist, PRAE Rice Expt. Station, PRAE

GENETIC EVALUATION AND UTILIZATION COURSE
(11 February-30 May 1980)

Bangladesh

Sunil Kumer Biswas, Scientific Officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Motahar Hossain, Scientific Officer, BRRI, Joydebpur, Dacca

Md. Abdul Jabbar, Scientific Officer, BRRI, Joydebpur, Dacca

Khatun Saleha, Scientific Officer, BRRI, Joydebpur, Dacca

Md. Abdul Wahab, Scientific Officer, BRRI, Joydebpur, Dacca

China

Yi-Zhong Cai, Agronomist, Shanghai Academy of Agricultural Science, Shanghai City

Zhi-Long Jiang, Breeder, Hunan Academy of Agric. Science, Rice Research Institute, Changsha City, Hunan Province

Dao-Yuen Li, Breeder, The Academy of Agric. Science of Guangxi, Nanning City

Yuang-Qing Li, Breeder, Hunan Academy of Agricultural Science, Changsha City

Sheng-Xiang Tang, Genetic Resource of Rice, Agricultural Academy of Zhejiang, Hangchou City

Ren-Cui Yang, Breeder, Fujien Agricultural College, Fujien Province

Ti-Bin Yang, Breeder, Jiangsu Agricultural Academy, Nangjing City

Rong-Xian Zhang, Plant Physiologist, Jiangsu Agricultural Academy, Nangjing City

Indonesia

Buang Abdullah, Rice Breeder Assistant, CRIA, Jl. Merdeka 99, Bogor

Mudjisihono Robertus Karsowiredjo, Research Assistant, Central Research Institute for Agric., Sukamandi, West Java

Malaysia

Guok Hup Ping, Rice Breeder, MARDI, Bumbong Lima, S.P.U., West Malaysia

Pakistan

Chaudhry Afzal, Rice Botanist, Rice Research Institute, Kala Shah Kaku

Abdul Hayee Bhutto, Asst. Research Officer, Rice Research Institute, Dokri

Philippines

Celestina N. Agbigay, Agronomist III, Bicol Rice and Corn Experiment Station, San Agustin, Pili, Camarines Sur

Sri Lanka

Bandaramanike Dissanayake, Agricultural Instructor, Agricultural Research Station, Mahailluppallama

Mudiyanselage Nimal Dissanayake, Research Officer, Department of Agriculture, Field Trial Division, Peradeniya

Chandralatha Rodrigo, Agricultural Expt'l Officer, Department of Agriculture, Field Trial Division, Peradeniya

Thailand

Satit Rajatasereekul, Rice Breeder, Chumpae Rice Experiment Station, Khon Kaen

Sargon Suvanatane, Rice Breeder, Koksomrong Rice Experiment Station, Lopburi Province

Nawarat Vaivananda, Rice Breeder, Rice Division, Department of Agriculture, Bangkok

GENETIC EVALUATION AND UTILIZATION COURSE
(18 August-5 December 1980)

Bangladesh

Md. Liakat Ali, Scientific officer, Breeding Division, Bangladesh Rice Research Institute, Joydebpur, Dacca

Ferdous Ara Begum, Scientific Officer, Plant Physiology Division, BRRI, Joydebpur, Dacca

Mohibul Hasan, Scientific Officer, Entomology Division, BRRI, Joydebpur, Dacca

Md. Fazle Rabbi, Scientific Officer, Entomology Division, BRRI, Joydebpur, Dacca

Burma

U Aung Thein, Farm Manager (Breeding), Agricultural Corporation, Rangoon

U Chit Ohn, Jr. Research Officer (Breeding), Rice Division, Agricultural Research Institute, Yezin, Pyinmana

U Saw Stanley, Deputy Farm Manager (Breeding), Agricultural Experiment Station, Hmawbi

China

Chen Shu-ping, Assistant Researcher (Geneticist), Chinese Academy of Agr'l Sciences, Beijing

Li Chin-shiu, Rice Breeder, Sichuan Academy of Agr'l Sciences, Chengdu, Sichuan

Linf Zu-ming, Beijing Agricultural University, Beijing

Xie Yue-fung, Hua Zhong Agricultural College, Wuhan, Hubei

Indonesia

Ir. Sriwidodo, Research Staff (Plant Breeding Dept.), LPPOM, J1. Pertanian, Maros, Ujung Pandang, South Sulawesi

Poernomo Indah Nurhati, Research Assistant (Entomology), CRIA Housing Compound, Sukamandi, West Java

Utami Pudji Kusumaning, Research Assistant (Plant Physiology), Kujung Housing Compound, D-25 Cikampek, West Java

Malaysia

Abdullah Md. Zain, Research Officer, MARDI, Krian, Parit Buntar, Perak, West Malaysia

Pakistan

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Pathan Abdullah, Breeder, Rice Research Institute, Dokri

Philippines

Remedios Panaguiton, Agronomist III, Midsayap Experiment Station, Bureau of Plant Industry, Midsayap North Cotabato, Region No. 12

Dolores delos Santos, Sr. Plant Pathologist, Bureau of Plant Industry, Visayas Experiment Station, Area No. 6, Iloilo City

Senegal

Joseph Dome, Rice Breeder, BP 29 Adrao WARDA, Richard-Toll, Senegal

Thailand

Chutchawan Aramchok, Agronomist, Huntra Rice Experiment Station, Ayutthaya

Luechai Arayarungsarit, Pathologist, Rice Division, Department of Agriculture, Bangkhen, Bangkok-9

Sangnuan Pongsamart, Agronomist, Rice Division, Department of Agriculture, Bangkhen, Bangkok-9

6-MONTH RICE PRODUCTION TRAINING PROGRAM
(10 March-5 September 1980)

Bangladesh

Shafi Uddin Kaisar Zaman, Scientific Officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Abdul Mannan, Scientific Officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Abdur Rashid, Scientific Officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Shahabuddin, Scientific Officer, Training, Communication, and Applied Research Division, Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

U Aung Nyein, Township Manager, Agriculture Corporation, Taikkyi

U Saw Antony, Township Manager, Agriculture Corporation, Okpo Township

India

Madhu Sudan Kundu, Program Officer, Lokasiksha Parishad, R. K. Mission Ashrama, Narendrapur-Pin-743508, W. B.

Gandra Sampath Rao, Agriculture Coordinator, Cross Office, Post Bhongir, Dist. Nalgonda, A. P.

Mandal Paresh Chandra, Agronomist, Indo-German Fertilizer Educational Project, West Bengal

Sarkar Sudhindra Kumar, District Agronomist, Indo-German Fertilizer Educational Project, West Bengal,

Das Tara Pada, District Agronomist, Indo-German Fertilizer Educational Project, West Bengal

Kuar Panchanan, Agronomist (Publicity), Indo-German Fertilizer, Educational Project, West Bengal

Indonesia

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Pathology Dept., CRIA, Jln. Merdeka 99, Bogor

Yacob Sirait, Extension Worker, Dinas Pertanian Rakyat Dati II, Pidie, Aceh

Soehadi, Extension Worker, Dinas Pertanian Rakyat, J1. Pemuda 48, Pekalongan, Jawa-Tengah

Soerodjo, Research Assistant, Plant Physiology Dept., CRIA, Jln. Merdeka 99, Bogor

Kenya

Jeremy Jackton Njokah, Agronomist, International Centre of Insect Physiology and Ecology, P. O. Box 30772, Nairobi

Malaysia

Ahmad Zohdi Bin Abd. Hamid, Manager, Federal Land Consolidation and Rehabilitation Authority (FELCRA), Seberang Perak, Teluk Sena, Parit, Perak

Mohamed Azizi B. Abd. Hamid, Agricultural Assistant, Department of Agriculture, Titi Gantung, Bota, Perak

Wan Abd. Aziz B. Muda, Agricultural Assistant, Department of Agriculture, Trengganu, West Malaysia

Nepal

Shyam Kajee Sakya, Agricultural Manager, Kankai Irrigation Project, Jhapa, c/o Dept. of Agriculture, Harihar Bhawan, Kathmandu

Pakistan

Muhammad Hussain Baloch, Assistant Research Officer, Rice Research Institute, Dokri, District Larkana

Sri Lanka

Jayasinghe Mudiyanselage Dharmasena, Agricultural Experimental Officer, Department of Agriculture, Peradeniya, Sri Lanka

Kumarasinghe Hettiarchige Ubayawansa Kumarasingha, Agricultural Instructor, D. A. E. O. Office, Kurunegala

Thailand

Methini Na Chiangmai, Agricultural Technologist, Rice Division, Department of Agriculture, Bangkok 9

Vinai Sarawat, Research Assistant, Cropping Systems Project, Faculty of Agriculture, Khon Kaen University, Khon Kaen

Somnuk Sriplung, Agronomist, Kalasin Research and Training Center, P. O. Box 7, Kalasin

IRRIGATION WATER MANAGEMENT TRAINING
(16 June-25 July 1980)

Indonesia

Dayat, J1. Nuri, No. 19A, Ujung Pandang, Sulawesi, Selatan

Kasir Sahuri, Central Java Design Unit, Jln. Briggen Sudiarto 379, P. O. Box 258, Semarang

Hadsan Sumalijaya, Dinas P. U. Seksi Pengairan, J1. Pasar Baru, Tangerang

Balubu Siregar, Dinas Pertanian, Propinsi Kalimantan Selatan, Jln. Sudirman No. 5, Banjarbaru, South Kalimantan

Tarwadi, Staf Bagian Pengawetan Tanah & ATR, Diperta Prop, Dati I Jawatengah

Malaysia

Teoh Kim Seng, Pejabat Jurutera Daerah III, Lembaga Kemajuan Pertanian Muda, (MADA), Pendang, Kedah

Philippines

Eduardo V. Balderada, On-Farm Facilities Study, National Irrigation Administration, CLSU, Muñoz, Nueva Ecija

Carmelo Cablayan, Irrigators Assistance Department, National Irrigation Administration, EDSA, Quezon City

Jose F. Mallari, Research & Development Dept., NIA, Central Office, EDSA, Quezon City

Chito P. Neric, National Irrigation Administration, Libmanan, Camarines Sur

Vic Vicmudo, NIA- CLGIP, Urdaneta, Pangasinan

Sri Lanka

Sinnathamby Jeyarajan, Malvam, Uduvil, Chunnkam

H. B. Nayakakorala, Agricultural Research Station, Maha Illuppallama

Thailand

Ratna Phanburananont, Petchburi Diversion Dam, Petchburi Province

Somsakdi Roungvitaya, Irrigation Division I, Tong Hotel Road 29, Chieng Mai

Ton Yoi Srirodbang, Irrigation Division of Amphur Srirachu, Cholburi

Sorajati Suriyacan, Maharaj Irrigation Project, Singburi

2-WEEK AGRICULTURAL ENGINEERING COURSE
(17-28 March 1980)

Bangladesh

Md. Hedayetul Islam, Deputy Production Manager, Bangladesh Machine Tools Factory, Ghazipur, Joydebpur, Dacca

China

Duan Zhicheng, Agricultural Engineer, Chinese Academy of Agricultural Mechanization Sciences, Beijing

Egypt

Mohammed Ahmed Ebrahim, 10 Gamah El Bahary St., Boulack El Dokroor, Giza

Gaber Mohamed El Khashab, Head, Ag. Mechanization, 69 El max St., Alexandria

India

Narinder Kumar Gupta, Ag. Engineer, c/o Standard Agri. Engg. Co., 824, Industrial Area, B. Ludhiana

Bhagwan Singh, Associate Professor, Ag. Engineering, G. B. Pant University of Agriculture and Technology, Pantnagar

Shri Madan Pandey, Scientist S-1, CIAE, Tegh Bahadur Complex, T. T. Nagar, Bhopal 462003, Madhya Pradesh

Indonesia

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Thailand

Chanchai Rojanasaroj, Agricultural Engineer, 151/46 Jangwathana Road, Bangkok

International activities

International projects and activities in 1980 included cooperative country projects, collaborative research, international research networks, training, and general services to national programs (e.g. workshops, conferences, symposia; distribution of rice literature). Cooperative country projects operated in Bangladesh, Burma, Indonesia, Pakistan, Philippines, and Thailand. Collaborative work was also done in India. Liaison scientists worked in Asia, Africa, and Latin America.

COOPERATION AND COLLABORATION

Bangladesh. A rice production specialist, a deepwater rice breeder, an agricultural engineer, and a research system specialist continued to work with the Bangladesh Rice Research Institute (BRRI).

Genetic resistance for diseases and insects was the principal strategy in the development of varieties. National surveys of insects and diseases were started and a monitoring system was launched. Screening procedures for drought, flood submergence tolerance, and for deepwater rice elongation are being developed to support the breeding programs.

Cropping systems. The cropping systems staff has succeeded in establishing a research network with 6 agencies operating 10 research sites in addition to the 4 active BRRI sites.

Soil fertility. In the area of soil fertility management, sites where zinc and sulfur deficiencies exist were identified and development of means for overcoming those difficulties was started.

Irrigation. The finding that addition of 5 cm water during October increased grain production 57% induced the government to authorize and encourage use of pump sets and tube wells during October.

Mechanization. The engineers developed a hand-powered pump and made IRRI designs available to local manufacturers. A government firm manufactured about 18 tillers/month and two other firms showed interest. Prototype threshers and axial-flow pumps were fabricated and tested.

Training. The BRRI 4-month rice production course was selected as the basic training for some 500 crop production specialists. Graduates function as BRRI field contact points and collaborators in carrying out varietal trials and in operating farmer-to-farmer seed production schemes.

Burma. Work in Burma on varietal improvement included testing of new introductions of the most important agroecological types of rice, including rainfed and irrigated wetland, dryland, deepwater, salt-tolerant, cold-tolerant, and heat-tolerant rice.

A total of 434 early-maturing (normally less than 130 days) wetland (irrigated) rice selections were grown in the dry season. At maturity 122 selections were made for preliminary performance tests and 110 selections were retained for further observation. In the wet season 927 selections were grown. From those, 230 entries were selected for preliminary performance tests and 277 selections were retained for further observations.

Eighty-six new crosses were made in 1980. Selections from the segregating generations of previous work involved over 10,000 progeny rows from which over 400 uniform lines were identified.

Twenty-five sites from 13 rice-growing townships were selected for tests of new selections in farmers' fields. The most widely adapted selections appeared to be B541b-Kn-58-5-3, BG51-46-5, and Mahsuri.

In the hybridization and selection program for dryland rice, plant selections from the segregating generations of previous crosses were dry-seeded at Yezin for the 1980 rainy season. Thirty-five crosses resulted in almost 3,000 progeny rows from which 371 uniform lines were selected.

Deepwater rices were grown at Yezin in the rainy season (shallow water) with further performance tests at Myaungmya and Mudon. The 139 lines grown included materials from the IRRI-Thailand program. Assessment of the important agronomic traits of the entries in the observational nursery at Yezin confirmed 39 entries for preliminary tests and 55 for retesting.

The IRLRON and other rainfed wetland rices were grown at Yezin but seepage kept nurseries well supplied with water in the rainy season. From 383 lines grown, 130 were selected for preliminary performance tests and 110 for retesting. From 191 crosses in pedigree rows, 277 uniform lines were selected but selection of individual plants is still in progress.

Salt-tolerant rices were grown in the dry season at Patheingyi and selections for desired agronomic traits (except yields) were made. Out of 127 lines, 34 were selected for preliminary performance tests and 68 for retesting.

Cropping systems. Research in rice-based cropping systems intensified with the appointment of an IRRI scientist to work in cooperation with a Burmese national counterpart. Organizing, establishing, and staffing of the cropping systems sites were the major activities of 1980. Seven sites that represent different agroclimatic zones were identified for testing cropping patterns and crop varieties. A baseline survey was initiated to gather information on soils, rainfall, water regimes, and other pertinent socioeconomic data. Training of project personnel started.

Mechanization. The IRRI team in Burma, in cooperation with the Agricultural Mechanization Department (AMD), continued efforts to introduce small-scale agricultural machines as a means of increasing cropping intensity. Most of the activity in 1980 concerned the manually operated mechanical transplanter. Following initial field trials and adjustment, some 25 machines were demonstrated for township managers from 72 townships. These demonstrations were successful and within a few months, 100 locally produced machines had been turned over to the Extension Division of the Agriculture Corporation for use in its training and demonstration courses.

India. There was intensified joint India-IRRI activity in collection of germplasm, for flexible exchange of early generation breeding material, for the facilitation of IRTP and INSFFER trial programs, and for specific research collaboration programs. The participation of India in the International Rice Testing Program for 1980 was 200 nurseries at 54 sites in 21 states.

Indonesia. Six IRRI scientists were assigned to a cooperative project in Indonesia — a breeder, a cropping systems agronomist, an economist, and a liaison scientist at Bogor and a soil scientist and a cropping systems agronomist at Maros. In addition, an agricultural engineer was assigned at Pasarminggu, Jakarta.

Genetic evaluation and utilization. Scientists at the regional research centers became significantly involved in the GEU program. This was best illustrated by the intiation of national monitoring tours. Indonesia, an active participant in IRTP monitoring tours since their inception, now uses national monitoring tours to bring rice scientists together to deal with specific problems. Scientists from different regions familiarize themselves with accomplishments and problems on a national basis. The first Indonesian monitoring tour was held in Java in the main (wet) season. The second tour covered tidal marsh areas of South and Central Kalimantan. Both tours were attended by Central Research Institute for Agriculture (CRIA) scientists, administrators, extension specialists, IRRI scientists, and representatives from other government and private agencies.

Two new varieties (Semeru and Cisadane) were released early in 1980 and three more elite lines were identified for release late in the year. Two of the three lines were developed by CRIA scientists at Bogor; the third was IR42, which had shown promise in the eastern region of Indonesia.

Continued success of the IRTP program in Indonesia was noted in 1980. IRTP was a significant source of germplasm for the Indonesian breeding program.

Indonesian breeding lines were grown at IRRI for a more complete evaluation and provided invaluable information to the Indonesian GEU program. An Indonesian scientist at IRRI assisted in the management of those breeding lines.

Soils. In the soil fertility program at Maros, South Sulawesi, several soils from two districts were evaluated in a screenhouse. Work on soil fertility maps started for the districts already surveyed. Progress was made in research to determine the most appropriate and accurate soil test for rice soils in South Sulawesi.

Mechanization. A consequences of mechanization study completed data collection in West Java but will continue through June 1981 in South Sulawesi. Preliminary analysis of the data started.

Cropping systems. A 2-week training program in June had 25 participants from throughout Indonesia's cropping systems program and provincial development project staff. The training covered all the major activities that economists in cropping systems research were expected to undertake, emphasizing how to collect and analyze data.

The cropping systems research program for eastern Indonesia (Maros, South Sulawesi) became well established. Four diverse research sites were used. During the year, on-farm cropping systems research for defining technologies appropriate for increasing farm productivity were pursued.

Pakistan. IRRI's Industrial Extension Program in Pakistan increased efforts to generate locally designed and manufactured farm machines. Machinery designs were provided to cooperative manufacturers in Pakistan. A tractor-operated thresher and IRRI-PAK animal-drawn seeder were tested during the 1980 crop seasons. The thresher work reflected a heavy demand in Pakistan for larger-size threshers.

Tests were also conducted on machines designed and developed by the IRRI Agricultural Engineering Department, including the lightweight air-screen grain cleaner, batch dryer, power tiller, and push-type paddy weeder. Also field-tested were a simple 16-hp four-wheel tractor from Thailand, a power-tiller-mounted crop harvester from China, and a paddy transplanter from North Korea.

Two major surveys were made in 1980 — one in the Barani areas to evaluate cost and labor effectiveness of manual and mechanical methods of wheat threshing; the other in the Punjab to assess different methods of harvesting and threshing paddy and to assess losses.

In 1980, IRRI and the Pakistan Agricultural Research Council started phase 3 of its cooperative rice project. The aim was large-scale implementation of the findings and recommendations of the project's phase 1 (applied research in farmers' fields) and phase 2 (pilot production program). Phase 3 was on about 260,000 ha of rice land in the Gujranwala district and involved two varieties (Basmati and IR6).

Philippines. The Philippines' increases in rice production, spearheaded by the nationwide Masagana 99 Rice Production Program, continued in 1980. The country had a 5-month buffer stock by mid-1980. From IRRI basic research results, the program emphasized the use of zinc sulfate (slight to moderate zinc deficiency is widespread in irrigated rice lands), the soil incorporation of a systemic insecticide, and basal incorporation of fertilizer before transplanting.

Sri Lanka. IRRI provided two short-term consultants to Sri Lanka to assist the Department of Agriculture in its rice breeding program and its resource capability survey.

The breeder traveled extensively with Sri Lankan scientists to monitor field performance of various varieties. He also participated in a tour of coordinated rice variety trials and attended meetings of subcommittees of the Rice Breeding Working Group.

The other short-term consultant assisted the staff of the resource capability survey. Visits were made to the districts where mapping was in progress. The survey will classify and group rice lands of Sri Lanka's Wet and Intermediate Zones into land systems and land elements having significance for rice production.

Thailand. Early in 1980 Thailand released the semidwarf varieties RD17 and RD19, which tolerate about 1 m of water. The rainfed varieties RD13 and RD15 (released in 1978) were planted widely in South and Northeast Thailand, respectively. Maturity and grain quality were important factors in farmer acceptance of RD13 and RD15.

Mechanization. The Thai-IRRI Agricultural Machinery Project continued to test the TH-8 thresher, manual transplanter, buffalo plow, and dryland seeder. Blueprints were made available to manufacturers. The number of firms building IRRI designs increased to 26 during 1980. Trials were made with the inclined-plate planter, plow sole fertilizer applicator, dryland hand weeder, and the rice hull furnace with a 2-ton dryer.

Cropping systems. Cooperation continued in cropping systems research and development of rice varieties for rainfed areas.

Africa. Under a memorandum of understanding with the International Institute of Tropical Agriculture (IITA), an IRRI liaison scientist is stationed at Ibadan, Nigeria. His major functions are to identify and develop plans of collaborative research with IITA regional and national research programs; to coordinate IRTP trials in cooperation with scientists at IITA regional organizations (such as WARDA) and national programs; and eventually to help set up IRTP-type trials that are more relevant for Africa.

The liaison scientist was active in the rice research program at IITA, especially in the screening of introduced materials, WARDA trials, and trials of the National Crop Research Institute of Nigeria.

Latin America. An IRRI liaison scientist for

Latin America is assigned to work at Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. Activities for Latin America concentrated on:

- evaluation, multiplication, and distribution of basic germplasm from IRRI and CIAT to national programs;
- identification of problems limiting rice production and their needs for research in various countries of the region;
- assembling and organizing data of IRTP nurseries distributed in 1978 and 1979; and
- evaluating the germplasm of IRTP nurseries distributed in 1980.

To increase the source of germplasm for the dryland rice nurseries for Latin America, seed of promising entries or donors was requested from the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) and from the Instituto Agronomico of Campinas (IAC), Brazil. Seed of 95 entries was received in 1980 — 41 from IRAT and 54 from IAC — and planted at CIAT for evaluation and seed multiplication. The improved types will be included in the Observational Nursery for Acid Soils and Yield Upland Nursery for 1981.

INTERNATIONAL NETWORKS

IRRI scientists continued to coordinate a number of international research networks. The continuing success of those networks involved mutual interest on the part of national programs and IRRI, joint planning and consultation on the kinds of entries or treatments to be included, joint evaluation of results, and joint planning of future work and activities of the network. The five such research networks in 1980 were:

- International Rice Testing Program,
- Cropping Systems Network,
- Agricultural Machinery Network,
- Agroeconomic Research Network, and
- International Network on Soil Fertility and Fertilizer Evaluation for Rice.

Liaison scientists were posted in Africa, India, Indonesia, Malaysia, Latin America, and Thailand, where they assisted in developing and administering collaborative projects and helped coordinate the activities of the research networks.

Table 1. Conferences, workshops, and symposia sponsored or cosponsored by IRRI, 1980.

Event	Date	Participants
IRRI/Office of Rural Development, Korea, collaborative research planning meeting	25-28 Feb	16
Cropping Systems Conference	3- 7 Mar	80
International Rice Research Conference and 20th Anniversary Symposium on Research Strategies	21-25 Apr	140
Tissue Culture Workshop	28-30 Apr	15
Nitrogen Workshop	28-30 Apr	27
IRRI/Indonesian Agroeconomic Survey Village Studies Workshop	25-27 Aug	36
Symposium on Potential Productivity of Field Crops	22-26 Sep	68
Cropping Systems Economists Workshop	6-11 Nov	14

TRAINING AND GENERAL SERVICES

Eight major meetings in 1980 brought nearly 400 participants to IRRI (Table 1).

Liaison scientists provided essential close contacts with national programs for identification and recommendation of scientists to participate in IRRI training programs and various conferences and workshops.

The participants in formal training courses spent about 50% of their time working on field and greenhouse experiments. This practical side of training was supported by lectures on basic principles and methodologies by IRRI and UPLB scientists.

Special short courses were offered to train workers — 24 persons from 6 countries — in component technology for rice-based cropping systems — economics, plant pathology, entomology, and cultivar testing.

Information resources, experimental farm, and service laboratories

LIBRARY AND DOCUMENTATION CENTER

Bibliographies. The 1979 Supplement to the *International Bibliography of Rice Research* was published in 1980. It contains 7,027 references to scientific rice literature, most of which appeared in journals in 1979. 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 78 rice literature translations, mostly from Japanese to English. It has an author index and a manually produced keyword index.

Supplement 1978 to the *International Bibliography on Cropping Systems* was also published in 1980. It embraces worldwide published and unpublished technical reports produced in 1978 and deals with all aspects of cropping systems for food crops. The entries are classified according to subject; items within each subject category are arranged alphabetically. An author index and a manually produced keyword index are provided.

The 1980 supplement to *Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute* was also produced in 1980. The supplement lists 138 titles, bringing the overall collection of theses and dissertations to a total of 1,025.

All new bibliographies were sent to agricultural libraries and documentation centers of the rice-producing regions. Essentially, all the citations included are available at IRRI.

Reference and circulation. Within IRRI, the number of books and journals and other library materials borrowed during 1980 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 3,317 monographs (books, pamphlets, and reprints) increased the overall monograph collection to 55,362. A total of 111 serial titles were added through subscriptions, exchanges, and some 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 Lembaga Penelitian Pertanian Maros, Indonesia; the Central Research Institute for Agriculture, Sukamandi Branch, Indonesia; IRRI, Sri Lanka; and the West African Rice Development Association, Liberia.

The Library continued to purchase books for IRRI research scholars and other training participants.

OFFICE OF INFORMATION SERVICES

The Office of Information Services distributed about 34,000 copies of major publications during 1980; 94% were sent to addresses in developing nations. About 8,000 publications were distributed free, mostly to libraries.

Major publications. Major publications released in 1980 were:

- Communication Responsibilities of the International Agricultural Research Centers
- Beyond IR8/IRRI's Second Decade
- Rice Improvement in China and Other Asian Nations
- Priorities for Alleviating Soil-Related Constraints to Food Production in the Tropics
- International Bibliography on Azolla
- Annual Report for 1979
- Research Highlights for 1979
- Agrometeorology of the Rice Crop
- Innovative Approaches to Rice Breeding
- Descriptors for Rice *Oryza sativa* L.
- Blue-Green Algae and Rice
- Report of a Planning Workshop on Irrigation Water Management
- Parentage of IRRI Crosses, IR1-IR30,000

Series publications. Four issues of the *IRRI*

Reporter were distributed to about 13,000 rice workers. Six issues of the *International Rice Research Newsletter* and *Subject Index 1979* were published. Ten issues of the IRRI Research Paper Series were published:

No. 46 A methodology for determining insect control recommendations
No. 47 Biological nitrogen fixation by epiphytic microorganisms in rice fields
No. 48 Quality characteristics of milled rice grown in different countries
No. 49 Recent developments in research on nitrogen fertilizers for rice
No. 50 Changes in community institutions and income distribution in a West Java village
No. 51 The IRRI computerized mailing list system
No. 52 Differential response of rice varieties to the brown planthopper in international screening tests
No. 53 Resistance of Japanese and IRRI differential rice varieties to pathotypes of *Xanthomonas oryzae* in the Philippines and in Japan
No. 54 Rice production in the Tarai of Kosi Zone, Nepal
No. 55 Technological progress and income distribution in a rice village in West Java

Training. OIS accepted one information specialist from Indonesia for degree training in 1980. An IRRI senior editor did short-term consultancies with the Education, Training, and Information Division, Department of Agriculture, Sri Lanka, and the University of Agricultural Sciences, Bangalore, India. He assessed training needs and identified personnel who could benefit from extended on-the-job training in OIS.

Research and training support. The Rice Production Training and Research Department and the Office of Information Services continued a program to develop a series of self-instructional slide-tape units on specific rice production problems and their solution. Each unit consists of a set of 60 to 80 colorslides on the problem, a prerecorded cassette tape, and a booklet.

Of the 62 units planned, 42 were completed in 1980. Sale of the units to national rice improvement training programs started.

Computerization of the IRRI mailing system. The program to computerize the IRRI mailing system to allow specific publications to be directed to the users that most need that information was completed.

EXPERIMENTAL FARM

The Experimental Farm Department continued to provide the labor needs of the research departments. Some portions of the upland farm — blocks UC and UF, and the lower portion of block UK — were converted into lowland rice fields. The new site for the farm machinery shed was filled. A total of 168.84 ha on the lowland rice farm was prepared and planted and 93.80 ha on the upland farm was readied for planting.

A total of 16.51 ha for seed multiplication was planted during the year. The varieties or selections multiplied were IR5853-162-1-2-3, IR50, IR20, and IR442-2-58 during the dry season and IR36, IR42, IR50, IR52, and IR54 during the wet season.

Fertilizer consumption was 155.15 t, 2.94% lower than in 1979.

Expenditures were $79,903.95 for insecticides and stickers, $21,193.74 for herbicides, and $207,765.98 for contract labor. Much of the increase for contract labor was because of an increase in the hourly rate of the laborers.

The 1980 income was $28,571.47 from the sale of farm products as rice seed, maize, sorghum, soybean, rice bran, milled rice, glutinous rice, mungbean, and cassava. The largest part of this income ($18,178.09) was from rice seed.

Rat control was intensified. Control methods used were baits, traps, electric fences, and digging of rat burrows; 98,013 rats were killed during the year.

ANALYTICAL SERVICE LABORATORY

A total of 35,315 plant samples, 5,514 soil samples, and 23,418 water samples were received by the Analytical Service Laboratory (ASL) for analyses. ASL did 44,131 plant analyses, 27,957 soil analyses, and 25,970 autoanalyzer determinations for ammonia and urea.

A modern atomic absorption spectrophotometer (Perkin Elmer Model 2380) with alternative nitrous oxide facility and microcomputer electronics was acquired.

A visiting consultant during the early part of the year demonstrated three analyses procedures: sen-

Table 1. Summary of analyses done by the Analytical Service Laboratory, IRRI, 1980.

Property analyzed	Determinations (no.)		
	Soil	Plant	Water samples[a]
Total elements (P, K, Zn, Fe, Mn, Mg, Ca, Cu, Na, Cr)	2,761	12,426	—
Total nitrogen or crude protein	3,833	31,641	—
Moisture	767	64	—
Exchangeable cations and cation exchange capacity	7,756	—	—
Available elements (P, Zn, Cu, Fe)	5,389	—	—
Organic carbon	3,226	—	—
pH and electrical conductivity	3,595	—	—
Particle size	630	—	—
Ammonia and urea	—	—	25,970
Total	27,957	44,131	25,970
Samples (no)	5,514	35,515	23,418
Sample preparation done	2,183	17,150	—

[a]Includes floodwaters, acid traps, and various soil extracts for NH_4–N and urea

sitized indophenol blue method for very low ammonium N, urea determination using diacetyl monoxime and thiosemicarbazide, and the azomethine-H method for boron. The methods can show as low as 0-5 ppm of the analyte in water samples such as floodwaters and acid traps. Table 1 summarizes the analyses done in 1980.

PESTICIDE RESIDUE LABORATORY

The Pesticide Residue Laboratory (PRL) transferred to its new site in the F. F. Hill Building.

The bulk of the PRL's work consisted of analyses of carbofuran and its metabolites in eggplant leaves and fruit. A summary of the analyses done during the year is given in Table 2.

Table 2. Summary of complete and gas-liquid chromatographic (GLC) determinations by the Pesticide Residue Laboratory, IRRI, 1980.

Constituent analyzed	Determinations (no.)	
	Complete	GLC only
Carbofuran and its metabolites	937	—
Butachlor	216	—
Others[a]	—	228[a]
Total	1,153	228

[a]Rice pigments and phenolics as TMS derivatives (Chemistry). Cell wall sugars as aldonitrile acetates (Chemistry).

PHYTOTRON

Forty-two research projects used the phytotron in 1980. The phytotron experiments are listed in Table 1.

Among the rooms, the glasshouse room had the highest occupancy (91%) and followed closely by the naturally lighted cabinet with 89% occupancy. Occupancy in the other rooms ranged from 69 to 70%. Two dark rooms, used as the incubation rooms for anther culture, had 70% occupancy.

Table 1. Allocation of IRRI phytotron space for 1980.

Title of experiment	Environment room used
Agronomy Department	
Nutrient uptake and water relations in rice under osmotic stress	Artificially lighted cabinet (KG)
Effects of water stress on reproductive development of rice	Glasshouse room and artificially lighted cabinet (KG)
Multiple Cropping Systems	
The effect of different temperature regimes on the ratoonability of some IRRI rice varieties	Glasshouse room
Plant Breeding Department	
Cold tolerance.	Glasshouse room, naturally lighted cabinet (3SA-L) and dark room
Inheritance of root system of rice (*Oryza sativa* L.)	Glasshouse room
Genetic studies on heat tolerance	Glasshouse room
Effect of high solar radiation and high diurnal temperature followed by low solar radiation and low diurnal temperature on sterility.	Naturally lighted cabinet (3SA-L)
Growing of three japonica stocks at low temperature.	Glasshouse room
Study of methods of growing rice in pots to achieve uniform flowering	Glasshouse room
Study of stability of male sterility mechanism in some cytoplasmic and genetic male sterile lines of rice	Glasshouse room and naturally lighted cabinet (3SA-L)
Plant Pathology Department	
Effect of nitrogen fertilizer levels and temperatures on the efficacy of granular systemic fungicides on leaf blast control.	Naturally lighted cabinet (3SA-L)
Effect of temperatures on the efficacy of seed treatment fungicides on leaf blast control.	Naturally lighted cabinet (3SA-L)
Growing of test plants to be used to study the effect of systemic fungicides on blast.	Glasshouse room
Effect of different constant and fluctuating temperatures on bakanae disease infection.	Naturally lighted cabinet (3SA-L)
Sheath rot inoculation experiments	Glasshouse room and naturally lighted cabinet (3SA-L)
Yellow dwarf-rice tungro virus transmission tests.	Naturally lighted cabinet (3SA-L)
Genetic analysis of rice resistance to bacterial blight.	Glasshouse room
The effect of temperature on the latent period of the rice ragged stunt virus in its vector and TN1 host plant.	Naturally lighted cabinet (KB)
Tissue culture research.	Glasshouse room, dark room, and naturally lighted cabinet (3SA-L)
Plant Physiology Department	
Oxygen release from rice roots	Glasshouse room
Pollen germination at high temperature.	Naturally lighted cabinet (KB)
Fertility of flowers under high and low light intensities at high air temperature	Artificially lighted cabinet (KG)
High temperature tolerance of rice varieties.	Glasshouse room
Screening for cold tolerance at panicle initiation	Dark room and cold room
Potential yield of IR varieties	Glasshouse room
Cold tolerance test at anthesis	Artificially lighted cabinet (KG)
Screening for cold tolerance at anthesis of the 1980 IRCTN	Artificially lighted cabinet (KG)
Differences in high iron concentration resistance of leaves among varieties	Artificially lighted cabinet (KG)
Effect of temperature on seedling emergence of calcium peroxide coated seeds	Naturally lighted cabinet (3SA-L)
Nature of aluminum toxicity in rice plants	Glasshouse room
Effect of different levels of nitrogen on spikelet sterility induced by cooling treatment at young seedling stage in rice (water culture)	Glasshouse room and artificially lighted cabinet (KG)
Low temperature tolerance of indica-japonica crosses at reduction division stage	Glasshouse room and naturally lighted cabinet (3SA-L)
Effect of air temperature on grain filling of indica-japonica crosses	Glasshouse room and artificially lighted cabinet (KG)
Agronomic characters of large and small grain variety and line under controlled environment	Glasshouse room
Soil Chemistry Department	
Zinc availability in rice soils	Glasshouse room
Soil Microbiology Department	
Heterotrophic N_2-fixation associated with rice	Glasshouse room
Temperature response of Azolla strains	Artificially lighted cabinet (KG)
Temperature requirements of various Azolla strains	Artificially lighted cabinet (KG)
Maintenance of Azolla strains stock cultures	Dark room
Ammonia volatilization and incorporation of ^{15}N by rice	Glasshouse room
Effect of temperature on the growth and composition of Azolla grown at 0.03 ppm of phosphorus by continuous flow of water culture.	Glasshouse room and naturally lighted cabinet (3SA-L)
Effect of light and temperature conditions on sporocarp formation	Artificially lighted cabinet (KG)

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SEMINARS

The seminars held at IRRI during 1980 are grouped as Saturday seminars, general seminars, and special seminars. The Saturday seminars report ongoing IRRI researches. Unless otherwise stated, the speakers were staff members.

Saturday seminars

Induced mutation of *Xanthomonas oryzae.* Mr. K. Tsuchiya and Dr. T. W. Mew.

Improving rice seedling emergence in flooded soil by use of calcium peroxide. Mr. F. T. Parao.

Oxygen release as a defense mechanism: nature of oxidizing power of rice roots. Dr. T. Ando.

Responses of azolla species and strains to phosphorus. Mr. B. P. R. Subudhi and Dr. I. Watanabe.

Nitrification in flooded soil. Mr. B. Padre, Jr., Ms. S. Santiago, and Dr. I. Watanabe.

Economic evaluation of farm machinery for small farm agriculture. Mr. R. Echevarria.

Genetic and pathological studies on resistance of rice to bacterial blight. Dr. O. Horino, visiting scientist, Plant Pathology Department, IRRI.

Herbicide evaluation in no-till upland crops under intensive cropping. Mr. R. Q. Lacsina, Dr. S. K. De Datta, and Dr. K. Moody.

Some findings on water distribution within the tertiaries of a gravity irrigation system. Mr. T. Moya and Dr. A. C. Early.

Water use patterns in different scales of pump irrigation systems. Messrs. M. Agua and D. Tabbal and Dr. S. I. Bhuiyan.

Socioeconomic issues in irrigation management. Ms. N. Tapay, Ms. M. L. Sipin, and Dr. A. C. Early.

Water balance and cropping performance of a small rice-producing watershed in the Philippines. Dr. A. C. Early, Ms. R. S. Clemente, Mr. C. U. Collado, Jr., Ms. M. L. Sipin, and Mr. D. M. Cablayan.

Development of biotypes of the brown planthopper *Nilaparvata lugens* (Stal). Dr. P. K. Pathak.

Mechanisms of moderate resistance to the brown planthopper *Nilaparvata lugens* (Stal). Dang Thanh Ho.

Cost of different types of irrigation systems in Central Luzon. Ms. P. Moya, Dr. L. E. Small, visiting agricultural economist, Agricultural Economics Department, IRRI, and Dr. S. I. Bhuiyan.

San Bartolome: beyond the green revolution. Dr. R. Huke, visiting scientist, Agricultural Economics Department, IRRI.

Target area delineation for rice-based cropping patterns in Iloilo Province. Mr. R. Magbanua and Dr. R. A Morris.

Double-cropping rainfed rice in Iloilo Province. Mr. F. Bolton and Dr. H. G. Zandstra.

The slow blast infection in rice. Dr. R. L. Villareal.

Genetic studies on rice ratooning ability. Mr. F. Cuevas.

Diallel analysis of root characteristics in rice. Mr. J. Armenta.

Inheritance of heat tolerance in rice. Mr. D. MacKill.

Varieties of upland crops for intensive cropping systems under rainfed-wetland rice in the Philippines. Mr. E. Godilano and Dr. V. R. Carangal.

Comparison of insect pests and natural enemy abundance in weekly and biannual rice cropping systems. Mr. P. C. Pantua and Dr. J. A. Litsinger.

Development of biotypes of *Nilaparvata lugens* (Stal). Drs. P. K. Pathak, E. A. Heinrichs, and M. D. Pathak.

Nuclear behavior in asexual reproduction and its implications on pathogenic variability of *Pyricularia oryzae.* Drs. K. Row, I. Gunawardena, and J. P. Crill.

Disease management of dryland crops grown before and after rice — chemical control. Mr. F. A. Elazegui and Dr. T. W. Mew.

Further studies on the transmission of rice ragged stunt virus. Mr. R. Daquioag.

Laboratory and greenhouse studies of boron toxicity in rice. Ms. M. C. Cayton.

Field studies of boron toxicity in rice. Ms. R. S. Lantin.

Varietal differences in phosphorus use efficiency in rice. Ms. M. R. Orticio.

Coastal saline soils in the Philippines as potential rice lands. Messrs. B. G. Quidez and M. Bernardo, and Dr. F. N. Ponnamperuma.

Technical and economic factors in adapting mechanical reapers to small rice farms. Messrs. I. Manalili, Ma Ji, and B. Duff.

Response of rice and wheat at seedling stage to aluminum. Ms. V. Coronel.

Variability in rice experimental data. Dr. M. B. de Ramos

An analysis of the cropping systems pattern monitoring data. Ms. M. Novenario and Dr. K. A. Gomez.
Adaptability of rice cultivars to different temperature patterns. Mr. Li Tai Gui, Dr. B. S. Vergara, and Mr. R. M. Visperas.
Screening cropping systems innovations within a whole-farm framework. Ms. E. Labadan.
Methodology of low temperature screening at different growth stages. Mr. Li Tai Gui, Dr. B. S. Vergara, and Mr. R. M. Visperas.
Mechanisms of moderate resistance in rice varieties to the brown planthopper *Nilaparvata lugens* (Stal). Mr. Dang Thanh Ho and Dr. E. A. Heinrichs.
Carbofuran — a direct growth stimulant of rice. Mr. M. S. Venugopal and Dr. J. A. Litsinger.

General seminars

Irrigation and agricultural development: the case of Bangladesh. Dr. S. I. Bhuiyan.
The National Irrigation Administration's current projects and future plans for irrigation development in the Philippines. Mr. B. Bagadion, assistant administrator, National Irrigation Administration, Quezon City.
The rural development program of the Asian Institute of Management. Dr. E. de Jesus, professor, Asian Institute of Management, Metro Manila.
Genetics in the service of rice improvement. Dr. G. S. Khush.
Farmers' approaches to irrigation management. Dr. R. de los Reyes, research associate, Institute of Philippine Culture, Ateneo de Manila University, Quezon City.
Irrigated crop production in Pakistan: problems and potentials for the INDUS food machine. Dr. A. C. Early.
Communication interaction patterns among members of two international agricultural research institutes. Mr. R. L. Cowell, visiting associate editor, Office of Information Services, IRRI.
Irrigation development and management for food self-sufficiency in Asia. Dr. K. Takase, deputy director, Project Department, Asian Development Bank, Manila.
Use of induced mutations in improvement of native rices adapted to adverse soils. Dr. M. Mahadevappa.
Allelochemics and plant defenses. Dr. R. C. Saxena.
Current status of insect control technology for rice-based cropping systems. Dr. J. A. Litsinger.
Weeds and rice. Dr. D. O'Brien, agricultural economist, National Crop Protection Center, University of the Philippines at Los Baños, College, Laguna.
Review of the current research on blue-green algae and phototropic nitrogen fixation at IRRI. Dr. P. Roger, visiting scientist, Soil Microbiology Department, IRRI.
Risk in farm planning. Dr. J. C. Flinn.
A comparative study of the soil zinc fractions determined by chemical methods and electroultrafiltration (EUF) and their relation to zinc content in rice. Dr. A. S. P. Murthy.
Economic evaluation of improving irrigation systems management: a progress report. Dr. L. E. Small, visiting agricultural economist, Agricultural Economics Department, IRRI.
Recent research with lepidopterous sex pheromones. Dr. W. Roelofs, professor of organic chemistry, New York Agricultural Experiment Station, Cornell University, Geneva, New York, USA.
Clay mineralogy of some rice soils in relation to their fertility management. Dr. M. I. Bajwa.
Social responsibility in international agricultural research. Dr. V. Ruttan, professor, Agricultural Economics, University of Minnesota, USA.
Management of everglade soils. Prof. George H. Snyder, soil chemist, Institute of Food and Agricultural Science, University of Florida, USA.
Color visuals from OIS — they're "slide magic." Mr. W. H. Smith.
Issues of cropping systems research at IRRI. Dr. H. Zandstra.
Rice production in pre-Spanish Philippines. Dr. W. Scott, Seminary Trinity College, Quezon City.
Rice and rural women in southern and eastern India. Dr. J. Mencher, professor, Anthropology Department, Graduate School, City University of New York, USA.
Varietal resistance of rice to insects in storage. Dr. B. M. Rejesus, associate professor of entomology, University of the Philippines at Los Baños College of Agriculture, College, Laguna.
The environmental impact of long-over geothermal power program. Mr. P. Barnett, senior geochemist, Geothermal Power Consultants to Energy Development Corporation, Philippine National Oil Company, Metro Manila.
The role of credit in agricultural development. Mr. T. Azada, administrator, Agricultural Credit Administration, Metro Manila.

Potentials and problems of hybrid rice. Dr. S. S. Virmani.

Factors affecting herbicide tolerance in dry-seeded rice. Dr. A. W. Ruscoe.

Development assistance to upland smallholders in the Southern Philippines: methods, result, and constraints. Mr. G. L. Denning, visiting associate field specialist, Rice Production Training and Research, IRRI.

The livelihood component of IIRR and the People School. Dr. T. Olsen, team leader of Livelihood Program, International Institute of Rural Reconstruction, Silang, Cavite.

Resource management issues for the eighties: five items for an Asian agenda. Dr. J. Cool, Ford Foundation representative, Ford Foundation, Manila.

Flat price structures and price stabilization for national grains organizations. Dr. J. Snell, senior marketing economist, College of Development Economics and Management, University of the Philippines at Los Baños, College, Laguna.

Integrated control of the rice gall midge in South China. Dr. Chiu Shin-Foon, professor of entomology, South China Agricultural College, Kwang-Chow (Canton), People's Republic of China.

The role of formal organization in agricultural technology utilization: the case of the Kabsaka project. Dr. R. Cuyno, program leader, Management of Rural Development Program, College of Development Economics and Management, University of the Philippines at Los Baños, College, Laguna.

Varietal resistance in relation to NGA rice marketing. Mr. J. Tanchanco, administrator, National Grains Authority, Quezon City.

The naked-seed rice and some contributions on its morphological and physiological characters. Dr. Tang Shi-Hua, director, Laboratory of Developmental Physiology, Shanghai Institute of Plant Physiology, Academia Sinica, People's Republic of China.

The U. S. National Plant Germplasm System. Dr. D. W. Barton, visiting director for research administration, IRRI.

Special seminars

Theory and practices of mechanical direct sowing of rice under submerged field. Prof. Shozo Mitsuishi and Prof. Yoshiki Nakamura, Ishikawa Prefecture, Japan.

Theory and practices of modern seed production systems for cereal crops in Japan. Dr. Hiroshi Ito, Ishikawa Prefecture College of Agriculture, Ishikawa Prefecture, Japan.

Oxidizing power of rice roots as a defense mechanism against iron toxicity. Dr. T. Ando.

Agricultural productivity in the Soviet Union. Dr. P. Desai, professor of economics, Department of Economics and the Russian Institute, Columbia University, and research associate, Harvard Russian Research Center, USA.

Introduction strategies for major genes determining crop resistance to diseases and pests. Dr. B. Trenbath, ecologist, Imperial College, London.

Dynamic characteristics of a tractor equipped with a rotary tiller. Engr. Y. Shibata, Yanmer Diesel Ltd , Kinomoto-Cho, Shiga-Ken, Japan.

Concept of weed management. Dr. L. J. Matthews, weed specialist, FAO, Rome.

Some studies on nitrogen losses in wetland rice soils. Dr. C. S. Weeraratna.

Aspects of general pest resistance in plants. Dr. P. Albersheim, professor of molecular, cellular, and development biology. Department of Chemistry, University of Colorado, USA.

Specific resistance mechanisms in plants — gene-for-gene interactions. Dr. P. Albersheim, professor of molecular, cellular, and development biology. Department of Chemistry, University of Colorado, USA.

The Philippine art scene. Mr. M. Duldulao, art critic.

Physical edaphology studies on rainfed rice-based cropping systems. Dr. S. S. Hundal.

Mechanisms of iron reduction in submerged soils. Dr. J. C. G. Ottow, visiting scientist, Soil Microbiology Department, IRRI.

The growing U. S. interest in organic agriculture and its relevance to third world countries. Dr. R. R. Harwood, director, Organic Gardening and Farming Research Center, Rodale Press, Emaus, Pennsylvania, USA.

Testing and evaluation of agricultural machineries in Japan. Mr. M. Ariyoshi, agricultural engineer, Oyama, Japan.

Measurement problems and safety precautions in the use of hydroprobe depth moisture gauge. Dr. H. U. Neue.

Finances

The Institute received $19,263,203.71 during 1980.

The Ford Foundation gave $315,565 — $100,000 for core operations and capital expenditure, and $215,565 in support of rice research and development in Thailand ($20,565), Bangladesh ($170,000), and the Philippines ($25,000).

The Rockefeller Foundation gave $253,429.46, which included $200,000 for core operations and capital needs, $26,400 toward the stipend and miscellaneous expenses of a postdoctoral appointee; $25,000 toward preparation and planning of a conference on chemical research and its application to the world's expanding food needs; and $2,029.46 as a grant for 1979-80 in appreciation for the cordial reception accorded to Rockefeller Foundation fellows.

The United States Agency for International Development (USAID) gave $5,574,080.18 — $3,830,000 for core operations, $50,702.18 for expanding, strengthening, and further institutionalizing the National Applied Research and Extension Program for Transplanted Rice; and $337,468.42 for industrial extension of small-scale agricultural equipment developed at IRRI.

USAID also released $1,355,909.48 for continuing contracts:

- $214,253.64 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 a USAID loan.
- $408,084.47 for supporting a 2.5-year project for accelerated development and use of improved rice technology in Indonesia.
- $99,035.25 for collaborative rice research in Pakistan.
- $273,557.22 for a project on the consequences of mechanization on small farms.
- $227,275.90 for the services of an industrial extension engineer for the small-scale agricultural equipment extension project of the Government of Indonesia.
- $133,703 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 in children.

The Japanese Government gave $2,800,000 for purchase of research and training equipment, for partial support of cropping systems research, for expenses of the Plant Physiology and Soil Microbiology Departments, and for partial support of the GEU program.

The Ministry of Overseas Development, United Kingdom, gave $1,148,250 for the core program.

The Canadian International Development Agency gave $1,088,750 for core operations; $341,855 for cooperation between the Bangladesh Rice Research Institute and IRRI; and $634,785.45 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 Centre (IDRC), Canada, gave $412,907.42. Of that $29,748 was part of a 3-year grant for cropping systems outreach in South and Southeast Asia. The IDRC grant included $43,306.42 as part of a 2-year support of research in cooperation with the Central Research Institute for Agriculture, Indonesia, to develop cropping systems for rainfed and partially irrigated rice areas and to adapt them in farmers' fields; $209,543 as part of a 4-year grant to support a multiple cropping research project at the Bangladesh Rice Research Institute; $120,430 for the International Rice Agro-Economic Network (IRAEN) Phase II; and $9,880 to support scholarships at IRRI and the University of the Philippines at Los Baños leading to MS in Weed Science.

The European Economic Community gave $1,352,885.51 for water management, scholarships for candidates from developing countries, and partial support of the GEU program.

The Australian Government gave $811,433.86, of which $583,569 was for core operations, including travel of Australian scientists, and $227,864.86 for expansion of technical assistance and collaborative relationships with the Bangladesh Rice Research Institute.

The Federal Republic of Germany gave $850,464.70 for core operations; $15,000 for support of a research associate; $9,129.47 for support of a visiting scientist in soil microbiology; and $79,125 as first installment for the construction of an Isotope Laboratory.

The International Development Association gave $255,000 for core operations and capital expenditures.

The United Nations Development Programme released $1,439,028, of which $1,152,900 was for the International Rice Testing Program; $274,128 to investigate nitrogen fixation associated with wetland rice; and $12,000 toward a meeting of the Nitrogen Fixation Advisory Committee.

The International Fund for Agricultural Development gave $500,000 for research on rice-based cropping systems.

The OPEC Special Fund gave $200,000 to support the GEU program.

The Government of Indonesia, using a World Bank loan, released $168,362 to IRRI for development of research facilities at the Sukamandi Branch of the Central Research Institute of Agriculture and for scientific and technical assistance to rice research at Sukamandi.

The Government of Denmark gave $165,158.16 for the core program.

The Government of the Philippines gave $100,000 for the core program.

The Government of Sweden gave $119,760.48 for the core program.

The Swiss Federal Council, represented by the Swiss Development Corporation, gave $255,700 to support the studies on the effectiveness of nitrogen fertilizers used for rice.

The Government of New Zealand gave $24,300 for the core program.

Since July 1976, a contract between IRRI and the International Centre of Insect Physiology and Ecology has supported a joint program for ecological research on rice planthoppers using funds from the Australian Government. In 1980, $25,562.01 was released for use.

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 $36,557.46.

In 1976, IRRI entered into a cost-reimbursement contract with the U.S. National Institutes of Health to study ways of increasing protein and essential amino acids in the rice grain through plant breeding. In 1980, $13,729.42 was reimbursed.

Other donors were:

- Philippine Council for Agriculture and Resources Research:
  - (a) cooperative applied research on rainfed rice $24,961.42
  - (b) cooperative project toward improved organization of small farmers for intensified rice production 5,421.62
- National Food and Agriculture Council, training government extension technicians 94,024.38
- International Board for Plant Genetic Resources, field collection of indigenous rice germplasm in South and Southeast Asia 20,000.00
- 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 ... 2,500.00
- FMC, International, entomological research 3,000.00
- Montedison, pest control 3,000.00
- Cyanamid Overseas Corporation, weed control and insect control 2,000.00
- Uniroyal Chemical, pesticide research 496.06
- Shell Chemicals Co., research on agricultural chemicals 6,756.75
- University Hohenheim Stuttgart, travel for Dr. Ottow's research project 4,370.40
- United Nations University, research on protein requirements of young Filipino adults 7,764.50
- Office of Rural Development, Korea, seed multiplication program and cooperative research program 86,590.00
- Kemanobel, pesticide research 500.00

Staff changes

January

Dr. Ian Fillery joined the Soil Chemistry Department as associate soil scientist in the International Fertilizer Development Centre (IFDC)-IRRI collaborative research.

Dr. Leonardo Gonzales joined the Agricultural Economics Department as associate agricultural economist under the joint IRRI-IFPRI Collaborative Project.

Dr. Mun-Hue Heu joined the Plant Breeding Department as plant breeder.

Dr. Jerry L. McIntosh began his 1-year sabbatical leave with the Benchmark Soils Project, University of Hawaii.

Dr. Floyd H. Nordland joined the Rice Production Training and Research Department as biologist and training specialist.

Dr. Rosendo K. Palis joined the Institute's Collaborative Project in Burma as agronomist.

Dr. John A. Varley of Tropical Soils Unit, Land Resources Development Center, United Kingdom, joined the Chemistry Department as visiting scientist.

February

Dr. Eric T. Craswell of IFDC, Alabama, completed his assignment at IRRI.

March

Dr. Osamu Mochida, entomologist with the Cooperative CRIA-IRRI Program in Indonesia, resigned.

April

Dr. Masao Kikuchi joined the Agricultural Economics Department as associate agricultural economist.

May

Mr. Robert Cowell completed his 1-year assignment as visiting associate editor, Office of Information Services.

Dr. Russell D. Freed, associate plant breeder under the joint GSL/IRRI Collaborative Program, resigned.

Dr. J. S. Nanda, plant breeder, Plant Breeding department, resigned.

June

Dr. Clarence C. Bockhop joined the Agricultural Engineering Department as agricultural engineer and department head.

Dr. Pierre A. Roger of the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) completed his 1-year assignment as visiting scientist, Soil Microbiology Department.

July

Dr. Virgilio R Carangal began his 1-year sabbatical leave at the North Carolina State University.

Mr. Glenn L. Denning of the Philippine-Australian Development Assistance Programme (PADAP) joined the Rice Production Training and Research Department as visiting associate field specialist.

Dr. Robert W. Herdt, agricultural economist of the Institute, completed his 1-year sabbatical leave at Cornell University.

Dr. Peter R. Hobbs, associate agronomist in the Institute's project in Bangladesh, resigned.

Ms. Debra Jefferson of the University of Missouri joined the Office of Information Services as visiting associate editor.

Dr. John P. Jones of the University of Florida joined the Plant Pathology Department as visiting scientist.

Dr. Hajimu Komada of Central Agricultural Experiment Station, Japan, joined the Soil Microbiology Department as visiting scientist for 2 months.

Dr. K. C. Ling, plant pathologist of the Institute, completed his 1-year sabbatical leave at the University of California.

Prof. Dr. J. C. G. Ottow of the Universitat Hohenheim joined the Soil Microbiology Department as visiting soil scientist.

Dr. M. C. Rush of the Louisiana State University completed his 1-year assignment as visiting scientist, Plant Pathology Department.

Dr. Leslie E. Small of Rutgers, State University of New Jersey, completed his 1-year assignment as visiting agricultural economist, Agricultural Economics Department.

Dr. S. S. Virmani joined the Institute as plant breeder for the Cooperative Project with the Arab Republic of Egypt.

August

Prof. Jacques L. Auclair of the University of Montreal joined the Entomology Department as visiting entomologist.

Dr. Foster B. Cady of Cornell University joined the Agronomy Department as visiting scientist.

Dr. Robert E. Huke of Dartmouth College completed his 1-year assignment as visiting scientist, Agricultural Economics Department

- Dr. Leo Dale Haws, head, Rice Production Training and Research Department, began his 1-year sabbatical leave at the Texas A&M University.
- Dr. U. S. Jones of Clemson University completed his 1-year assignment as visiting agronomist, Agronomy Department.
- Mr. Donald O. Kuether, agricultural engineer, Agricultural Engineering Department, resigned.
- Mr. John A. McMennamy, agricultural engineer, Agricultural Engineering Department, resigned.
- Mr. C. J. Moss joined the Institute as agricultural engineer in the Cooperative Project with the Arab Republic of Egypt.
- Dr. J. P. G. Webster of Wye College joined the Agricultural Engineering Department as visiting agricultural economist.

September

- Dr. W. Harvey Reissig of New York State Agricultural Experiment Station completed his 1-year assignment as visiting entomologist, Entomology Department.

November

- Mr. John P. Brien of the University of Sydney joined the Office of Information Services as visiting scientist.
- Dr. Johnny W. Pendleton joined the Multiple Cropping Department as agronomist and department head.
- Dr. Hubert G. Zandstra, agronomist and head, Multiple Cropping Department, resigned.

December

- Dr. Donald W. Barton, director, New York State Agricultural Experiment Station, Cornell University, completed his 1-year assignment with the Office of the Director General.
- Dr. Floyd H. Nordland, biologist and training specialist, Rice Production Training and Research Department, resigned

Crop weather

Total 1980 rainfall was 2,303 mm (1979 total was 1,888 and 1959-80 mean is 2,040). The wettest months were October, June, July, and November (312-386 mm); the driest month was April (16.1 mm). Much of the rainfall was due to 15 tropical cyclones that crossed the country between February and November — 2 affected dry season field research at IRRI and 3, IRRI outreach trials in the Cagayan Valley.

Total evaporation was 1,925 mm. Solar radiation and humidity were above average for all months. There was more bright sunshine during February, March, April, and May than during the rest of the year. Highest maximum temperature was in May (34.1° C), and the lowest minimum was in February (20.9° C). Humidity ranged from 81 to 90%.

Table 1 shows the weather data for 1980.

Table 1. Weather elements for 1980, and 1959-80 average, IRRI.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
						Rainfall							
Totals for 1980	17.5	16.4	122.3	16.1	175.2	364.9	342.9	264.0	190.0	385.9	312.5	95.0	2,303
Mean 1959-80	41.2	19.0	30.3	33.6	194.0	243.2	262.0	271.9	264.1	238.5	272.1	170.5	2,040
						Evaporation (mm)							
Totals for 1980	142.5	174.3	212.0	233.0	216.6	146.0	147.2	140.9	129.3	132.8	129.8	120.8	1,925
Mean 1959-80	135.7	158.3	211.4	240.5	213.6	159.8	144.8	139.1	128.9	134.3	114.0	111.5	1,892
						Solar radiation (g/cal cm²)							
Totals for 1980	12,871	14,332	15,767	17,165	16,851	14,427	14,308	14,582	11,694	13,097	11,694	10,776	167,564
Mean 1959-80	10,718	11,891	15,128	16,455	15,564	13,466	12,916	12,278	11,675	11,369	9,923	9,432	150,815
						Bright sunshine (h)							
Totals for 1980	185.9	214.5	254.0	288.0	237.3	179.1	186.4	175.9	100.8	165.9	189.7	126.9	2,304
						Max temperature (°C)							
Mean 1980	29.6	31.0	32.1	33.7	34.1	32.3	31.4	31.5	31.1	31.6	31.0	29.4	
Mean 1959-80	29.0	30.1	31.7	33.7	33.9	32.8	31.7	31.4	31.4	31.0	30.1	29.1	
						Min temperature (°C)							
Mean 1980	21.4	20.9	21.2	22.6	23.5	23.8	23.1	22.9	23.2	23.3	22.7	22.1	
Mean 1959-80	20.8	20.7	21.4	22.7	23.6	23.4	23.3	23.1	23.0	22.8	22.5	21.9	
						Relative humidity (%)							
Mean 1980	90	85	84	83	81	88	87	87	88	88	90	90	
Mean 1959-80	86	84	80	79	79	82	84	86	87	86	86	87	

ANNUAL REPORT FOR 1980

Research highlights

Genetic evaluation & utilization (GEU) program

Control & management of rice pests

Irrigation & water management

Soil & crop management

Environment & its influence

Constraints on rice yields

Consequences of new technology

Cropping systems program

Machinery development & testing