INTERNATIONAL RICE RESEARCH INSTITUTE

Annual Report for 1981

INTERNATIONAL RICE RESEARCH INSTITUTE

ANNUAL REPORT FOR 1981

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ANNUAL REPORT FOR 1981

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*Left during the year.
**Transferred during the year.
***On study leave.
†On project appointment.
††On part-time basis.
†††On emergency appointment.
‡Acting as of 1 June 1981.

About this report

This 20th annual report includes research reported during 1981. The department or departments that performed the research are identified in italics below the topic heading. For example:

DISEASE CONTROL

Plant Pathology Department

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

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

This report makes reference to three fundamental types of rice culture. Dryland (upland) culture means rice grown without irrigation in unbunded fields. Rainfed 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 sigh (×). For example, PTB33×IR30 is written PTB33/IR30. The sequence of crosses is indicated by the number of slant bars. (PTB33 × IR30) × IR36 is written PTB33/IR30//IR36. The fourth and further crosses are designated /4/, /5/, and so on. Backcrosses are indicated by a superscript numeral.

Scoring of morphological characters and of damage due to rice pests and 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.

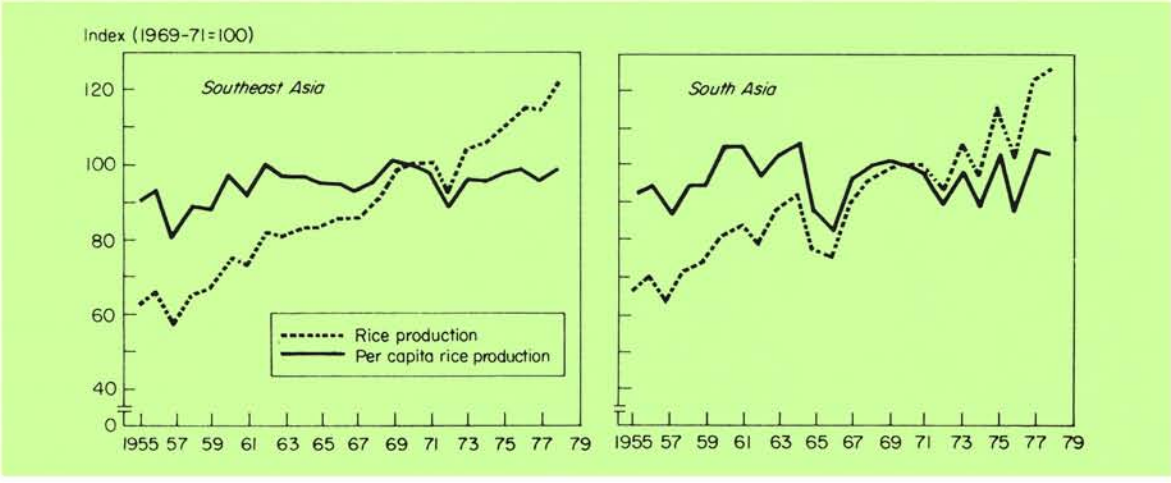
The report uses generic names instead of brand names for chemicals. Use of a commercial or brand name when the generic name is unobtainable does not constitute an endorsement of the product.

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.

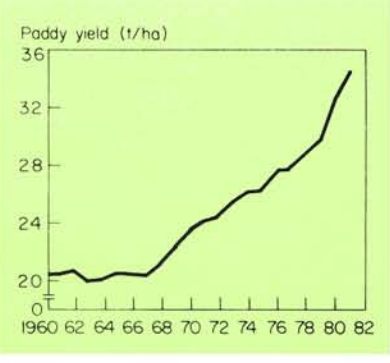
Research Highlights

MOVING AHEAD BUT STANDING STILL

Rice production in most Asian countries during the past decade has continued to rise. Total production has increased and so has yield per hectare. For most countries, however, the increases have done no more than keep pace with population growth. Until 1979, in terms of rice production, we seemed to be moving ahead rapidly, but in terms of rice available to each individual, we were doing little better than standing still (Fig. 1).



1. Trends in rice production and per capita rice production in South and Southeast Asia.



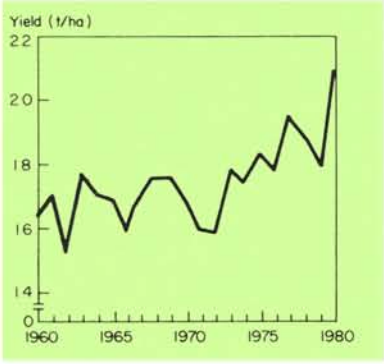
2. Yields of paddy in Indonesia have steadily moved higher since 1968. The first modern variety was released in 1967. Varieties resistant to brown planthopper biotype 1 were released in 1975; varieties resistant to biotype 2, in 1976. Peta Baru 36 (IR36) was released in 1977.

Mean yields have increased steadily, since 1967 in Indonesia (Fig. 2), since 1972 in the Philippines (Fig. 3), and since 1978 in Burma (Fig. 4). The progress in Indonesia and Burma since 1978 has been outstanding.

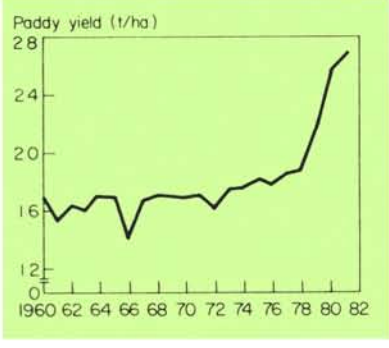
Indonesia was for many years a major importer of rice. In 1981, it produced more rice than it consumed, although rice imports were continued to build reserves. And, as rice yields and production increased in Indonesia, so did per capita consumption — from about 115 kg/person per year in 1970 to 130 kg in 1980.

This tipover from deficit to surplus is to the credit of the Indonesian research and extension agencies involved. IRRI is proud to have shared in that success, through our training programs (in which Indonesians have participated more than any others, through our cooperative projects in Indonesia, and through the success of Peta Baru 36, the IRRI-bred variety (IR36) now grown on more than 60% of the irrigated rice area in Indonesia.

Burma, Indonesia, and the Philippines give a satisfying feeling of moving ahead. But other areas continue to remind us that we are "standing still." For parts of India and Bangladesh, rice production lags



3. Paddy yields in the Philippines have increased steadily since 1972, a year marked by an unusual combination of heavy rains and severe drought. IR36, which in 1981 became the world's most widely grown rice variety, was released by the Philippine Seed Board in 1976.



4. Paddy yields in Burma turned upward sharply in 1978. That year (crop year 1977-78) 10% of the rice area was planted to modern varieties. By 1980-81 the area planted to modern rices was 41% of total area. In 1977-78, the Agriculture Corporation launched its Whole Township Production Program, a concentrated rice extension effort.

behind population growth. In the Punjab in Northern India, rice yields have increased steadily since 1960, averaging more than 4 t/ha in recent years. But in Eastern India, average yields in 1979 (the latest year for which statistics have been published) were still less than 2 t/ha (Fig. 5). In Bangladesh, yields tended to increase during the past decade, but in 1980 the national average was still only 2 t/ha (Fig. 6).

IRRI often gets the comment that the modern IR rices are suited only to well-irrigated fields and have little impact elsewhere. *Research Highlights for 1975* posed the question: "What about the other three?" What about the farmers without irrigation who farm three-quarters of the rice lands in tropical Asia? It described the efforts initiated that year to develop rices adapted to the nonirrigated areas.

The nonirrigated areas often are referred to as rainfed, but they embrace a wide range of rice-growing environments. Nonirrigated areas include lands subject to seasonal deep flooding and tidal inundations. Figure 7 illustrates the relative extent of categories of the world's rice land.

At first glance, the irrigated area is slightly more than half of the total. But when the temperate-area rice lands of China, Japan, and the United States are excluded, the proportion of irrigated land falls below one-third of the total.

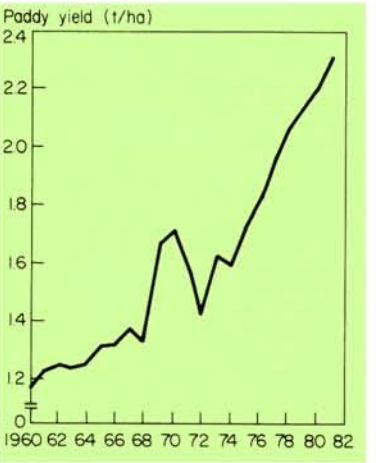
On the basis of water regime, the rainfed rice area subdivides into dryland, shallow, deepwater, and floating rice areas. Dryland areas are those not normally submerged, shallow areas are subject to flooding to 30-cm depth, deepwater areas are flooded to 1-m depth, and floating rice areas are those in which floods normally exceed 1-m depth. These subdivisions are convenient for mapping purposes, but are a poor guide to the rice varieties needed for the rainfed areas.

In a large proportion (about half) of the shallow rainfed areas, conditions during much of the growing season closely approximate those of fully irrigated areas. Varieties developed for irrigated areas are well suited for these favorable shallow rainfed areas, especially if they have some ability to tolerate or recover from drought, which IR36 has.

In the Philippines and Indonesia, the irrigated rice area accounts for only about 30% of the total. But much of the remainder is shallow rainfed rice land, and much of that is in the favorable category. Adoption of modern varieties by farmers in those areas has contributed to the yield improvements of recent years (Fig. 8), even though occasional drought inevitably restricts yields.

In 1981, IRRI constraints studies showed that, although farmers use modern varieties on at least the more favored rainfed areas, they are reluctant to use more than low levels of fertilizer because of the risk that drought or other factors will prevent a response. Studies to date suggest that the farmers are probably correct in their refusal to risk expenditure on inputs, and emphasize the need to develop better varieties and management practices for the rainfed areas. If a greater degree of drought resistance, as well as resistance to insects and diseases, can be incorporated into varieties, a positive response to fertilizers would be more certain and yield levels would increase considerably.





5. Yield trends of rice in northern and eastern India show the failure of production in eastern India to move above the 2-t/ha yield levels.

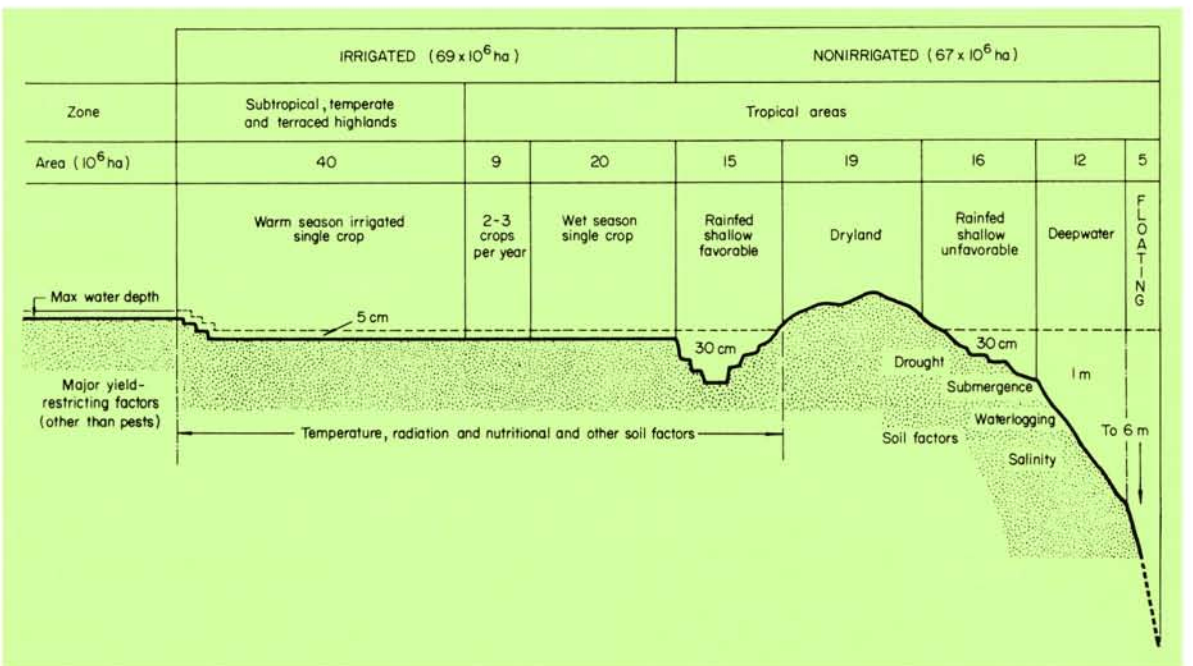
6. Average rice yields in Bangladesh moved above the 2-t/ha level in 1980.

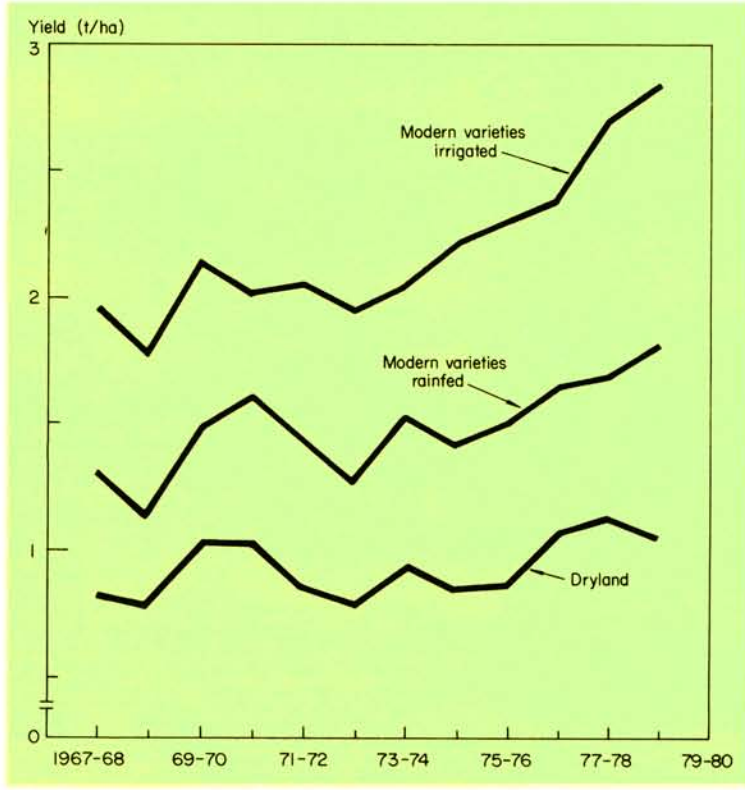
Eastern India, where a large proportion of the area is subject to flooding to 60-cm depth and where the water remains stagnant for much of the year, presents a scientific challenge that has yet to be met. The failure to make progress in these areas is shown by an almost static yield curve (Fig. 5).

There also has been little improvement in the yields obtained from dryland rice —for instance, in the Philippines (Fig. 8). There is an even greater need to develop better adapted varieties for these more drought-prone areas. The same is true for the deepwater areas, although varieties RD17 and RD19 — which were released in 1980 in Thailand for deepwater farmers — continue to show promise.

IRRI will maintain its efforts to develop technology to increase rice yields for farmers with irrigated land, where rice production is currently running fast. But we are not moving ahead of population growth in the

7. The world's rice areas divide almost equally into irrigated and rainfed. More than 60% of the irrigated area is, however, in China and India. Only about 20% of the rainfed — shallow rainfed — has environments favorable to rice growing.





8. Data from the Philippine Bureau of Agricultural Economics indicate a steady increase in yields from modern rice varieties in irrigated and rainfed fields.

rainfed areas, where yields have been standing still for some time and are only now starting to creep forward. If rice production is to keep pace with population growth during the next decade, it is essential that we run faster with rice improvement for the rainfed areas.

During 1981, plans were initiated to give a much sharper focus to the efforts to develop improved varieties for the different rainfed areas. Interdisciplinary teams for dryland rice and deepwater rice had been established earlier. Those teams have been strengthened and teams have been organized to deal with the shallow but submergence-prone areas, the waterlogged areas, and the tidal swamp areas. There are serious barriers to progress for these problem areas, but those rice lands form a large enough proportion of the world's rice area to make breaking the barriers essential (Fig. 7). The research reported here describes the 1981 work directed to improvement of rainfed as well as irrigated rice.

With the increase in irrigated land area in the past 6 years, we now speak of efforts to improve the lot of the other two tropical rice farmers who do not have the benefits associated with irrigation. About half of IRRI's budget is directed to improving the lot of these less advantaged farmers.

Genetic evaluation and utilization (GEU) program

Genetic resources program

Plant Breeding and Statistics Departments

FIELD COLLECTION **6**
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FIELD COLLECTION

Plant Breeding Department

Systematic field collection of traditional rice varieties continued, partly with funds provided to national centers by the International Board for Plant Genetic Resources (IBPGR). Funds from the IBPGR also assisted national centers in improving seed storage facilities, in conducting local training courses, and in shipping seed samples to IRRI.

Field canvassing in Bangladesh, Burma, India, Indonesia, Nepal, and Thailand added 1,898 samples to IRRI's collection in 1981. IRRI staff members also collected 72 Philippine varieties. Table 1 summarizes 10 years of collection in 14 Asian countries.

Conservation of wild-rice relatives. Although IRRI maintains a collection of wild species in the genus *Oryza*, the total holding is only 1,096 accessions. About 560 accessions are immediate wild relatives of *O. sativa*, *O. rufipogon*, *O. nivara*, the *spontanea* forms of *O. sativa*, and the *O. perennis* species-complex. IRRI scientists also have collected wild taxa while traveling in tropical Asia but no special effort has been made to search for wild rices, making the limited collection a weak spot in the total conservation program. On the other hand, several wild taxa have been identified by IRRI staff as possessing rare or high levels of resistance to major diseases and insects. For instance, a strain of *O. nivara* collected from U.P. State, India, has provided the only known source of resistance to grassy stunt virus. IRRI virologists recently found that two strains of Taiwan's wild rice *O. perennis* have higher levels of resistance to ragged stunt virus than any *O. sativa* cultivar tested so far. Several other wild species, more remotely related to *O. sativa*, have high levels of resistance to green leafhoppers and brown planthoppers.

In September-October 1981, IBPGR-IRRI Rice Advisory Committee members visited the germplasm-rich Jeypore Tract in east India, where they observed wide genetic diversity among both the primitive cultivars and the wild rice *O. nivara* and the *spontanea* forms of *O. sativa*. Jeypore is one of the few places in the world where tribal women still collect self-perpetuated, free-shedding wild rice from ponds or swamps (Fig. 1). But self-perpetuating wild rices are becoming fewer and increasingly infused with cultivated rice genes as a result of natural crosses between the two taxa, a process of genetic erosion. Genetic erosion is undoubtedly even faster in areas where progressive agriculture is advancing more rapidly.

The Committee has recommended that IBPGR and IRRI assign a higher priority to the genetic conservation of the four wild relatives of *O. sativa*. Other priorities were suggested for the remaining wild species in the genus. The Committee also developed recommendations related to operational

Table 1. Indigenous rice varieties collected in 14 collaborating countries with IRRI's direct or indirect participation, 1971-81.

Country	Years	Indigenous varieties collected (no.)	
		Direct IRRI participation	Indirect IRRI participation
Bangladesh	1973-81	2,451	2,857
Bhutan	1975-76	–	121
Burma	1973-74, 1976, 1980	225	967
India	1976, 1978-81	–	5,208[a]
Indonesia	1972-76, 1978-81	5,103	4,681
Kampuchea	1973	280	–
Laos	1972-73	–	899
Malaysia	1973-79	–	972
Nepal	1971-72, 1979-81	–	1,688
Pakistan	1972-73, 1976, 1979	–	772
Philippines	1973-76, 1977-81	582	2,053
Sri Lanka	1972, 1975-76, 1978-81	1,675	550
Thailand	1973, 1975-76, 1978-81	–	2,650
Vietnam	1972-75, 1978-80	108	650
	Total	10,424	24,068

[a] Estimate based on seed samples received at IRRI.



1. Jeypore (east India) tribal woman collecting self-perpetuated, free-shedding wild rice.

aspects of conservation and the training of field collectors.

INSTITUTIONAL EXCHANGES

Plant Breeding Department

IRRI continued to receive duplicate samples from the collections of other institutions. The major donors of 6,092 samples deposited into the germplasm bank were:

- Bangladesh Rice Research Institute — 64 aus varieties.
- Agricultural Research Institute, Burma — 561 varieties.
- Chinese Academy of Agricultural Sciences, Peking, China — 1,025 varieties from the collection of Chekiang Provincial Academy of Agricultural Sciences.
- The Rice Research Station at Pattambi, Kerala; the G.B. Pant University of Agriculture and Technology at Pantnagar, U.P.; the All-India Coordinated Rice Improvement Program at Hyderabad; and the Rice Research Station at Moncompu, Kerala — 380 samples.
- International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria — 255 samples of IITA's breeding materials.
- Indonesia — 48 varieties collected from central Kalimantan.
- Nepal — 720 varieties.
- Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT), Montpellier, France — 309 *O. sativa* varieties, 99 *O. glaberrima* varieties, and 1 wild taxon, all collected from West Africa.
- Bureau of Plant Industry and Bureau of Agricultural Extension, Philippines — 105 varieties.
- Vietnam — 92 varieties from the north.
- West Africa Rice Development Association, Monrovia, Liberia — 340 swamp varieties collected from Sierra Leone.

Replacement samples also were obtained for 142 accessions that had become nonviable during storage.

The International Rice Testing Program furnished 880 entries from international nurseries for preservation.

The National Institute of Agricultural Sciences (NIAS) of Japan and IRRI began to systematically consolidate their rice collections. The two institutes compared accession lists to identify duplicate samples and nonduplicate holdings. As a result, IRRI furnished the NIAS Germplasm Seed Storage Laboratory with 314 varieties not in the NIAS collection that reportedly had originated in Japan. NIAS will assist IRRI in rejuvenating and preserving such varieties.

SEED INCREASE, REJUVENATION, AND DISTRIBUTION

Plant Breeding Department

In the dry season, 2,917 plots were grown for initial seed increase and 6,000 accessions were rejuvenated to provide seed for canning. In the wet season, 6,708 plots were planted for characterization and 4,875 accessions were rejuvenated.

As one of its primary services, the germplasm bank continued to supply seed to rice researchers all over the world. In response to 206 requests, 4,376 seed samples were sent to foreign researchers. In response to 422 requests within IRRI, 29,056 samples were furnished. Moreover, 1,021 samples of African rices and wild species were distributed. Although the total number of seed samples supplied has been about the same for the last 4 years, the number of requests has increased steadily (Table 2).

A large collection of traditional cultivars known locally to have special characteristics has been assembled by field collectors of national centers and IRRI. Seeds are distributed to IRRI's GEU

Table 2. Distribution of seed samples by the IRRI Germplasm Bank, 1977-81.

Year	Seed samples[a] (no.)		
	Oryza sativa		Other species
	Inside IRRI	National programs	
1977	50,354 (196)	4,126 (148)	653 (22)
1978	31,941 (182)	7,316 (142)	1,174 (43)
1979	26,694 (268)	3,260 (157)	1,074 (46)
1980	29,734 (337)	3,659 (156)	1,216 (65)
1981	29,051 (318)	4,376 (206)	1,021 (44)

[a]Number inside parentheses indicates the number of seed requests processed.

scientists for evaluation soon after the initial cycle of seed multiplication is completed. During 1981, special types provided to IRRI staff included 68 deepwater rices, 111 varieties tolerant of adverse soil factors, 7 cold-tolerant indica varieties, and 1,270 drought-resistant or dryland varieties.

INVENTORY, CHARACTERIZATION, AND DATA PROCESSING

Plant Breeding and Statistics Departments

At the end of 1981, the IRRI germplasm bank had registered 57,027 accessions of *O. sativa*, 2,575 accessions of *O. glaberrima*, 1,096 populations of wild species, and 678 genetic testers and mutants. About 5,000 recently received seed samples await initial planting and seed increase. During the past 10 years, more than 12,000 additional seed samples were not counted as registered accessions because the seeds either did not germinate or were obvious duplicates.

During 1981, the morphoagronomic traits in the field of 6,708 accessions were systematically described. Laboratory measurements of panicle and grain characters on 2,400 accessions were completed. By the end of the year, field records of 52,260 accessions had been made, but only 40,619 accessions were completely characterized because of a shortage of manpower in the laboratory.

Data on 46,954 accessions have been entered in the computerized files. During the year, the morphoagronomic file and the GEU-traits file were used extensively to identify accessions requested by rice researchers.

PROCESSING SEED FOR MEDIUM- AND LONG-TERM STORAGE

Plant Breeding and Statistics Departments

The system of vacuum-packing rice seed in aluminum cans for medium- and long-term storage was initiated in mid-1980. By the end of 1981, only 6,121 of the 40,977 accessions grown for this purpose had been packed. The very low percentage of accessions being canned can be ascribed to the meager quantity of high-quality seed identified by visual selection as suitable for canning. Poorly developed or discolored seeds and mechanical mixtures often made up a large portion of a harvested seedlot. It would be desirable to rejuvenate accessions under relatively disease- and insect-free conditions.

When an accession has produced sufficient seed for canning, a second 30-g seedlot is sealed in aluminum-foil envelopes and sent to the U.S. National Seed Storage Laboratory in Ft. Collins, Colorado, for duplicate storage. This duplication adds to the security of the collection. Duplicates of 3,863 accessions were made during 1981.

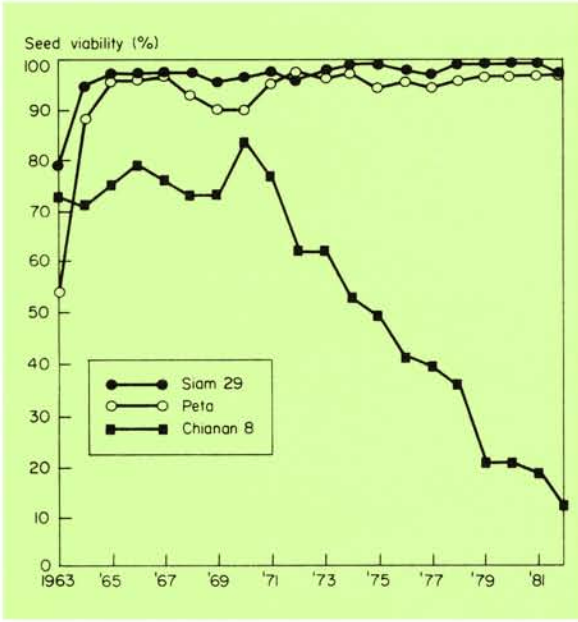
Records on seed rejuvenation and canning were entered in the computerized files.

MONITORING VIABILITY OF STORED SEEDS

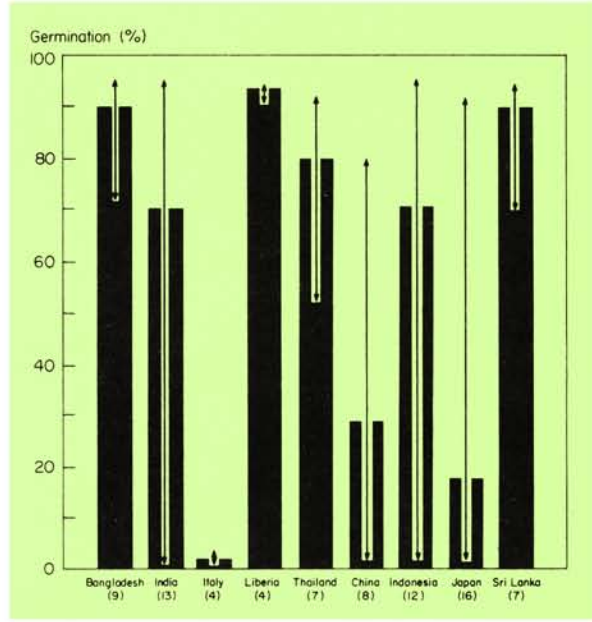
Plant Breeding Department

Of 3 control varieties (Peta, Siam 29, and Chianan 8) kept at 8-9% moisture content in the medium-term storage room (2° + 1° C) for 18 years, the 2 tropical varieties Peta and Siam 29 consistently showed 96% germination. Viability of the temperate-zone variety Chianan 8 dropped to 63% after 9 years (Fig. 2) and fell to 11% at the end of this year. Peta has moderately strong dormancy, Siam 29 very strong dormancy, and Chianan 8 no dormancy.

Among the thousands of rice cultivars held in short-term cold storage (19°-21° C, 45-50% R.H.) at 11% moisture content in unsealed paper bags for 3 years, 80 accessions of different geographic origins were randomly sampled and tested for viability. Marked differences were observed (Fig. 3). Cultivars from temperate regions had 0-93% viability. Most tropical cultivars had above 90% viability. Cultivars from humid regions generally were more



2. Seed viability of 3 rice varieties kept in the medium-term storage room at IRRI from summer 1963 through 1981.



3. Average seed viability of 80 accessions originating from 9 countries. Arrows indicate viability range. Numbers in parentheses indicate sample size. IRRI, 1981.

viable than cultivars from drier climates. Such varietal differences were more striking in short-term storage than in medium-term storage (2°-3° C) inside airtight containers for 9 years.

The findings clearly indicate differential seed longevity among cultivars. They also point to the need for including different types of control varieties in rice seed storage tests. IRRI has grown 5-10 accessions of different variety groups each crop season since 1980. The seeds are used as control samples for periodic viability tests.

Comparison of seed moisture content, seed containers, and storage conditions. Changes in viability of seed samples dried to two moisture content levels (6 and 12%), packed in different containers, and stored under a range of environments have been monitored since June 1979. Varieties IR34, IR36, and H4 were used. The containers were kraft paper envelopes, aluminum foil-polyethylene envelopes, and hard polyethylene grain-sample bottles. Storage conditions were ambient temperature 24°-32° C and relative humidity (RH) 80-100% in a basement room, 19° C and 55% RH in the short-term storage room, 5°-6° C in a refrigerator, 2°-4° C in the medium-term storeroom, -10° C in the long-term room, and -20° C in a laboratory freezer.

Seeds packed in paper envelopes lost all viability after 6 months' storage under ambient temperature and high humidity. But seeds with 12% moisture content packed the same way and stored in plastic bottles remained viable up to 12 months. Seeds with 6% moisture content were viable up to 18 months.

Seeds with 12% moisture content packed in foil envelopes began to show a drop in viability after storage for 18 months under ambient temperatures. Seeds of IR34 and IR36 had less than 10% viability at 33 months; seeds of H4 kept 75% viability. No changes were noticeable in seeds stored in foil envelopes in refrigerated areas.

Seeds with either 6 or 12% moisture content showed no significant change in viability when stored in paper bags inside the short-term room or refrigerator. Also, no viability was lost in different packages stored for 33 months in the air conditioned environment of the short-term room, refrigerator, medium-term room, long-term room, and deep-freeze.

When seed viability dropped under ambient conditions, H4 generally showed a slower loss in viability than did IR34 or IR36. H4 has the highest level of grain dormancy.

TRAINING GENETIC STOCK OFFICERS

Plant Breeding Department

IRRI continued to provide short-term training on rice genetic resources management. Seven Chinese GEU trainees spent 2 weeks to 2 months with the staff of the germplasm bank to learn about aspects of genetic conservation. The trainees have been given partial responsibility for maintaining local rice collections at their home stations. A staff member from the Vietnam Agricultural Science Institute in Hanoi, Vietnam, spent the first half of his 4-month training with the germplasm bank.

Genetic evaluation and utilization (GEU) program

Agronomic characteristics

Agronomy and Plant Breeding Departments

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YIELD PERFORMANCE AND NITROGEN RESPONSE OF RICE CULTIVARS

Agronomy Department

Agronomic characteristics and nitrogen response of several cultivars were tested at IRRI, in farmers' fields, and at the Philippine Bureau of Plant Industry (BPI) stations in Camarines Sur, Iloilo, and Nueva Ecija.

Irrigated rice. *IRRI.* In the dry season, 6 varieties and 22 promising IR lines were evaluated at 5 nitrogen levels (Table 1). Without added nitrogen, IR42 and 9 other lines yielded 3 t/ha or higher; at high nitrogen, IR8192-200-3-3-1-1 yielded highest (7.5 t/ha).

Among the early-maturing lines, IR19743-25-2-2-3-1 outyielded IR36, IR50, and IR54 at 90 kg N/ha. Brown planthoppers severely damaged IR8 and IR20 in the reproductive stages.

In the wet season, IR36 yielded highest (5.4 t/ha) at 100 kg N/ha. With zero fertilizer nitrogen, early-maturing IR9729-67-3 yielded 4.2 t/ha (Table 1). IR8192-200-3-3-1-1, the highest yielder in the dry season, lodged during the spikelet-filling stage. Most test rices yielded well at 60 kg N/ha. An F_1 hybrid cross, 97A/IR54F_1, has good agronomic

Table 1. Yield of rice varieties and promising lines at 5 nitrogen levels[a] in irrigated plots, IRRI, 1981 dry and wet seasons.

Designation	Dry season						Wet season					
	Growth duration (days)	Yield[b] (t/ha)					Growth duration (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		0 kg N/ha	30 kg N/ha	60 kg N/ha	100 kg N/ha	120 kg N/ha
IR8	134	1.7[c]	1.4[c]	1.5[c]	1.3[c]	1.6[c]	132	1.1	–[d]	0.7	0.7	1.4[e]
IR20	119	2.0	2.6[c]	2.7[f]	1.8[f]	1.5[f]	125	1.2	1.3	1.2	0.4[d]	0.4
IR36	117	2.8	4.6	5.7	6.2	6.0	107	3.2	4.1	4.8	5.4	3.5
IR42	140	3.8	5.8	6.5	6.5	6.7	136	3.2	4.1	4.5	4.2	4.2
IR50	113	2.5	3.9	4.8	5.5	5.4	–	–	–	–	–	–
IR54	127	2.8	5.1[e]	4.9	6.3[e]	4.7	125	3.6	4.3	4.5	3.2	3.6
IR8192-200-3-3-1-1	127	3.6	5.8	6.1	6.9	7.5	125	2.6	3.6	3.7	3.8	2.4
IR9129-209-2-2-2-3	113	2.3	4.0	5.1	5.2	5.6	–	–	–	–	–	–
IR97A/IR54$_{F1}$	–	–	–	–	–	–	125	2.8	3.5	3.7	3.3	3.8
IR9729-67-3	–	–	–	–	–	–	97	4.2	4.1	4.5	4.0	4.3
IR9752-71-3-2	104	2.4	3.8	4.4	5.0	5.6	97	2.2	3.7	4.9	4.8	5.2
IR13423-10-2-3	129	3.1	5.0	5.6	6.1	6.2	124	3.6	4.7	4.7	5.2	4.2
IR13423-17-1-2-1	133	3.3	5.2	6.0	6.2	7.3	124	3.1	4.5	5.0	5.0	4.6
IR13427-40-2-3-3-3-3	–	–	–	–	–	–	107	2.8	3.5	4.9	5.2	4.6
IR13429-109-2-2-1	113	2.1	4.0	4.5	5.0	4.8	107	3.2	4.1	4.9	4.6	3.2
IR13429-196-1-2-1-1	108	2.6	3.9	4.5	5.2	5.3	–	–	–	–	–	–
IR13429-299-2-1-3-1	108	2.8	4.2	4.4	5.0	5.2	107	2.5	3.6	4.7	4.8	3.4
IR13525-43-2-3-1-3-2	132	3.1	5.0	5.8	6.5	6.5	124	3.9	4.4	5.0	4.5	3.9
IR13540-56-3-2-1	–	–	–	–	–	–	130	3.4	3.9	4.3	3.5	2.6
IR15314-30-3-1-3	140	2.9	4.9	5.4	5.9	5.8	–	–	–	–	–	–
IR15314-43-2-3-3	140	3.8	5.5	6.4	6.8	6.6	136	3.3	3.2	3.8	3.8[e]	3.7
IR15318-2-2-2-2-2	132	3.2	5.4	6.5	6.6	7.0	–	–	–	–	–	–
IR15529-256-1	132	3.2	5.6	6.2	6.4	7.0	–	–	–	–	–	–
IR17488-2-3-2	140	2.9	5.5	6.2	5.9	6.2	132	3.0	3.1	3.9	3.8	3.7
IR17494-32-1-1-3-2	132	3.0	5.5	6.0	6.5	6.6	125	2.5	3.7	3.8	4.3	3.1
IR19661-131-1-3-1-3	133	3.4	5.4	5.9	6.5	6.3	130	2.8	3.8	3.7	4.3	3.1
IR19672-155-2-1-1-3	–	–	–	–	–	–	132	3.8	4.0	4.0	4.0	3.8
IR19728-9-3-2-3-3	–	–	–	–	–	–	97	3.2	4.1	4.3	4.5	4.0
IR19735-5-2-3-2-1	105	2.7	4.5	5.0	5.7	6.2	97	3.5	3.9	4.7	5.0	4.3
IR19743-25-2-2-3-1	111	2.7	4.6	6.3	6.2	6.5	97	3.4	4.5	4.1	4.5	4.1
IR19743-40-3-3-2-3	104	1.8	3.8	4.3	5.6	5.8	–	–	–	–	–	–
IR19743-46-2-3-3-2	105	2.0	4.1	4.3	6.1	6.2	97	2.8	4.2	4.5	4.4	4.1
IR19746-28-2-2-3	105	2.5	4.6	5.8	6.1	6.1	97	4.0	4.2	5.1	4.9	4.4
IR25588-32-2	–	–	–	–	–	–	107	3.7	4.2	5.1	4.6	3.8
Peta	141	2.5	2.9	3.0	2.0	1.9	136	1.8	1.6	1.1	1.4	0.9

[a]Each nitrogen treatment included 30 kg N/ha topdressed 1 week before panicle initiation in the dry season and 20 kg N/ha per week before panicle initiation in the wet. [b]Av of 3 replications. [c]Hopperburned during hard-dough stage. [d]No harvest. [e]Two replications only. [f]Hopperburned during hard-dough stage. Scored 9 on Standard Evaluation System for Rice.

characters but is highly susceptible to brown planthoppers and virus diseases.

Farmer's field. In the dry season, IR8192-200-3-3-1-1 outyielded four IR varieties and three promising lines in a farmer's field at zero fertilizer nitrogen (Table 2). Early-maturing IR9752-71-3-2 yielded highest, 7.2 t/ha, at 150 kg N/ha. Yields of other rices declined after 100 kg N/ha (Fig. 1).

Maligaya. In the dry season, all cultivars, except Peta, responded well to nitrogen at the Maligaya Rice Research and Training Center irrigated plots. IR36 gave the highest and most stable yield at 120 kg N/ha (8 t/ha). IR42 yielded more than 7 t/ha at 120-180 kg N/ha; IR50 yielded similarly at 90-150 kg N/ha.

The breeding lines yielding 7 t/ha or more at 90 kg N/ha included IR19743-25-2-2-3-1, IR13429-109-2-2-1, and IR13423-17-1-2-1. IR19743-25-2-2-3-1 consistently yielded 7 t/ha or more as nitrogen was increased from 90 to 180 kg N/ha. Without nitrogen fertilization, IR8192-200-3-3-1-1 outyielded all test rices with 4.4 t/ha.

In the wet season, most cultivars responded only up to 60 kg N/ha (Table 3). Only IR42 yielded 6 t/ha or more at 120 kg N/ha. Other rices that yielded higher than 5 t/ha at 60 kg N/ha were IR20, IR19672-155-2-1-1-3, IR13423-10-2-1, IR8, and IR13423-17-1-2-1. IR36 yielded highest in unfertilized plots.

Bicol. Yields were relatively low in both seasons at the Bicol Experiment Station. In the dry season, tungro virus destroyed some plots planted to IR8, IR42, and Peta, and water stress at the reproductive stage depressed yields of most rices. The highest dry-season yield was from IR13525-43-2-3-1-3-2 at 120 kg N/ha (Table 4). IR13423-17-1-2-1 yielded almost 4 t/ha in unfertilized plots.

In the wet season, IR42 and IR19672-155-2-1-1-3 yielded more than 5 t/ha at 30 kg N/ha and more than 4 t/ha in unfertilized plots. The highest yield was 5.7 t/ha from IR13525-43-2-3-1-3-2 at 60 kg N/ha.

Visayas. At the Visayas Experiment Station in the dry season, IR50 outyielded all test rices with 6.1 t/ha at 150 kg N/ha (Table 5). At that nitrogen rate, IR13429-109-2-2-1 yielded 5.7 t/ha. In unfertilized plots, IR8192-200-3-3-1-1 yielded highest (3.8 t/ha).

In the wet season, nitrogen response was comparable to or even better than that in the dry season, when irrigation-water control was poor. At 60 kg N/ha, IR13525-43-2-3-1-3-2 yielded 6.5 t/ha —much better than the highest yield in the dry season. IR54, IR19728-9-3-2-3-3, and IR13423-10-2-1 yielded similarly, about 6.4 t/ha at 60 kg N/ha. In unfertilized plots, IR13429-109-2-2-1, IR8192-200-3-3-1-1, and IR19728-9-3-2-3-3 yielded more than 5 t/ha.

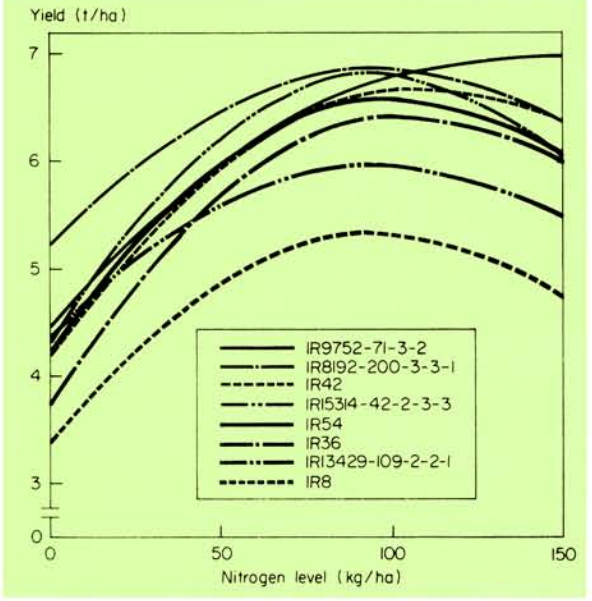
Rainfed rice. *IRRI*. IR46 yielded highest at 30 kg N/ha. Without nitrogen, IR13146-41-3 and IR14632-22-3 yielded 3.2 t/ha (Table 6).

Farmer's field. IR9852-22-3 and IR13146-13-3-3 yielded 5.2 t/ha with no fertilizer nitrogen and 5.8 t/ha at 80 kg N/ha (Table 7). Yields did not increase with increasing nitrogen levels.

Table 2. Yield of rice varieties and promising lines at 4 nitrogen levels[a] in an irrigated farmer's field, Laguna, Philippines, 1981.

Designation	Dry season					Wet season				
	Growth duration (days)	Yield[b] (t/ha)				Growth duration (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	50 kg N/ha	100 kg N/ha	150 kg N/ha
IR8	145	3.3	5.2	5.0	5.0	125	3.5	3.8	3.1[c]	5.0
IR36	119	3.7	5.7	6.4	6.0	111	5.3[d]	6.2	5.6	5.7[d]
IR42	145	4.3	5.7	6.9	6.3	131	4.5	5.1	4.7	5.0
IR54	141	4.0	6.5	6.0	6.2	–	–	–	–	–
IR8192-200-3-3-1-1	141	5.1	6.9	6.4	6.5	118	4.9	4.6	3.1	4.1
IR9729-67-3		–	–	–	–	102	M[e]	4.6	4.3	5.1
IR9752-71-3-2	111	4.3	6.2	6.5	7.2	–	–[f]	–[f]	–[f]	–[f]
IR13429-109-2-2-1	119	4.4	5.7	5.8	5.5	111	4.3	4.8[d]	3.8	2.8
IR13429-299-1-1		–	–	–	–	111	5.1	5.8	3.5	3.1
IR15314-43-2-3-3	145	4.2	6.4	6.5	6.2	–	–	–	–	–

[a]Each nitrogen treatment included 20 kg N/ha topdressed 1 week before panicle initiation. [b]Av of 3 replications. [c]Affected by ragged stunt. [d]Av of 2 replications because of rat damage. [e]Missing because of rat damage. [f]No harvest because of total rat damage.



1. Yield of IRRI rices at 4 nitrogen levels in irrigated farmers' fields, Laguna Province, Philippines, 1981 dry season.

ABILITY TO EXPLOIT SOIL NITROGEN

Agronomy Department

Two experiments were conducted to evaluate 105 IR rices for their ability to exploit soil nitrogen under wetland conditions in the 1981 dry season. The design was a split plot with three replications. The main plots were two nitrogen levels (0 and 60 kg N/ha); the subplots were the rice varieties.

In Experiment 1 (cultivars 1-45), 15N $(NH_4)_2SO_4$-depleted was used. In Experiment 2 (cultivars 46-105), ordinary ammonium sulfate was used.

Grain yield differences were significant in both experiments (Table 8, 9).

In Experiment 1, IR13423-10-2-3 yielded highest (4.2 and 5.2 t/ha in unfertilized and fertilized plots).

In Group 1 of Experiment 2, IR19743-25-2-2-3-1, IR19746-28-2-2-3, IR19792-15-2-3-3-3, and IR19791-12-1-2-2-2 responded similarly to 60 kg N/ha, yielding more than 6 t/ha (Table 9). With no nitrogen added, IR19743-25-2-2-3-1, IR19791-12-1-2-2-2, IR19743-46-2-3-3-2, and IR19799-9-1-2-2-2 yielded more than 4 t/ha.

In group 2, IR13240-108-2-2-3 outyielded the other rices at 60 kg N/ha; IR15795-232-3-3-3-2 yielded highest in plots without added nitrogen

Table 3. Yield of rice varieties and promising lines at 6 nitrogen[a] levels in irrigated plots, Maligaya Rice Research and Training Center, Nueva Ecija, Philippines, 1981.

Designation	Dry season								Wet season							
	Growth duration (days)	Yield[b] (t/ha)							Growth duration (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			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	136	3.5 abc	4.5 fg	6.2 abcde	5.9 de	6.3 abc	5.9 g		126	3.0 abc	3.9 bcdefg	5.4 abcd	4.7 abc	4.8 bcd	4.6 ab
IR20	118	3.3 abcd	5.8 abcdef	6.1 abcde	6.4 bcde	6.4 abc	5.9 efg		126	3.3 ab	4.7 abc	5.7 ab	5.2 ab	5.2 bc	4.7 ab
IR36	113	4.0 ab	6.9 a	7.0 abc	8.0 a	7.2 a	7.3 abc		111	3.0 abc	4.6 abcd	4.2 efgh	4.4 bcd	3.4 efg	2.4 d
IR42	136	3.5 abc	5.8 abcdef	6.5 abcd	7.1 abcd	7.1 ab	7.6 a		129	3.3 ab	4.9 ab	6.0 a	5.9 a	6.5 a	4.8 a
IR50	109	3.2 abcd	6.4 abc	7.4 a	7.2 abc	7.3 a	6.8 abcde		—	—	—	—	—	—	—
IR54	123	3.5 abc	5.3 cdefgh	6.1 abcde	6.7 bcde	6.3 abc	6.1 cdefg		123	2.9 abc	4.6 abcd	4.5 cdefgh	4.4 bcd	4.9 bcd	2.6 d
IR8192-200-3-3-1-1	117	4.4 a	6.6 ab	6.9 abcd	7.5 ab	6.7 ab	6.8 abc		123	3.1 abc	4.0 bcdef	4.4 defgh	4.3 bcd	4.5 bcde	4.1 ab
IR9129-209-2-2-3	109	3.5 abc	6.0 abcd	6.5 abcde	7.3 abc	6.4 abc	6.7 abcdef		—	—	—	—	—	—	—
IR9729-67-3	—	—	—	—	—	—	—		95	2.6 abc	2.9 fgh	3.0 ij	2.4 f	3.1 fg	1.6 e
IR9752-71-3-2	98	2.1 d	4.1 hij	5.2 e	6.6 bcde	5.9 bc	7.1 abcd		97	1.9 c	2.6 h	3.5 ghi	3.1 ef	4.1 cdef	2.7 d
IR13423-10-2-3	123	3.5 abc	6.5 abc	6.5 abcd	7.2 abc	7.0 ab	6.9 abcd		123	3.6 a	4.6 abcd	5.7 abc	5.0 abc	4.0 cdef	4.4 ab
IR13423-17-1-2-1	123	2.8 bcd	5.4 bcdefg	7.0 abc	7.2 abc	6.9 ab	7.1 abcd		123	2.9 abc	4.4 abcd	5.4 abcde	5.0 abc	5.1 bc	3.9 bc
IR13429-109-2-2-1	109	2.9 bcd	6.4 abc	7.2 ab	6.8 abcde	7.2 ab	6.9 abcd		109	2.7 abc	4.5 abcd	4.1 fghi	2.3 f	3.4 efg	2.9 cd
IR13429-299-2-1-3-1	—	—	—	—	—	—	—		109	2.7 abc	4.3 abcd	3.7 ghi	4.0 cde	3.4 efg	2.8 cd
IR13525-43-2-3-1-3-2	109	3.0 bcd	5.6 abcdefg	6.0 abcde	7.0 abcde	6.2 abc	5.2 fg		115	2.7 abc	3.1 efgh	4.5 cdefgh	4.2 bcd	4.7 bcd	4.3 ab
IR15314-43-2-3-3	120	3.4 abc	5.6 abcdefg	6.2 abcde	6.2 cde	6.1 abc	5.4 fg		123	2.8 abc	3.9 cdef	4.5 cdefgh	4.4 bcd	4.5 bcde	3.9 bc
IR17494-32-1-1-3-2	130	3.1 abcd	4.7 efghij	5.7 de	5.8 e	6.2 abc	5.6 efg		123	2.8 abc	3.6 cdefgh	4.6 bcdefg	4.7 abc	5.1 bc	4.4 ab
IR19661-131-1-3-1-3	131	3.7 abc	5.5 bcdefg	6.5 abcd	7.5 abc	6.8 ab	6.3 abcdef		—	—	—	—	—	—	—
IR19672-155-2-1-1-3	—	—	—	—	—	—	—		123	3.5 a	5.0 a	5.7 ab	5.2 ab	5.5 ab	4.3 ab
IR19728-9-3-2-3-3	—	—	—	—	—	—	—		95	2.2 bc	3.1 efgh	3.4 hi	3.5 de	3.8 defg	2.8 cd
IR19743-25-2-2-3-1	105	3.8 abc	6.0 abcd	7.3 a	7.2 abc	7.0 ab	7.1 abcd		—	—	—	—	—	—	—
Peta	144	3.1 abcd	3.6 i	2.6 f	2.4 f	3.2 d	1.2 h		137	2.7 ab	2.7 gh	2.3 —	2.4 i	2.8 f	2.0 g	d

[a]Includes 30 kg N/ha topdressed 5-7 days before panicle initiation (DBPI) in the dry season and 20 kg N/ha topdressed 5-7 DBPI in the wet. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 4. Yield of rice varieties and promising lines at 6 nitrogen[a] levels in irrigated plots, Bicol Experiment Station, Pili, Camarines Sur, Philippines, 1981.

Designation	Dry season							Wet season						
	Growth duration (days)	Yield[b] (t/ha)						Growth duration (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		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[c]	135	—	—	—	—	—	—	122	3.2 bcde	3.5 def	3.6 f	3.5 bcd	2.9 cd	1.9 d
IR20	118	2.4 d	4.1 cd	2.6 e	1.8 e	1.5 e	2.7 de	128	2.9 cde	4.4 bcdef	4.3 cdef	4.2 abc	4.2 ab	3.0 bc
IR36	111	3.3 abc	4.7 abc	4.7 abcd	4.7 abcd	4.5 bcd	3.3 cd	112	3.6 abcd	4.5 abcd	4.3 cdef	3.9 abc	3.8 bc	2.6 bcd
IR42[c]	132	—	—	—	—	—	—	136	4.5 a	5.4 a	5.5 ab	4.9 a	5.0 a	4.1 a
IR50	103	3.2 abcd	5.2 ab	5.3 a	4.6 bcd	4.9 bc	3.4 c	—	—	—	—	—	—	—
IR54	118	3.1 abcd	3.3 e	5.1 abcd	4.6 bcd	4.4 cd	4.5 ab	122	3.7 abc	3.9 cdef	4.2 cdef	3.6 bcd	3.5 bcd	2.3 bcd
IR8192-200-3-3-1-1	116	2.7 cd	4.4 c	5.4 a	5.1 bc	5.2 ab	4.3 ab	118	3.4 bcd	4.3 bcde	4.2 cdef	2.7 d	1.8 e	2.0 cd
IR9129-209-2-2-3	103	3.2 abc	4.7 abc	4.4 cd	4.8 bcd	4.5 bcd	4.8 a	—	—	—	—	—	—	—
IR9729-67-3	—	—	—	—	—	—	—	105	3.0 cde	4.4 bcde	(4.6 bcdef)	4.0 abc	4.2 ab	3.1 b
IR9752-71-3-2	97	2.6 cd	4.6 abc	5.1 abc	5.0 bc	5.0 bc	4.5 ab	98	2.6 de	3.0 fg	3.7 ef	3.1 cd	3.3 bcd	3.2 ab
IR13423-10-2-3	121	3.3 abc	4.5 bc	5.3 a	5.0 bc	4.5 bcd	4.4 ab	122	3.2 bcde	4.4 bcde	4.3 cdef	3.4 bcd	2.8 d	2.5 bcd
IR13423-17-1-2-1	121	3.9 a	4.2 c	4.9 abcd	4.5 cd	4.1 d	3.8 bc	115	3.5 bcd	4.5 abcd	4.9 abcd	3.6 bcd	3.6 bcd	3.3 ab
IR13429-109-2-2-1	109	3.5 ab	5.3 a	5.1 abc	5.4 ab	4.8 a	4.4 ab	105	3.5 abcd	4.3 bcde	(4.3 cdef)	3.8 bc	3.9 bc	2.7 bcd
IR13429-299-2-1-3-1	—	—	—	—	—	—	—	105	3.9 abc	4.3 bcde	4.3 cdef	4.3 ab	4.3 ab	3.3 ab
IR13525-43-2-3-1-3-2	111	3.3 abc	4.8 abc	4.8 abcd	5.8 a	4.8 bcd	4.9 a	118	3.7 abc	4.3 bcde	5.7 a	5.0 abc	3.7 bcd	2.5 bcd
IR15314-43-2-3-3	125	3.0 bcd	3.4 de	4.3 d	4.5 cd	3.5 e	3.8 bc	131	3.7 abc	4.6 abc	4.6 bcdef	5.1 abc	4.1 ab	2.7 bcd
IR17494-32-1-1-3-2	125	2.7 bcd	4.2 c	4.4 cd	4.4 cd	4.3 cd	3.3 cd	133	2.9 cde	3.9 cdef	3.8 def	3.3 bcd	3.2 bcd	2.0 d
IR19661-131-1-3-1-3	125	3.1 abcd	3.5 de	4.9 abcd	4.2 d	4.5 bcd	2.3 c	—	—	—	—	—	—	—
IR19672-155-2-1-1-3	—	—	—	—	—	—	—	121	4.2 ab	5.3 ab	4.9 abc	3.8 bc	2.7 d	2.7 bcd
IR19728-9-3-2-3-3	—	—	—	—	—	—	—	94	2.3 e	3.4 ef	4.7 abcde	3.5 bcd	4.2 ab	3.4 ab
IR19743-25-2-2-3-1	125	3.2 abc	4.7 abc	5.2 ab	5.1 bc	4.4 cd	4.5 ab	—	—	—	—	—	—	—
Peta[c]								142	2.3 e	2.1 g	2.6 g	1.7 e	1.7 e	1.8 d

[a] Includes 30 kg N/ha topdressed 5-7 days before panicle initiation (DBPI) in the dry season and 20 kg N/ha topdressed 5-7 DBPI in the wet. [b] Separation of means in a column by Duncan's multiple range test at the 5% level. [c] Severely damaged by virus diseases. Data taken from these varieties were incomplete and unreliable and were excluded from statistical analysis.

Table 5. Yield of rice varieties and promising lines at 6 nitrogen levels in irrigated plots. Visayas Experiment Station, Hamungaya, Jaro, Iloilo, Philippines, 1981.[a]

Designation	Dry season							Wet season						
	Growth duration (days)	Yield[b] (t/ha)						Growth duration (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		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	130	2.4 cdefg	2.5 f	4.1 cdef	3.4 cde	3.1 hij	2.7 de	121	3.2 def	4.8 abcd	4.8 bcd	5.0 bcde	4.0 e	3.2 e
IR20	122	3.6 ab	5.4 a	5.5 a	4.5 abc	3.7 fghi	3.5 cd	117	3.7 bc	4.6 abcd	4.7 bcd	4.8 cde	5.0 abcde	3.9 bcde
IR36	108	3.2 abcdef	4.8 ab	4.7 abcde	4.8 abc	5.2 abc	5.0 a	104	4.6 abc	5.8 a	5.9 ab	6.0 abc	5.3 abcd	4.0 bcde
IR42	136	1.8 g	3.0 def	3.3 fg	3.4 de	3.7 fghi	2.7 de	132	3.6 bcdef	4.8 abcd	5.0 bcd	5.7 abcd	5.7 abc	5.0 abc
IR50	105	3.2 abcdef	4.1 bc	5.4 ab	5.5 a	6.1 a	4.9 a	—	—	—	—	—	—	—
IR54	116	3.4 abcd	3.6 cde	4.1 cdef	4.4 bcd	4.9 bcd	3.6 bcd	117	4.6 abc	5.6 ab	6.4 a	6.0 abc	4.9 abcde	3.7 cde
IR8192-200-3-3-1-1	116	3.8 a	4.3 bc	4.4 bcde	4.8 abc	4.1 defg	4.5 ab	117	5.1 a	5.2 abc	5.4 abc	5.8 abc	5.1 abcde	4.8 abcd
IR9129-209-2-2-3	105	3.5 ab	4.0 bc	4.8 abcde	5.1 ab	5.0 abcd	5.0 a	—	—	—	—	—	—	—
IR9729-67-3	—	—	—	—	—	—	—	96	4.5 abc	4.6 abcd	5.0 bcd	4.8 cde	4.6 cde	3.0 e
IR9752-71-3-2	102	2.3 defg	2.9 def	3.7 efg	4.1 bcd	4.0 efgh	4.0 abc	96	3.8 bcde	4.0 cde	4.4 cd	5.6 abcde	4.3 de	3.6 de
IR13423-10-2-3	122	3.4 abc	3.9 bcd	5.2 ab	4.8 abc	3.5 fghi	3.3 cde	119	4.0 abcd	5.4 ab	6.3 a	6.3 a	5.7 abc	5.0 abc
IR13423-17-1-2-1	129	2.3 efg	4.0 bc	4.1 cdef	5.0 ab	4.5 cdef	4.0 abc	119	3.5 cdef	4.5 bcde	5.0 bcd	4.9 cde	4.7 bcde	4.7 abcd
IR13429-109-2-2-1	111	3.1 abcdef	4.4 abc	4.9 abcd	5.0 ab	5.7 ab	4.7 a	104	5.2 a	5.2 abc	5.4 abc	5.3 abcde	4.5 cde	4.1 bcde
IR13429-299-2-1-3-1	—	—	—	—	—	—	—	103	4.7 abc	5.5 ab	5.8 ab	6.0 abc	6.1 a	5.6 a
IR13525-43-2-3-1-3-2	108	3.3 abcde	4.4 abc	4.7 abcde	4.5 abc	3.8 fghi	3.7 bcd	117	4.8 ab	5.6 ab	6.5 a	6.0 abc	5.9 ab	5.7 a
IR15314-43-2-3-3	132	2.1 fg	2.8 ef	3.8 efg	4.3 bcd	3.3 ghi	3.2 cde	120	2.7 ef	3.4 e	3.8 de	4.5 de	5.0 abcde	3.8 cde
IR17494-32-1-1-3-2	122	2.7 bcdefg	4.3 bc	3.9 defg	3.8 cde	2.9 ij	2.8 cde	120	4.0 abcd	5.0 abc	5.4 abc	5.9 abc	5.0 abcde	4.7 abcd
IR19661-131-1-3-1-3	130	2.1 fg	2.9 def	2.9 g	3.1 ef	3.0 hij	3.2 cde	—	—	—	—	—	—	—
IR19672-155-2-1-1-3	—	—	—	—	—	—	—	120	2.4 f	3.7 de	4.1 de	4.5 e	4.0 e	3.4 de
IR19728-9-3-2-3-3	—	—	—	—	—	—	—	96	5.1 a	5.6 ab	6.4 a	6.2 ab	5.1 abcde	5.1 ab
IR19743-25-2-2-3-1	102	2.5 bcdefg	4.2 bc	5.1 abc	4.9 ab	4.4 cdef	4.2 abc	—	—	—	—	—	—	—
Peta	146	2.6 bcdefg	2.9 def	3.0 g	2.3 f	2.3 j	2.3 e	138	2.9 def	3.7 de	2.1 e	2.9 f	2.4 f	2.0 f

[a] Includes 30 kg N/ha topdressed 5-7 days before panicle initiation (DBPI) in the dry season and 20 kg N/ha topdressed 5-7 DBPI in the wet season. [b] Separation of means in a column for each cropping season by Duncan's multiple range test at the 5% level.

Table 6. Yield of rice varieties and promising lines at 5 nitrogen levels[a] in rainfed wetland plots. IRRI, 1981 wet season.

Designation	Growth duration (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
IR36	110	1.8	1.6	2.9	1.8	3.7
IR42	139	2.7	3.7	3.6	2.8	3.7
IR46	119	2.9	4.0	3.9	3.3	3.8
IR52	119	2.3	2.8	2.8	2.1	2.8
IR9852-22-3	132	2.6	2.1	3.5	3.0	3.1
IR13146-41-3	132	3.2	3.2	3.3	3.0	3.3
IR131349-3-2-2	150	2.1	2.7	2.3	2.5	2.6
IR13365-253-3-2	139	3.1	2.6	3.6	2.5	2.5
IR13146-13-3-3	127	3.0	3.5	3.5	3.2	3.4
IR14632-22-3	132	3.2	3.1	3.6	3.5	3.6
IR18189-14-3-1	143	2.2	2.3	2.5	2.7	2.5
IR19670-206-3-3-3-3	140	2.6	2.4	2.8	2.4	2.8

[a]Each nitrogen treatment included 20 kg N/ha topdressed 1 week before panicle initiation. [b]Av of 3 replications.

Table 7. Yield of rice varieties and promising lines at 4 nitrogen levels[a] in a rainfed wetland farmer's field. Laguna, Philippines, 1981 wet season.

Designation	Growth duration (days)	Yield[b] (t/ha)			
		0 kg N/ha	40 kg N/ha	80 kg N/ha	120 kg N/ha
IR36	107	4.2	5.0	4.6	4.5
IR42	126	4.3	4.6	4.8	5.1
IR46	114	5.0	4.9	4.9	5.2
IR52	114	4.9	5.2	4.8	5.0
IR9852-22-3	126	5.2	5.2	5.8	5.7
IR13365-253-3-2	126	4.0	4.6	4.5	4.5
IR13146-13-3-3	126	5.2	5.5	5.8	5.5
IR19670-206-3-3-3-3	124	4.3	4.6	5.1	4.0

[a]Each nitrogen treatment included 20 kg N/ha topdressed 1 week before panicle initiation. [b]Av of 3 replications.

(Table 9). IR36 yielded lowest without fertilizer nitrogen.

In Group 3, the two top yielders without fertilizer nitrogen were IR42 (5.3 t/ha) and IR15324-117-2-2-3. But IR42 ranked 4th (5.6 t/ha) at 60 kg N/ha. IR54 at 60 kg N/ha yielded 5.9 t/ha.

IR42 efficiency in using soil nitrogen. Each year, elite IRRI breeding lines and named IR varieties are evaluated for their nitrogen response and yield potential under wetland rice culture. When the data for the 1976-81 wet seasons are averaged with the data for all experiments conducted at IRRI and cooperatively with three BPI experiment stations, IR42 appeared to be a more efficient user of soil and fertilizer nitrogen than IR36, the most widely grown variety of rice in the world (Fig. 2). Because of heavy insect and disease pressure, IR8 performed poorly at all nitrogen levels.

GROWTH DURATION

Plant Breeding Department

Evaluation of early-maturing selections continued during 1981. Many selections with a growth duration of 100 days or less were evaluated in replicated yield trials during dry and wet seasons at the IRRI farm. Several lines yielded as well as IR36 although they matured 8-10 days earlier (Table 10). They are being evaluated in coordinated trials in the Philippines and in IRTP nurseries. Two of the most

Table 8. Yield of cultivars at different nitrogen levels (experiment 1). IRRI, 1981 dry season.

Designation	Yield[a] (t/ha)		
	0 kg N/ha	60 kg N/ha	Variety av
Group 1 (1-15)			
IR8455-78-1-3-3	3.6 abc	4.6 abcd	4.1 abc
IR8608-167-1-2	3.0 d	4.3 bcd	3.6 de
IR9708-51-1-2	3.0 d	4.2 cd	3.6 e
IR9729-67-3	3.9 a	5.0 a	4.4 a
IR9752-1-2-1	3.1 bcd	4.8 abc	3.9 bcde
IR9752-71-3-2	3.0 cd	4.8 abc	3.9 bcde
IR15429-268-1-2-1	3.3 abcd	5.0 a	4.1 abc
IR19722-9-1-3-2-1	3.1 bcd	4.0 d	3.6 e
IR19728-9-3-2-3-3	3.0 cd	4.6 abcd	3.8 cde
IR19729-5-1-1-3-2	3.7 ab	4.5 abcd	4.1 abc
IR19735-5-2-3-2-1	3.7 ab	5.0 a	4.3 ab
IR19743-8-1-2-2-2	3.3 abcd	4.9 ab	4.1 abc
IR19746-27-3-3-1-3	2.9 d	4.6 abcd	3.7 cde
IR19747-23-3-2-1	3.5 abcd	4.6 abcd	4.0 abcd
IR19819-23-1-2-2-3	3.3 abcd	4.5 abcd	3.9 bcde
Group 2 (16-30)			
IR36	3.3 abc	4.6 abcd	3.9 abcd
IR50	3.4 abc	4.6 abcd	4.0 abc
IR8608-75-3-1-3	3.3 abc	4.4 abcd	3.9 bcd
IR8608-298-3-1-1-2	3.2 abc	4.2 cd	3.7 cd
IR9209-217-1-2-2	3.0 c	4.6 abcd	3.8 cd
IR9224-22-2-2-2-3	3.0 c	4.1 d	3.6 d
IR9729-106-1-2-2	3.2 abc	4.4 bcd	3.8 cd
IR13240-82-2-3-2-3-1	3.8 a	5.0 ab	4.4 a
IR13427-40-2-3-3-3-3	3.2 abc	4.3 cd	3.7 cd
IR13429-95-3-2-2-2	3.1 bc	4.1 d	3.6 cd
IR13535-64-6-2-3-2	3.4 abc	4.3 cd	3.8 cd
IR15496-219-2-3-2	3.8 a	4.8 abc	4.3 ab
IR15689-173-1-1-1-3	3.4 abc	4.5 abcd	3.9 bcd
IR15723-38-1-2-3-3	3.4 abc	4.4 bcd	3.9 bcd
IR15795-151-2-3-2-2	3.7 ab	5.1 a	4.4 a
Group 3 (31-45)			
IR13540-56-3-2-1	3.5 bcde	4.7 abcd	4.1 bcdef
IR15529-175-2-3-2-1	2.9 e	4.1 d	3.5 g
IR15529-253-3-2-2-2	3.6 abcd	4.2 d	3.9 def
IR19588-162-1	3.3 cde	4.5 cd	3.9 def
IR21912-131-3-3	3.3 cde	4.7 abcd	4.0 cdef
IR26	3.9 ab	5.0 abc	4.5 ab
IR38	3.9 ab	4.6 abcd	4.3 abcdef
IR2863-38-1	3.1 de	4.6 bcd	3.9 def
IR54	3.7 abcd	4.6 bcd	4.2 bcdef
IR42	3.7 abcd	5.0 abc	4.4 abc
IR2863-39-2-8	4.0 ab	5.2 ab	4.6 a
IR8192-200-3-3-1-1	4.1 ab	5.2 ab	4.6 a
IR9846-145-3-3	3.8 abc	4.9 abc	4.3 abcde
IR11248-148-3-2-3-3	3.7 abcd	4.9 abc	4.4 abc
IR13423-10-2-3	4.2 a	5.3 a	4.7 a

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

Table 9. Yield of different rice cultivars at different nitrogen levels (experiment 2). IRRI, 1981 dry season.

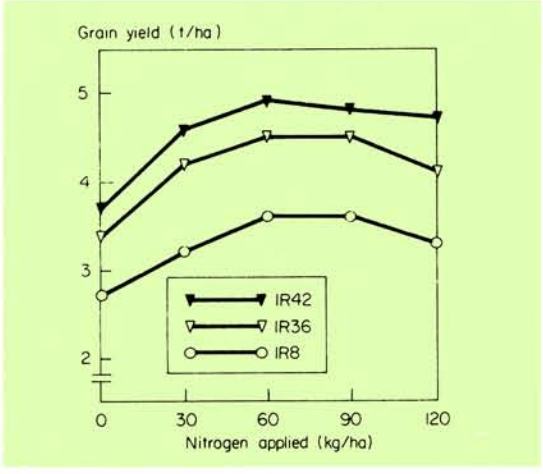
Variety or line	Grain yield[a] (t/ha)		
	0 kg N/ha	60 kg N/ha	Variety av
Group 1 (46-58)			
IR19743-25-2-2-3-1	4.5 a	6.6 a	5.6
IR19743-40-3-3-2-3	3.8 bc	5.5 bcde	4.7
IR19743-46-2-3-3-2	4.5 ab	5.8 abcde	5.2
IR19746-28-2-2-3	3.5 c	6.2 ab	4.9
IR19791-12-1-2-2-2	4.5 ab	6.0 abcd	5.3
IR19792-15-2-3-3-3	4.1 abc	6.1 abc	5.1
IR19799-9-1-2-2-2	4.2 abc	5.1 e	4.6
IR19805-12-1-3-1-2	4.0 abc	5.2 e	4.6
IR19807-21-2-2-2-2	3.8 bc	5.9 abcde	4.9
IR19819-18-3-2-1-1	4.0 abc	5.1 e	4.6
IR19819-31-2-3-1-1	4.3 ab	5.3 de	4.8
IR19822-4-1-2-2-3	3.9 abc	5.1 e	4.5
IR19822-17-3-3	4.1 abc	5.4 cde	4.7
Group 2 (59-82)			
IR36	3.6 b	5.5 abc	4.5 abcde
IR50	3.8 b	4.9 bcde	4.3 cde
IR8608-139-1-1-3	4.2 ab	5.4 abc	4.8 abc
IR8608-189-2-2-1-3	4.1 ab	5.6 ab	4.8 abc
IR9129-209-2-2-2-3	3.8 b	4.9 bcde	4.3 cde
IR9761-19-1	3.7 b	4.3 de	4.0 de
IR13240-108-2-2-3	4.2 ab	6.1 a	5.2 a
IR13384-79-2	3.9 ab	4.8 bcde	4.4 cde
IR13427-60-1-3-2-2	3.6 b	5.0 bcd	4.3 cde
IR13427-69-1-2-2-1	4.3 ab	5.3 abcd	4.8 abc
IR13429-130-2	4.1 ab	5.0 bcd	4.5 abcde
IR13429-109-2-2-1	3.8 b	5.8 ab	4.8 abc
IR13429-196-1-2-1-1	4.2 ab	4.5 cde	4.4 bcde
IR13429-196-1-20	4.0 ab	4.8 bcde	4.4 bcde
IR13429-287-3	3.8 b	5.2 abcd	4.5 abcde
IR429-299-2-1-3	4.4 ab	5.6 ab	5.0 abc
IR13525-43-2-3-1-3-2	4.5 ab	5.7 ab	5.1 ab
IR13535-21-2-3-3-2	4.4 ab	5.0 bcd	4.7 abcd
IR13538-48-2-3-2	4.2 ab	5.0 bcd	4.6 abcd
IR13539-100-2-2-2-3	3.8 b	3.9 e	3.9 e
IR15795-199-3-3	4.1 ab	5.5 abc	4.8 abc
IR15795-232-3-3-3-2	4.9 a	5.5 abc	5.2 a
IR18272-58-3-3-3	4.0 ab	5.5 abc	4.8 abc
IR18353-83-2-2	4.6 ab	5.4 abc	5.0 abc
Group 3 (83-105)			
IR38	4.3 bcd	5.2 abcd	4.8 bcd
IR42	5.3 a	5.6 ab	5.5 a
IR54	4.5 bcd	5.9 a	5.2 ab
IR21841-27-2-3	3.2 e	4.3 ef	3.8 h
IR21841-81-3-3	3.9 bcde	5.1 abcde	4.5 cdefg
IR21842-69-3-3	3.9 bcde	5.1 abcde	4.5 cdefg
IR21929-26-3	4.5 bc	5.2 abcde	4.8 bcd
IR2797-105-2-2-3	4.2 bcd	5.1 abcde	4.7 bcde
IR13423-17-1-2-1	4.4 bcd	5.6 ab	5.0 abc
IR13524-21-2-3-3-2-2	3.8 cde	4.6 cdef	4.2 efgh

Continued on next page

Table 9 continued

Variety or line	Grain yield[a] (t/ha) 0 kg N/ha	60 kg N/ha	Variety av
IR15314-30-3-1-3	4.2 bcd	5.1 abcde	4.6 bcdef
IR15314-43-2-3-3	3.7 cde	4.2 f	4.0 fgh
IR15318-2-2-2-2-2	4.4 bcd	5.2 abcd	4.8 bcd
IR15323-26-3-2	3.9 bcde	4.9 bcdef	4.4 cdefg
IR15323-78-1-3-1	4.0 bcde	5.0 bcdef	4.5 cdefg
IR15324-12-2-3-3-2	4.1 bcde	4.5 def	4.3 defgh
IR15324-36-2-2-3	4.4 bcd	5.4 abc	4.9 abc
IR15324-117-2-2-3	4.7 ab	5.7 ab	5.2 ab
IR15529-26-1-1-2-1	3.6 de	4.3 ef	3.9 gh
IR17488-2-3-2	4.3 bcd	5.3 abcd	4.8 bcde
IR17492-18-6-1-1-3-3	4.5 bc	5.6 a	5.2 ab
IR17494-32-1-1-3-2	4.3 bcd	5.2 abcd	4.6 bcde
IR19661-131-1-3-1-3	3.7 cde	4.4 def	4.0 fgh

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



2. Grain yield of 3 rices at different nitrogen levels, averages for IRRI and 3 experiment stations of the Philippine Bureau of Plant Industry (Maligaya, Bicol, and Visayas), 1976-81 wet season.

promising — IR9729-67-3 and IR9752-71-3-2 — are now in the most advanced testing stages.

SOURCES OF SEMIDWARFISM

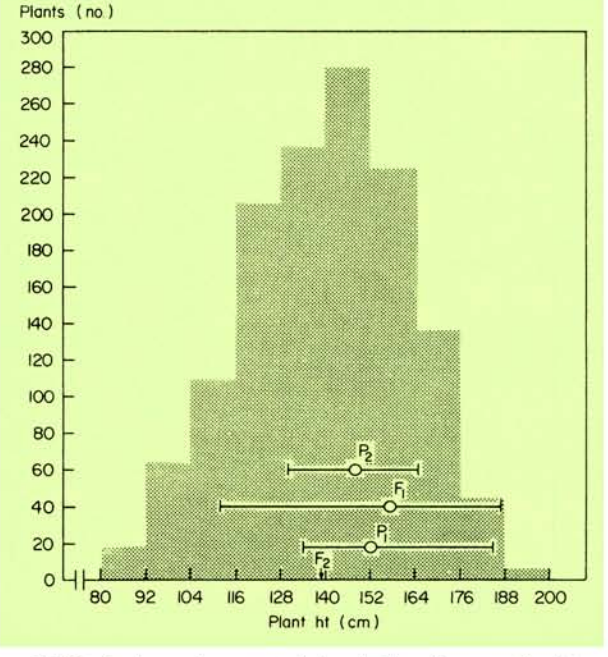
Plant Breeding Department

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 (Dgwg). During 1981, the F_2 segregation was investigated in seven crosses that involved semidwarf parents nonallelic to the Dgwg

Table 10. Early-maturing lines evaluated at IRRI. 1981.

Selection	Growth duration (days)	Yield (t/ha) Dry season	Wet season
IR8455-78-1-3-3	100	6.2	4.6
IR9729-67-3	100	7.2	5.1
IR9752-71-3-2	98	7.5	4.7
IR15429-268-1-2-1	97	6.8	5.1
IR19729-5-1-1-3-2	97	6.1	4.3
IR19735-5-2-3-2-1	100	6.5	4.9
IR19743-25-2-2-3-1	96	6.4	4.6
IR19743-40-3-3-2-3	97	5.8	4.6
IR19746-28-2-2-3	97	6.0	4.5
IR36 (check)	108	6.9	4.7

source. Hoyoku/Calrose 76 (sd_1) produced F_2 segregates that fell within the parental range, indicating that the parents have the same semidwarfing gene or share a compound locus. In the other four crosses in the F_2, many plants were tall and a few were shorter than the shorter semidwarf parent of the two. The crosses were TR 17/Short Straw Starbonnet, Tainan 5-72-534 mutant/ D66 (d_2), CI 9858 (d_3)/ Culture 854 and Calrose 76/ Culture 854.



3. Distribution and averages of plant heights of parents (P_1, P_2) and F_1 and F_2 plants in the cross Baok (P_1) (Mahsuri (P_2). Horizontal lines show the range of parents and F_1 plants; the arrow shows the average of the F_2 populations. IRRI, 1981.

Calrose 76 (sd_1)/ D66 (d_2) did not show clearcut transgressive segregation on either end of the F_2 distribution, although the parents carried different semidwarfing genes. Similarly, while Hoyoku and D24 (d_4) differed in their height genes, only a small number of Hoyoku/ D24 of F_2 plants were taller than Hoyoku and these plants still belong to the semidwarf class (95-110 cm).

The Central Rice Research Institute in India has reported that semidwarf segregates may be obtained from tall/ tall crosses involving Baok, a bulu variety of Indonesia. We have made 3 such crosses, but only the F_2 population of Baok/ Mahsuri tolerated a brown planthopper epidemic and produced valid F_2 data (Fig. 3). Only a few F_2 plants were taller than Baok and a substantial number were shorter than either parent. Some fell in the semidwarf range. Whether such short plants will breed true for short stature and whether some of them carry the sd_1 gene needs to be ascertained in the F_3.

Genetic evaluation and utilization (GEU) program

Grain quality

Chemistry and Plant Breeding Departments

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BREEDING PROGRAM

Plant Breeding and Chemistry Departments

IRRI has made crosses with parents having intermediate amylose content for several years. Two such parents, C4-63 and BPI121-407, were initially used in hybridizations and progeny. Lines of improved plant type with intermediate amylose content were selected. They included IR4215-301-2-2-6, IR4570-124-3-2-2-2, IR5657-33-2, IR2053-521-1-1, IR7963-30-2, and IR9129-109-2-2, which were used extensively in crosses because they lacked at least one trait essential for a released variety. Many progeny lines with intermediate amylose and most other essential traits are being evaluated in advanced trials. The most promising are: IR24632-60-3-3-2, IR25571-55-3, IR25588-32-2, IR25588-36-2-3, IR25621-105-1-2, IR24863-8-2-3, IR25863-61-3-2, IR25861-31-1-3, IR25861-145-2-3, IR25882-32-1-3, IR25922-39-3-2, IR21820-38-2, IR21841-62-2-1-3, IR22082-41-2, and IR25916-3-2.

POSTHARVEST QUALITY

Chemistry Department

Milling quality of promising lines. Promising IRRI lines from the agronomy yield trials with intermediate fertilizer nitrogen treatment were screened for milling quality. Hardness of raw rice was also estimated with the Instron food tester to simulate the Kiya hardness tester method. Crushing hardness, when the cracking sound was heard, corresponded to a shoulder in the hardness curve. The mean hardness value of 20 individual grains of brown or milled rice was determined per sample at crosshead speed of 1 cm/minute and with the 50-kg load cell.

Among 25 rices — Peta, 8 IRRI varieties, and 16 lines from the 1980 wet-season crop aged at least 4 months after harvest — percentage hull ranged from 21 to 28%, total milled rice 61 to 72%, and head rice yield 32 to 62% from rough rice, corresponding to 9-15% by weight bran-polish removal by a McGill miller no. 2 from brown rice. Among 5 IRRI varieties, Peta, and 21 promising lines in the 1981 dry season, the values ranged from 21 to 29% hull, 63 to 73% total milled rice yield, and 32 to 67% head rice yield from rough rice, corresponding to 8-12% by weight bran-polish removal. The McGill miller no. 2 was preferred to the Satake TM-05 mill because it gave a wider spread of values. Oven drying was preferred to shade drying in simulating actual drying operations. Also, because of higher moisture content (13% vs 12%) and the curing effect of heat, shade-dried grains did not crack as well and had 1.5-3.5 kg lower hardness values than oven- or sun-dried samples.

Detailed correlation studies were made on replicate 1 of the 1981 dry-season crop. Brown-rice hardness with an Instron correlated positively with head milled-rice hardness and milled-rice yield, and negatively with the milled-rice whiteness measured with a Kett whiteness meter (Table 1). Results with head-rice hardness were similar except that the negative correlation with degree of milling was significant. Brown rice is preferable to head rice for hardness measurement because in the milled samples, the softer grains have already been cracked during milling.

Use of the actual decrease in 100-grain weight during milling gave lower estimates of degrees of milling because of the loss of brokens with the bran-polish in the standard method based on total milled rice yield. But the results were highly variable and did not correlate significantly with any other parameters, including degree of milling (Table 1). Degree of milling and total milled rice yield were negatively correlated but the r value was not unity because milling yield was expressed on a rough-rice basis, which is also affected by percentage hull ($r = -0.89^{**}$). Whiteness of milled rice was positively correlated with degree of milling and negatively with hardness of grain and total and head rice yield (Table 1). But whiteness values still showed a wide range among milled rices of similar degrees of milling.

Duplicating milling tests using replicate field samples had little effect on the milling quality indexes based on one replicate (Table 1). But correlation coefficients involving degree of milling improved slightly.

Crushing hardness of brown rice may be used as an indicator of total and head rice yield of rough rice, but the method still needs refinement to improve the correlation coefficient. All the other correlations were expected because the brown rices were milled under the same pressure and period in the McGill miller.

Table 1. Linear correlation coefficients among milling quality indexes of 27 rough rices. IRRI, 1981 dry season.

Property	Range	Mean	Correlation coefficient with: Head rice hardness	Degree of milling	Decrease in grain wt	Total milled-rice yield	Head rice yield	Milled-rice whiteness
A. *Replicate I only*								
Brown rice hardness (kg)	8.1-12.0	10.3	0.84**	-0.30	-0.10	0.40*	0.69**	-0.47*
Head rice hardness (kg)	6.7-10.4	8.6		-0.43*	0.04	0.50**	0.72**	-0.53**
Degree of milling (%)	7.7-12.7	9.5			0.19	-0.85**	-0.56**	0.59**
Decrease in wt per grain (%)	5.7-11.4	8.0				-0.18	-0.22	-0.05
Total milled rice yield (%)	66.3-72.9	69.5					0.51*	-0.53**
Head rice yield (%)	34.0-67.7	51.8						-0.50**
Milled-rice whiteness (Kett)	34.5-53.0	42.5						
B. *Mean of replicates I and II*								
Degree of milling (%)	7.8-12.0	9.4			0.29	-0.90**	-0.65**	0.72**
Decrease in wt per grain (%)	5.8-11.8	8.3				-0.31	-0.38	0.05
Total milled rice yield (%)	63.4-73.0	69.2					0.52**	-0.49**
Head rice yield (%)	32.0-67.4	51.7						-0.54**
Milled-rice whiteness (Kett)	34.2-52.0	42.6						

Yellowing of wet grain. Piling of cut stalks of rice after harvest before threshing may cause stack burning of grains, particularly if grain temperature exceeds 60° C. The presence of wet straw accelerates the heating of the stack. Whiteness (Kett) values of brown rice from freshly harvested rough rice with moisture contents from 12.5 to 25%, wet basis, stored in sealed bottles in a 60° C oven for 4 days, decreased from 21.5 to 17.2 for IR36 and from 21.0 to 16.6 for IR42. Brown rice at 25% moisture also gave a whiteness value of 16. Even milled rice at 25% moisture showed uneven yellowing. Thus, both heating and high moisture content contribute to yellowing. Heating probably results from microbial respiration on the surface of the moist rough rice because few brown rice grains actually had lesions.

Estimation of degree of starch gelatinization in the sample with low gelatinization temperature (GT), IR42, showed only partial gelatinization from 13% in the unheated control to 25% for 18-25% moisture samples. Gelatinization was probably less for the intermediate-GT rice, IR36, which yellowed similarly to IR42. That suggests that all rices are similarly prone to this deterioration. Salt-soluble proteins and the amount of dye bound from Acilane orange G, an indicator of lysine content, were also lower in the yellow rice. Actual lysine assay of the severely yellow IR42 sample, however, revealed a high milled-rice lysine content (3.6%). These results contrasted with those of Swedish workers who reported that prolonged storage of barley at 67° C at about 12.5-15% moisture gave the greatest depletion of total lysine, from 3.7 to 2.6% of protein. At higher moisture levels, lysine losses were lower. Thus, heating does not adversely affect nutritional value, but it makes the grain unattractive. Heating also makes the grain harder, as shown by the higher head rice yield.

VARIETY PREFERENCE TESTS AND SURVEYS

Chemistry Department

Country samples. Two types of waxy rices were obtained for characterization from the Taiwan Agricultural Research Institute, Wufeng, Taichung. The long-grained type is used to make rice puddings and similar dishes; the short-grained type is used for sweetened rice cake and rice balls. Amylose contents were similar, but the two long-grained samples had intermediate-GT grains and harder neutral-gel consistencies in 0.15 M potassium acetate than the short-grained sample (Table 2).

Among six high-amylose rices, one waxy, and one of intermediate amylose from Malaysia, only Sri Malaysia II had hard gel consistency. The waxy rice is used for rice cakes, desserts, and sweets. Among five Vietnamese rices tested, three had intermediate and two high amylose.

Table 2. Physicochemical properties of waxy milled rices from Taiwan, China.

Variety name	L-W ratio	Amylose (%)	Alkali spreading value[a]	Gel consistency (mm)	Neutral gel consistency (mm)	Cooked-rice Instron hardness (kg)
Hsinchu Waxy 4	1.61	1.3	7.0 (L)	100	100	5.1
Taichung Waxy 46	1.61	1.5	6.4 (L)	100	100	5.0
Hung-Chueh-chu	1.94	1.6	4.6 (I)	88	37	5.4
Wu-ko-chu	2.11	1.5	6.4 (L/I)	100	83	4.8

[a]Refers to rating of individual grains L = low 6-7; I = intermediate 4-5.

Samples of three scented fine rices, four non-scented coarse rices, and a red rice for *chapati* were received from the Rice Research Institute, Dokri, Pakistan. Sind Basmati had higher amylose and harder cooked grain than the two traditional scented rices Basmati 370 and Jajai 77 (Table 3). Samples of Mehran 59 (IR6-156-2) and IR8 both had high amylose, low GT, and hard gel consistency. The eating quality of Mehran 59 is reported better than that of IR8; Mehran 59 had softer gel than IR8 in 0.2 N KOH at 80 mg/2 ml. This difference was also reflected in the greater Amylograph setback and consistency and lower breakdown of IR8 paste than Mehran 59 paste in two sets of samples. IET 4094 (CR156-5021-207) has medium gel consistency and GT, which suggests softer cooked grain. But the cooked-rice hardness values of freshly cooked grains of Mehran 59, IR8, and IET 4094 were similar. IR2053 has the softest texture of the coarse rices because of its intermediate amylose content. Dwarf Red Gunja, used for *chapatis*, has properties similar to those of Mehran 59, but has a red pericarp.

Nine Nepalese rices were analyzed to verify if they are japonica types. Only three samples had the japonica-type amylose content (16-20%) and alkali spreading values (6-7); they were Chianung 242, IET 2938 (RP502-3), and Pokharali Mashino. The others had high amylose (27-29%). Instron hardness values for cooked rice were 5.5-6.4 kg for the low-amylose group and 7.0-8.6 kg for the high-amylose samples. Stickiness values were 155-194 g·cm and 62-80 g·cm, respectively. Amylograph data confirmed the higher setback and consistency of the high-amylose rices.

Oryza glaberrima. The starch properties of 182 samples from the International Institute of Tropical Agriculture collection of traditional *O. glaberrima* rices from Africa were analyzed. Most of the samples had red pericarps but six were not pigmented. Milled-rice amylose content ranged from 21.7 to 30.0%, dry basis. One hundred thirty were high amylose, and the rest, intermediate amylose. All were mainly of low-starch GT type, ranging in alkali spreading value from 5.8 to 7.0. One hundred had soft gels, 68 medium gel, and 14 hard gel. Nine

Table 3. Physicochemical properties of 8 Pakistani milled rices from Rice Research Institute, Dokri. IRRI, 1981.

Sample name	Amylose (%)	Alkali spreading value	Gel consistency (mm)		Cooked-rice Instron hardness (kg)
			100 mg rice	80 mg rice	
Basmati 370	21.9	4.8	42	76	6.2
Sind Basmati	25.4	7.0	37	85	9.2
Jajai-77	20.8	5.6	38	66	7.6
Mehran 59	29.5	7.0	34	64	9.2
IR8	28.4	7.0	30	36	8.9
IET 4094	28.1	5.0	41	96	9.1
IR2053	21.7	3.5	52	87	6.2
Dwarf Red Gunja	28.4	6.5	32	70	8.3

of those with hard gel had intermediate amylose content.

FACTORS THAT AFFECT COOKED-RICE PROPERTIES

Chemistry Department

Survey of cooking methods. Forty-one respondents from 27 countries were surveyed by mail on cooking methods used in their laboratories. The benchmark information will be used in planning cooperative tests on rice cooking methods. Thirty-seven laboratories reported cooking rice for texture evaluation (20 used sensory evaluation, 12 used instrument methods, and 5 used both methods). An equal number used the rice-cooker and the excess-water method of cooking. Nine respondents determined volume expansion ratios and 11 measured water absorption ratios. Twelve respondents measured elongation ratio during cooking and 12 ran Amylograph viscosity. Only five laboratories reported measuring the aroma of rice grain.

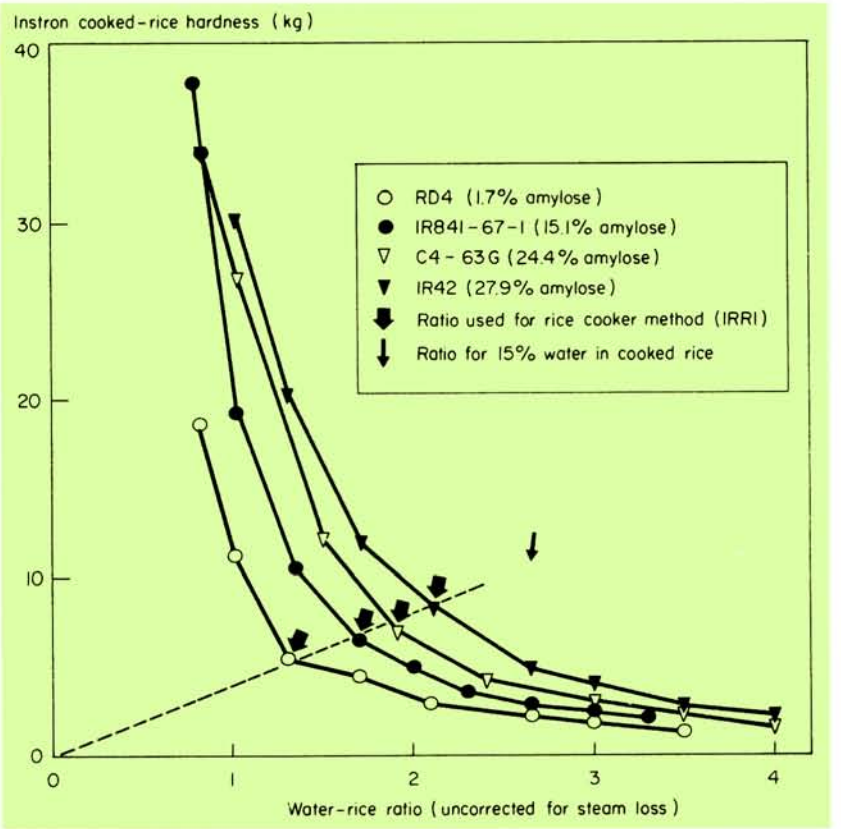
All 29 respondents using indirect methods for measuring cooking quality of milled rice measured amylose content, 26 measured alkali spreading value, 16 estimated gel consistency (mostly on high-amylose samples), and 9 measured protein content.

Rationalization of cooking methods. Rice is cooked either in the amount of water it will absorb to obtain the desired texture, or in excess water to optimum degree of cooking (time required for the center of the grain to become translucent). With the excess-water method, all rices had the same water content (73-75%, wet basis).

In 1980, IRRI showed that the rice cooker (double boiler) method, with a water-rice ratio of 2.46 in the inner pot to achieve the same water content of 73.7% in the excess-water method, gave boiled rices with hardness similar to that of rices prepared in excess water. That was confirmed with the use of a water-rice ratio of 2.65:1 to give 75% water in 1981. Water content of the 10 cooked rices was more reproducible in the cooker method (74.7-75.3%) than in the excess-water method (69-76%). Thus, the extracted starch in cooking gruel was less important than water content in determining grain hardness in the excess-water method. The water-rice ratio in the IRRI rice cooker method had been arbitrarily adjusted about 1974 on the basis of consultation with food technologists at the Institute of Human Ecology, University of the Philippines at Los Baños, to 1.3 for waxy samples, 1.7 for low amylose, 1.9 for intermediate amylose, and 2.1 for high amylose. A fixed ratio of 1.8 was previously used but an adjusted ratio based on amylose content was adapted because consumers normally adjust the water-rice ratio to attain the desired texture of cooked rice.

The study of the effect of water-rice ratio, using one sample each of the four amylose types, the rice cooker as a double boiler, and the Instron food tester with extrusion cell, demonstrated the primary role of water content of rice in determining cooked-rice hardness. The spread of hardness values was wider with the use of a water-rice ratio constant between 1.7 and 2.1 than at 2.65 (75% water in cooked rice) or with water levels adjusted to amylose content (Fig. 1). The relative-hardness rankings of the four varieties followed their amylose contents at any water-rice ratio. With the adjusted water-level method, the points coincided with a straight line with the intercept at the origin. Thus, for screening of breeding materials of diverse amylose contents, a constant water-rice ratio between 1.7 and 2.1 is more sensitive than 2.65 or the excess-water cooking method, because of the wider spread in hardness values. When cooking waxy and low-amylose samples alone, lower water-rice ratios are desirable to obtain the desired cooked-rice texture. For example, Japanese workers use a water-rice ratio of 1.1-1.5 for japonica rice, according to the mail survey.

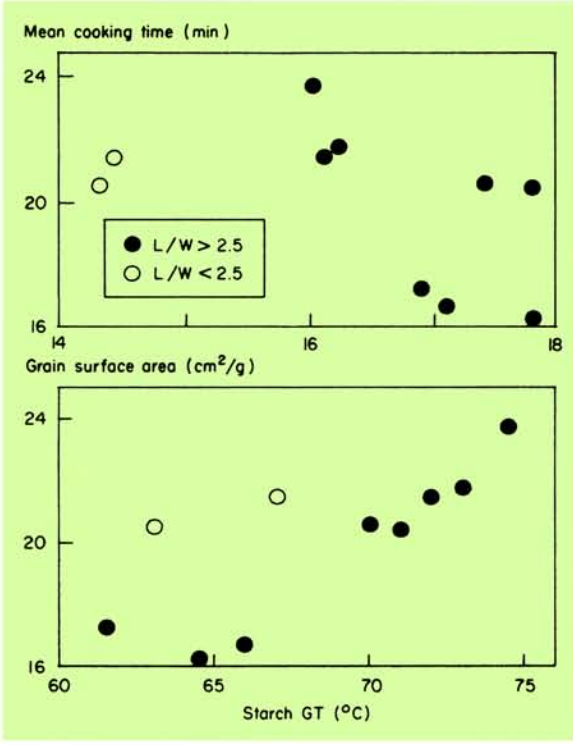
In some laboratories, rice is cooked in a casserole in an oven at 162° or 176° C, 28 minutes with cover and 5 minutes without. Because water loss during cooking is high, water-rice ratio of 3.5 is needed to achieve 75% water in cooked grain by this method at 162° C. The resulting cooked rice had hardness values similar to those of rice prepared in the rice cooker to achieve 75% water. Again, the importance of water content of cooked rice in determining grain hardness was demonstrated; actual grain temperature remained at 100° C as long as free water remained in the casserole.



1. Hardness of cooked rice decreased progressively with increasing water-rice ratio used during cooking. Differences in hardness among amylose types were maintained but were higher at water-rice ratio 1.7-2.1 than that at 2.65, representing 75% water content of cooked rice. IRRI, 1981.

Major factors determining cooking rate. Using 20 varieties differing in grain size and shape, Indian workers earlier reported that cooking time was primarily related to the grain's surface area, which is a function of its size and shape and generally unrelated to other grain properties. In contrast, kinetic studies by Japanese and Korean workers concluded that at temperatures lower than 110° C, the reaction rate of rice components with water limits the cooking rate; the rate of diffusion of water toward the interface of uncooked core was limiting only at 110° C or higher. In sister lines differing in GT, IRRI research has shown that cooking time in excess water is positively correlated with GT of starch (Annual report for 1967).

To resolve this question, the grain dimensions were measured and the surface area per gram of milled rice was calculated for 10 milled rices of diverse properties, characterized in the 1980 cooperative test on instrument methods for cooked-rice texture. The samples had diverse grain weights (15-21 mg), lengths (5.4-7.1 mm), widths (2.0-2.7 mm), and thicknesses (1.5-1.9 mm). Mean cooking time, determined by 11 cooperators, was used. Surface area per gram ranged from 14.3 to 17.8 cm^2, starch GT from 61.5 to 74.5° C, and mean cooking time from 16.2 to 23.8 minutes. A plot of cooking time as a function of surface area and GT showed better relationship of cooking time with GT ($r = 0.75$*) than with surface area per gram ($r = -0.49_{ns}$) (Fig. 2). Brazos and Calrose, the two coarse rices with length-width ratio (L:W) < 2.5, did not fit the trend in either case. Despite their low surface area, they cooked as fast as some rices with large surface areas. Both have low GT (67° and 63° C) and the two rices with large surface area and cooking time >20 minutes had intermediate GT (70° and 71° C). In the GT-cooking time scattergram, the eight fine-grained samples showed a good fit of linear correlation ($r = 0.93$**), suggesting that grain thickness or surface area also affects cooking time, but less than the reactivity of the grain with water, as



2. Mean cooking time of milled rices differing in grain properties correlated less with grain surface area than with starch gelatinization temperature (GT). IRRI, 1981.

reflected in starch GT. The scattergram of grain thickness with cooking time had even poorer relationship ($r = 0.37_{ns}$) than grain surface with cooking time, even when the two coarse-grained rices were excluded ($r = 0.39_{ns}$ and -0.62_{ns}). Alkali spreading value and starch GT were negatively correlated ($r = -0.89^{**}$, $n = 10$).

Stickiness tests. In the beam balance technique for determining stickiness of cooked rice, 10 grains are pressed with a constant weight and for a constant period of time with a Bakelite plate, and the weight required to lift the plate from the rice is considered its stickiness index. With various instrument methods, rice is compressed either with a constant weight or pressure, or to a constant clearance. IRRI has used 17 g cooked rice and a constant clearance of 0.4 mm with its Instron stickiness method, but has tended to overload the 5-kg-load cell. Therefore, the constant pressure method was used in lieu of constant clearance. Cooked rice (2.5 g) was pressed with the 3.6-cm-diameter plunger at 10 mm/min crosshead speed until pressure was 4 kg. Pressure was held for 20 seconds, then the plunger was raised. The work required to lift the plunger, in gram-centimeters, was again calculated as stickiness. Maximum force, in grams, may also be used as a stickiness indicator, but is not applicable to waxy rices (Table 4). Values were lower with the constant pressure method even when expressed on a per-unit area of contact basis, because the grains were not pressed as much as in the 0.4-mm clearance method. Relative ratings of the samples by both stickiness tests, however, were similar.

Gel consistency in water. The use of water instead of 0.2 N KOH as solvent in the gel consistency test is identical to the use of boiling water in cooking rice. It is suitable for waxy and low-amylose rices but aqueous gels of high-amylose rices have been found unstable. Among waxy milled rices, water gel consistency values had a wider range (34-74 mm) for 200 mg/2 ml water than for 100 mg/2 ml 0.2 N KOH (76-100 mm). But neutral gel consistency values (200 mg/2 ml 0.15 N potassium acetate) ranged from 28 to 83 mm and high-GT rices all had hard gel (28-37 mm).

Among the 8 waxy rice starches, gel values also spread more with water (150 or 200 mg) than with 0.2 N KOH as solvent (135 mg). Panpet 63 had the

Table 4. Comparison of stickiness values by constant clearance of 0.4 mm using a 6.9- × 6.9-cm plunger and by constant pressure of 4 kg using a 3.6-cm diameter plunger.[a] IRRI, 1981.

Cooked sample	Amylose type	Stickiness value at				
		Constant clearance		Constant pressure		
		(g·cm)	(g·cm/cm²)	(g)	(g·cm)	(g·cm/cm²)
IR8	high	68	1.42	131	4.1	0.40
IR32	high	108	2.25	344	10.0	0.98
IR24	low	150	3.12	554	15.6	1.53
IR833-6-2	waxy	505	10.5	542	31.8	3.12

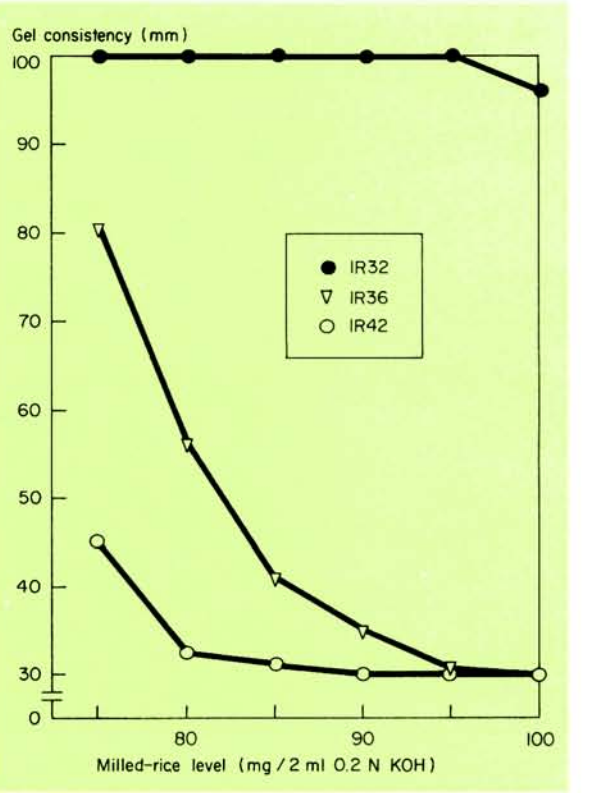
[a] Plunger area of 48.0 and 10.2 cm², respectively.

hardest gel in both 0.2 N KOH and water. Its amylopectin also had the hardest gel in water (115 or 165 mg). The starch and amylopectin of RD6 had the softest gels.

Ten low-amylose milled rices had a narrow range of gel consistency values in both 0.2 N KOH and water (100 mg) and had mainly soft gels. The corresponding starches had soft gels in KOH (135 mg) but their gel consistencies ranged from 32 to 90 mm in water (100 mg). The two intermediate-GT samples had hard starch gels. The gel consistencies in KOH of 11 intermediate-amylose milled rices, ranged from 36 to 70 mm (100 mg), but ranged from 38 to 100 mm (100 mg) in water. With the corresponding starches, gel consistencies ranged from 32 to 92 mm in KOH (135 mg) and from 31 to 86 mm in water (100 mg). Gel values of both milled rice and starch in the two solvents did not tally.

Modified gel consistency test. Some rice samples with soft or medium gel such as IR32 and IR36 sometimes harden progressively during storage. Attempts to use a water solvent for high-amylose rice were unsuccessful because of rapid syneresis or gel breakdown, which separates starch precipitate and free water. As a solution, reduction of rice concentration below 100 mg readily verified the classification of rice samples at 100 mg/2 ml 0.2 N KOH. Weights of 80-90 mg were effective. Figure 3 shows that IR36 and IR42 had hard gels at 100 mg, but IR36 showed its typical medium gel value at 80 mg, while IR42 retained its hard gel. Thus the screening had to be run at 80 mg/2 ml KOH to ensure that the check samples give typical gel types — soft for IR32, medium for IR36, and hard for IR42. Instead of duplicate gel runs at 80 or 100 mg, two milled-rice levels such as 100 mg and 80 or 90 mg without replication may be used.

So far IRRI has only determined gel length and viscosity in its gel consistency test. To obtain actual gel-consistency values of high-amylose milled rices, gels of milled rices were prepared from 5 g flour in 25 ml 0.2 N KOH for determination of texture profile by the double-bite technique with an Instron Food Tester. The hot gels were poured into 2.2-cm-diameter × 2-cm-high molds and cooled for 1 hour. At a crosshead speed of 40 mm/minute and clearance of 0.4 cm and 1.6 bites/minute, the hardness values of the gels were: IR32, 0.86 kg; IR36, 1.52 kg; and IR42, 1.74 kg.



3. Decreasing the milled-rice concentration in the gel consistency test can optimize the differences in values between the various gel consistency types: IR32 soft, IR36 medium, and IR42 hard. In this set of samples, 80 mg gave better differentiation than 100 mg. IRRI, 1981.

Rices with unusual amylose-GT combinations. A study of the properties of milled rice and starch of rices identified in the germplasm bank screening for starch properties as having unusual combinations of amylose-GT was completed. Waxy rice with intermediate GT was similar to low- than to high-GT waxy rices in properties. Intermediate-GT, low-amylose rice was intermediate in properties to low- and high-GT types because the high-GT rices had somewhat lower amylose content than the others. High-GT, intermediate-amylose rices were closer to intermediate-GT rices than to low-GT samples. The same seemed true for high-GT, high-amylose rices.

Properties of starch and its fractions. Studies relating differences in gel consistency of milled rice with starch properties, particularly amylopectin molecular weight (MW) continued. Amylose and amylopectin were obtained by crystallization of amylose as the pentanol complex from gelatinized

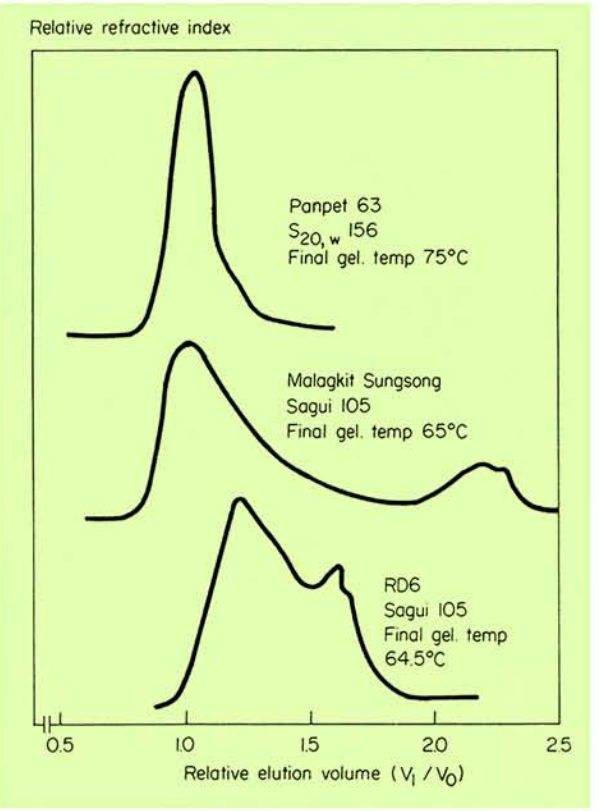
starch. Amylopectin was recovered from the supernate, and the amylose-pentanol complex was precipitated once from 1-butanol-saturated water. Values for sedimentation constants, obtained in 1980, were verified, then corrected. Amylose degree of polymerization (DP) was estimated by analysis of its reducing end group.

Waxy starch. Earlier results with waxy starches indicated that cooked products such as cakes from rices with high GT and higher MW of amylopectin, based on sedimentation constant and intrinsic viscosity, harden faster on storage than cooked products from rices with low GT. A detailed study of amylopectins among 8 waxy rices showed that sedimentation constant $S_{20,w}$ in an analytical ultracentrifuge correlated positively with starch GT ($r = 0.80$*) (Table 5). MW indexed by $S_{20,w}$ was verified to be consistent with MW distribution of amylopectins on Sepharose CL-2B gel filtration. Low-GT Malagkit Sungsong and RD6 amylopectins had lower mean MW than high-GT Panpet 63 amylopectin (Fig. 4).

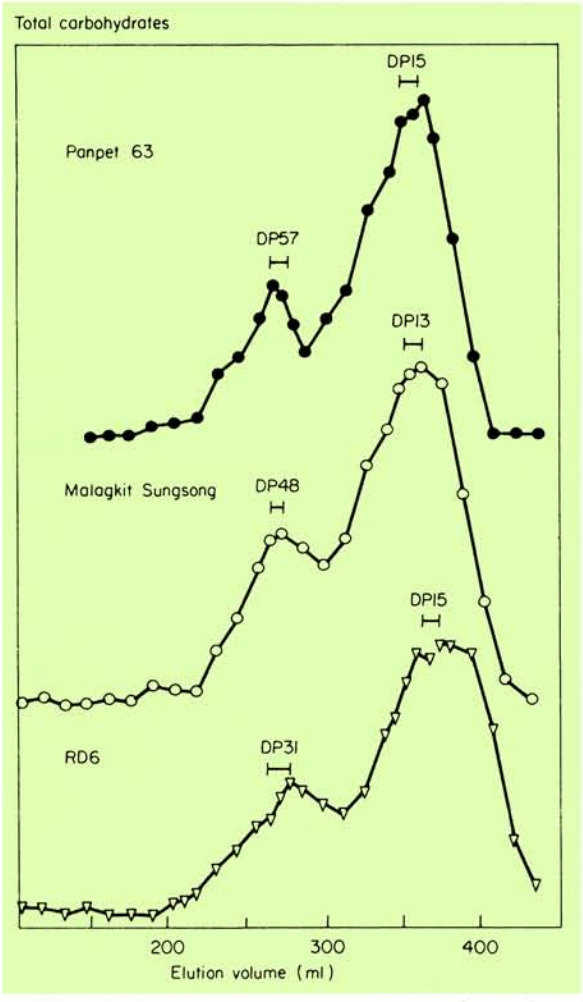
Size difference may be due to differences in actual number of glucose units per molecule and to differences in shape or degree of branching. Isoamylase treatment of waxy amylopectins to remove branch points showed similar bimodal distribution of the resulting linear B (24-30%) and A (69-74%) fragments on Sephadex G-50 gel chromatography (Fig. 5). These results suggest that the degrees of branching of the waxy amylopectins were similar and that the observed differences in sedimentation and gel filtration data were mainly due to MW differences. The absence of a higher MW fraction after isoamylase treatment (Fig. 5) verified the absence of amylose in 1-butanol-saturated-water soluble autoclaved waxy rice starch.

The hot water-soluble fraction of waxy rice amylopectin also was higher (61-68%) for all low-GT waxy starches, except Malagkit Sungsong (49%), than for high-GT starch amylopectin (44-48%). A possible explanation is the presence of high MW ($V/Vo = 1$) fraction in Malagkit Sungsong, which was absent in RD6 (Fig. 4). Results were similar for the starch granules in 1980.

Amylose assay for waxy rice. Korean chemists have reported the feasibility of assaying for amylose content in waxy rice starch by the use of a higher starch-iodine ratio. The method can also be adapted to the AutoAnalyzer. Iodine-binding capacity (IBC) of purified waxy rices ranged from 0.1 to 0.9%, equivalent to 0.5-4.9% amylose based on an IBC value of 19% for amylose. Actual colorimetric analysis showed values of 0.3-0.5% by the manual method and 0.4-0.9% by the AutoAnalyzer method. Standard curve was prepared with IR29 starch (0.5% amylose) and potato amylose (IBC 19%). The method was satisfactory with 100 mg waxy rice flour or rice starch. Evidently, by reducing the iodine in solution to one-seventh the amount in the standard procedure, the iodine preferentially complexed with amylose than with amylopectin. Amylose values obtained with this method were lower than those obtained by the standard amylose assay (1.5-2.5%) using also waxy rice-potato amylose standard mixture. This revised method is recommended for the amylose assay of waxy milled rices and starch.



4. Amylopectins of waxy rices differing in molecular size based on sedimentation constant on ultracentrifugation also differed in molecular size distribution on Sepharose CL-2B gel filtration (2.6 × 84 cm). Amylopectins eluted in the order of decreasing molecular size. IRRI, 1981.



5. Removing the branch points of amylopectins of waxy rices differing in molecular size resulted in a similar distribution of the 2 linear short-chain types from Sephadex G-50 gel filtration (2.6- × 94-cm column). The results suggest that the amylopectins had similar degree of branching. IRRI, 1981.

Nonwaxy starch. High-MW amylopectin seemed more important than high-MW amylose for hard aqueous starch gels among low-amylose starches (Table 5). The poor-quality Korean rice Tongil had only slightly lower MW of starch fractions than the japonica variety Jinheung. Among intermediate-amylose samples, starch GT correlated positively with amylopectin $S_{20,w}$ ($r = 0.80^{**}$, $n = 11$), as with waxy starches. Starch and amylopectin gel consistency ranged from hard to soft for all three GT types. Among two low-GT (IR8 and IR42), two intermediate-GT (IR5 and IR32), and two high-GT (BKN6987-62 and H4) high-amylose starches, the intermediate-GT starches had higher mean hot water-soluble fraction (37%) than low-GT (24%) or high-GT (22%) samples, in agreement with previous data for low- and intermediate-GT samples.

Amylose and amylopectin prepared from high-amylose starches usually have IBC values, reflecting impurity. Amyloses may have IBC of 15% (instead of 19-20%) and amylopectins, 5% (instead of <1%). Isoamylase treatment of amylopectins gave three fractions on Sephadex G-50 gel filtration instead of the usual two fractions obtained from waxy amylopectin. The highest MW fraction had a mean DP of 42-73 glucose units, indicating that they had lower MW than rice amylose (Table 5). The presence of low-MW linear chains in the amylopectin molecule that gives a blue-colored complex with iodine can explain the high IBC of this fraction. The low MW of the amylose makes its alcohol complex soluble in alcohol-saturated water during amylose crystallization.

Two high-MW amyloses were rechromatographed on Sepharose CL-2B into the void volume fraction, which stained greyish brown or blue violet with iodine, and a subsequent fraction, which gave a blue to greyish-blue color with iodine. The results suggest contamination of amylose with amylopectin or with a fraction intermediate in branching between amylose and amylopectin, which can still stain blue with iodine.

Starch lipids and choline content. Granular rice starch has been prepared by the removal of protein using sodium dodecyl benzene sulfonate (DoBS) detergent from milled-rice flour. This method, however, partially extracts the starch-bound lipids, and the DoBS also complexes with starch. Room temperature extraction of starch lipids with water-saturated 1-butanol (WSB) extracts only a fraction of the total to the same extent as refluxing 95% ethanol. Complete extraction requires refluxing WSB with simultaneous gelatinization of the starch. Six DoBS-prepared nonwaxy rice starches had 0.36% mean cold WSB lipids and 0.70% hot WSB lipids. By contrast, two nonwaxy rice starches prepared by alkaline protease removal of protein had 0.74% mean cold WSB lipids and 0.91% hot WSB lipids. Evidently DoBS had more reducing effect on the cold WSB lipid fraction than on the hot WSB fraction.

Analysis of 6-glucosyl phosphate ester and choline content of DoBS rice starches by starch chem-

Table 5. Range of properties of starch and its fractions.

Amylose type	GT type[a]	Samples (no.)	Starch[b] gel consistency (mm)		Amylopectin gel consistency[c] (mm)	Amylopectin $S_{20,w}$ (Swedbergs)	Amylose $\overline{DP}$ (glucose units)
			0.2 N KOH	Water			
Waxy	Low	4	92-100	60-100	46-95	105-120	–
	Int.*	1	98	67	80	106	–
	High	3	40-98	42-52	54-91	156-187	–
Low amylose	Low	4	84-100	57-85	72-99	136-171	154-539
	Int.*	1	64	32	88	186	500
	High	2	60,100	90,100	80,90	121,164	178,510
Intermediate amylose	Low	3	35-52	31-65	44-100	103-111	540-608
	Int.	5	42-92	33-68	30-90	136-187	470-1120
	High*	4	32-100	32-64	30-93	146-182	638-1050
High amylose	Low	2	30,32	32,88	29,45	49,81	830,831
	Int	3	28-90	31-100	38-95	24-158	763-1210
	High*	2	39,75	32,50	–	90,106	1390,1800

[a]Asterisk (*) denotes unusual amylose-GT combination. [b]135 mg/2 ml 0.2 N KOH. Water gel consistency: 100 mg/2 ml water for nonwaxy starch and 200 mg/2 ml water for waxy starch. [c]165 mg/2 ml water.

ists at Kagoshima University (Japan) confirmed that most of the phosphorus (P) content of 2 waxy rice starches (93-98%) was C6-glucose-P. In 6 nonwaxy rice starches, 6-glucosyl-P ranged from 0.17 to 0.70 ≥mol/g or 2-12% of total P. Choline content of nonwaxy starch followed closely the P content, and the choline-P molar ratio ranged from 0.75 to 0.89. Choline is a component of the phospholipids that complex with starch. Cold WSB defatting, which removed 52% of lipids, also removed 45% of P and 41% of choline content of 2 DoBS-prepared rice starches.

Phosphorus of alkaline protease-prepared rice starch was higher than that of DoBS-prepared starch. In addition, cold WSB defatting only reduced P content by about 30%. Cold-WSB extracted lipids (0.60% of two starches) had less contamination and had a neutral lipid-glycolipid-phospholipid ratio of 40:5:55. The high glycolipid fraction of DoBS-prepared starch (lipid ratio 1:1:1) had been shown to be due to DoBS contamination, with solubility similar to glycolipids on silicic acid fractionation.

Degree of branching of amylose. Starch chemists at Kagoshima University, Japan, have demonstrated the multibranched nature of potato and tapioca amyloses. Isoamylase or pullulanase alone does not completely debranch the amyloses but their combined action is required, suggesting that more than half of the branches were maltosyl residues. Seven of our once-recrystallized rice amyloses with IBC 19-20% and β-amylolysis limits of 72-84% were characterized at Kagoshima. The $\overline{DP}$ ranged from 532 to 793 glucose units. The mean chain length of their branches ranged from 101 to 157 glucose units, corresponding to 3.4-7.6 branches/amylose molecule. Rice amylose had lower MW than potato and tapioca amyloses. American starch chemists reported that amylose contains 2-6 branches/1,000 glucose residues.

Degree of gelatinization of rice products. Degree of gelatinization was determined in rice products by the greater water solubility of gelatinized starch. The starch was then hydrolyzed with glucoamylase, and the resultant glucose was estimated. The completely gelatinized sample used 10 N NaOH as the gelatinizing agent. This method was applied to "yellow" rice, parboiled rice, and extruded expanded rice. Dilute alkali (0.2 N NaOH), instead of pH 4.8 0.4 M acetate buffer, was later used to dissolve the gelatinized starch, and 95% ethanol was added as wetting agent to minimize clumping.

Five Indian rices parboiled 10 minutes at 85°, 100°, and 108° C were obtained from the Paddy Processing Research Centre, Tirivarur, as milled rice together with the raw control. Instron grain hardness increased with severity of heat treatment: 6.0-7.7 kg for raw samples, 8.3-10.4 kg for 85° C parboiled, 9.4-12.4 kg for 100° C parboiled, and 9.8-12.4 kg for the 108° C parboiled. The glucoam-

ylase method showed an increase in gelatinization by 20 to 97 percentage points from 5-33% to 53-102% for 108° C-gelatinized starch, with the percentage gelatinization, in general, increasing with higher parboiling temperature. Percentage gelatinization, with flour ground in a Wig-L-Bug amalgamator under polarized light, ranged from 34 to 66% for raw samples, 74 to 88% for 85° C parboiled, 86 to 98% for 100° C parboiled, and 98 to 100% for 108° C parboiled. The high values for raw rice resulted from starch damage during grinding in the Wig-L-Bug amalgamator.

The results were similar for extruded rice from blends of IR29 and IR32 milled rices from the Department of Food Science and Technology, UPLB, with extruder die temperatures of 40°, 50°, 70°, and 90° C. All samples showed some expansion and had high percentage gelatinization, which tended to be lowest for the 40° C extruded samples for blends with low-, intermediate-, and high-amylose content. Evidently, a more sensitive method is still needed to differentiate between retrograded and amorphous fractions of gelatinized starch in these rice products.

Microtest for complexing ability with starch gel. A review of variables affecting the aqueous gel consistency of defatted IR29 rice starch (Annual report for 1980) showed that grinding for 40 seconds in a Wig-L-Bug amalgamator softened gel, probably because of breakdown of starch molecules. Sieving to obtain a 100-mesh flour was adequate for starch because starch granules were small enough for dispersion. A 100-mesh milled rice flour would be adequate for gel consistency but an adequate mill was not available.

The defatted starch of C4-63G was also compared with that of IR29 for aqueous gel consistency. Both IR29 and C4-63G gels were hardened by the addition of 0.2 ml 0.025% thymol blue in ethanol and the acidification with 0.03 N acetic acid or use of 0.15 M potassium acetate instead of water. Starches of both rices were softened by use of 0.3 N KOH for dispersion, followed by neutralization with acetic acid, and by use of the 0.2 N KOH solvent. The added Hengar alumina granule increased the pH of the gel by 0.5 unit. Addition of 1% (starch basis) palmitic acid, stearic acid, and methyl stearate had a dramatic hardening effect (29-44 mm) on gels of both starches and the effects of tripalmitin and tristearin were less (7-9 mm). Lysolecithin (1.5%) also had a hardening effect (12-30 mm).

Defatting rice starch with WSB at $\leqslant$ 40° C resulted in a slight (2-10 mm) or marked (29-34 mm) softening effect on 5 of 6 rice starches, except IR8 starch, whose gel consistency changed from 90 mm to 60 mm on defatting. Waxy and intermediate-amylose rices and IR5 showed the softening effect. The unusual behavior of IR8 starch may reflect also its anomalous behavior. Wig-L-Bug grinding of its undefatted starch hardened the gel from 75 mm to 60 mm.

Although waxy (IR29) and intermediate-amylose (C4-63G) defatted starches behaved similarly in complexing reactions with model compounds, their reactions to the water-soluble extracts from the 8 whole milled-rice samples differed. Although these fractions at 1-3% of starch hardened IR29 starch gels, they softened or had no effect on C4-63G starch gels. The negative relationship between gel consistency and gel viscosity, measured with a Wells-Brookfield microviscometer, was more consistent with IR29 starch than with C4-63G starch.

Water extractable starch-complexing substances. *Milled rice.* Previous studies have demonstrated that both lipids (fat) and polysaccharides extracted by water hardened the IR29 starch gel when added at 1-2% of the starch. The 25°-40° C water extracts from flours of 5 elongating (elongation ratio 1.7-2.1) and 4 nonelongating rices (elongation ratio 1.4-1.5) were destarched and obtained in 0.1-0.8% yield. The preparations contained carbohydrates, lipids, and protein. All tended to harden IR29 starch gels. Boiling water extracts also were rich in carbohydrates or lipids. In general, the 95%-ethanol-soluble lipid-rich fraction had greater hardening effect on IR29 starch gel than the insoluble fraction. The polyuronic acid fraction ranged from 0 to 3% only.

Since rice is cooked as whole grain rather than as a flour, a study was initiated to determine the nature of the water-extracted materials during cold water washing and during cooking. A pair of waxy, intermediate-amylose, and high-amylose rice samples and 2 samples of IR7167-7-2-3 well-milled rices differing in GT and gel consistency were used. The samples had 0.4-0.7% dietary fiber and 0.3-0.4% crude fiber and 0.1-0.5% free sugars. Cold-(<

40° C) and hot- (100° C) water extracts of the eight rices were freeze-dried. All extracts were fractionated into refluxing petroleum ether-soluble, hot (60-70° C) 80% ethanol-soluble and residual fractions. Mean recoveries of cold-water extract were 1.7% of milled rice, of which 0.2% was ether soluble and 0.4% was ethanol soluble. Mean yield of hot-water extract was 6.8% of milled rice, of which 0.1% was ether soluble and 0.2% was ethanol soluble. Waxy rices had more hot water-soluble fraction. The samples have not been destarched and starch would be in the residual fraction insoluble in ether and ethanol.

The whole cold-water extracts tended to harden IR29 starch gel. While all three fractions were hardening, the ether and ethanol fractions had better hardening effect than the residual fraction on IR29 starch gel consistency and viscosity. All the whole hot-water extracts also had a hardening effect on IR29 gel. Either the ether or ethanol fraction had the greatest hardening effect on IR29 gel at 1-2% of starch.

Bran and germ. Cold- and hot-water extracts of defatted IR32 bran and germ were similarly prepared by destarching with *B. subtilis* α-amylase. Mixed β-glucan, unlike barley and oat β-glucan could not be precipitated from bran with Calcofluor or Tinopal fluorescent dyes. Recovery of both destarched cold- and hot water-soluble extracts were 1.3% for bran and 1.2% for germ. Fractionation of the extracts with saturated ammonium sulfate precipitated 32-44% of the extracts.

All extracts hardened IR29 starch gel, but the hot-water extract was more hardening than the cold-water extract for both bran and germ. The ammonium sulfate precipitate was also slightly more active than the soluble fraction. The water-insoluble residue still hardened IR29 starch gel. In contrast, bran cell-wall preparation softened IR29 gels.

Nonstarch polysaccharide preparations. *Milled-rice cell walls.* Cell walls were prepared from milled rices of eight varieties differing in direction of grain expansion during cooking (lengthwise or girthwise) by the method developed in 1979. The cell-wall preparations were recovered at 0.3-0.7% of milled rice and had similar neutral sugar composition (major sugars: arabinose, xylose, mannose, and glucose) and solubility fractions in water (10%) and alkali (60%). The cell walls from elongating rices D25-4 and Basmati 370 had smoother surfaces based on scanning electron micrographs than those from IR36.

Phenols and polysaccharides rich in arabinose, xylose, glucose, and uronic acids were preferentially extracted from IR32 and IR36 cell walls with water at 100° C and dilute alkali. A polysaccharide staining blue with iodine-potassium iodide was eluted with 0.25 M NaOH from DEAE-cellulose column chromatography of water and 4 M KOH fractions of IR32 walls, thus confirming the presence of amyloid-type xyloglucan in milled rice, reported by Japanese researchers.

Proteins in cell-wall preparations were mainly protein bodies not bound to polysaccharides, according to gel electrophoresis and trichloroacetic acid precipitation data. They were contaminated with the *Bacillus licheniformis* α-amylase used for destarching the gelatinized rice, as reflected by lysine contents as high as 8%. The protein fraction had only trace hydroxyproline, in contrast to data of Japanese and American workers.

The whole-cell-wall preparations all hardened defatted IR29 starch gel. In general the hot-water and 4-M-KOH fractions also hardened IR29 gel.

Bran and germ cell walls. Cell walls prepared from IR32 and IR29 (waxy) bran and germ were similar in composition. Scanning electron micrographs clearly demonstrated the contamination of bran with subaleurone cell walls. Bran had higher fiber content than germ and the recoveries of the cell-wall preparations (30%) approached their modified neutral detergent fiber content (28%). Principal component neutral sugars were arabinose, xylose, and glucose. The 0.5-M NaOH or KOH and 8 M urea solvents preferentially extracted polysaccharides rich in arabinose, xylose, and uronic acid, but 6 M NaOH-0.81 M boric acid extracted mannose-rich polysaccharides. DEAE cellulose-borate chromatography of the 0.5 M NaOH extracts gave fractions of similar arabinose-xylose ratios.

Proteins in the cell-wall preparations had only 0.4-1.6% hydroxyproline, in contrast to the values obtained by American workers. They were mainly present as glycoproteins based on disc gel electrophoretic data. The preparations were autofluorescent in the UV and rich in phenols, mainly ferulic

acid.

In contrast to milled-rice cell walls, the bran and germ walls softened defatted IR29 starch gels, even at 0.2% of starch. The water-soluble or 8-M urea fraction had the greatest softening effect.

Hull polysaccharides. Because contamination of brown rice and bran by hull polysaccharides is possible, particularly during parboiling, a similar survey was made of polysaccharides of hull of IR32 (nonwaxy) and IR29 (waxy) rice. Hull was precleaned by aspiration and sieving to remove brown-rice contamination. The neutral detergent fiber content of hull (85%) was much higher than that of bran (32%) and milled rice (< 1%); so were the ash (24-26%) and lignin (15-16%) contents. The major fractions of hull were those soluble in alkali (45%) and the insoluble, cellulose-rich fraction (50-55%). Cellulose plus lignin contents (52-56%) closely approximated the residual fraction.

Complexing ability of the hull and its solubility fractions on IR29 defatted starch (Annual report for 1980) showed the hull to be softening. All fractions, other than the residue, however, tended to harden the IR29 gel.

Genetic evaluation and utilization (GEU) program

Disease resistance

Plant Pathology Department

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Evaluation of GEU elite lines and IR varieties for resistance to bacterial, fungal, and viral diseases continued. Of 104 entries screened against 12 rice diseases, 42 were resistant to 1 disease, 31 to 2 diseases, and 16 to 3 diseases (Table 1). Only line IR13540-56-3-2-1 was resistant to sheath rot, narrow brown leaf spot, grassy stunt, and ragged stunt diseases. IR46 and IR3646-8-1-2 were resistant to three diseases.

RESISTANCE TO FUNGUS DISEASES

Bakanae. GEU elite lines and IR varieties were evaluated for reaction to bakanae by the seed-soaking method of inoculation. Entries were scored on percentage of seedling infection: 0-30%= resistant, 31-60%= intermediate, 61-100%= susceptible.

Of the 224 entries tested, 52.7% were resistant, 39.7% intermediate, and 7.6% susceptible (Table 2). Some of the resistant rices were IR8, IR43, IR52, IR8073-65-6-1, and IR8192-200-3-3-1-1; some of the susceptible were IR42, IR5420-1-1-2, IR9764-45-2-2, IR15496-219-2-3-2, and IR19762-2-3-3.

Leaf scald. Evaluation for resistance to leaf scald continued during the 1981 wet season. Entries from GEU elite lines and 46 rices from the leaf scald screening set were inoculated in the field by the clipping method. An arbitrary scale of 0-9 (0 = highly resistant, 9 = very susceptible) was used to classify varietal reaction.

Of all the entries evaluated, 24.6% were resistant, 47% intermediate, and 28.4% susceptible. Rices that showed resistance included IR8192-200-3-3-1-1, IR5853-18-2, IR5894-73-3, IR4422-143-2-1, and IR4722-245-1-1. Susceptible rices included IR36, Bahagia, IR8111-6-2, Pattambi 1751, BG35-2, and BR168-2B-23.

Stem rot. GEU elite lines and some IR varieties were evaluated for resistance to stem rot. Entries were scored in the field under natural infection at maturity, on an arbitrary scale of 0-9 (0 = most resistant, 9 = most susceptible). None of the 77 entries evaluated were found to be resistant to stem rot.

Blast. Evaluation in IRRI blast nurseries continued in 1981. Of 75,498 entries tested, 13.5% were resistant, 18.3% intermediate, and 68.6% susceptible (Table 3). Some cultivars that have consistently shown high resistance to blast at IRRI and other locations around the world are Tetep, Carreon, Dawn, IR5533-PP854-1, IR3259-PP5-160-1, IR1905-PP11-29-4-61, and IR9660-50-3-1-1.

Sheath blight. A total of 5,616 rice entries from breeding materials and the germplasm bank collection were screened against sheath blight in the 1981 dry and wet seasons. As in previous years, no variety or line showed a resistant reaction. Almost all — 93.5% of the test materials — exhibited intermediate reactions; 6.4% were susceptible (Table 4).

Multiple resistance. Not one of the 102 entries screened in 1981 for resistance to sheath blight, narrow brown leaf spot, brown spot, and sheath rot was resistant to all four diseases. Line IR19764-23-2-2-1-3 was resistant to narrow brown leaf spot and sheath rot, and moderately resistant to brown spot; it had intermediate resistance to sheath blight.

RESISTANCE TO RICE VIRUS DISEASES

The resistance of 24,525 entries — 7,518 to tungro, 7,475 to grassy stunt, and 9,532 to ragged stunt — was determined by mass screening in the greenhouse. Percentage of infected seedlings indicated the degree of resistance.

Several rice wild taxa were included in the tests for resistance to ragged stunt. Eleven with different accessions, were found to be resistant (Table 5).

Field reactions to tungro of 54,127 entries in pedigree nurseries were scored on the Standard Evaluation System for Rice (SES). Tungro disease incidence in the nurseries was enhanced by the transplanting of 865,000 TN1 seedlings exposed to tungro-viruliferous insects.

Qualitative resistance to ragged stunt. Sitopas, an Indonesian variety, was found to be tolerant of ragged stunt. When infected seedlings were grown to maturity in the screenhouse, disease symptoms were generally masked, but not the vein swellings. Infected plants produced panicles with more filled than unfilled grains.

Resistance to tungro of IR34. The mechanism and stability of resistance to rice tungro of IR34 were studied. Nine successive generations of green leafhopper *Nephotettix virescens* were reared on IR34. In each generation, adults were tested for

Table 1. Disease reactions of GEU elite lines and IR varieties. 1981.

Variety or line	Disease[a] reaction[b]											
	BI	LSc	StR	BK	ShB	BS	ShR	NBLS	BLB	RTV	GSV	RSV
IR8	S	S	I	R	S	S	S	I	S	I-S	R	S
IR20	S	R	S	I	I	I	S	I	R	S	R	S
IR36	S	S	S	I	I	I	S	I	I	S	I	S
IR42	S	R	S	I	I	I	I	I	R	S	I	S
IR43	S	I	–	R	S	–	S	I	R	I	I	S
IR46*	S	R	I	I	I	–	I	R	I	I	R	S
IR50	S	S	S	S	I	I	S	I	I	S	I	S
IR52	S	I	S	R	S	–	I	S	I	I	R	I
IR54	S	I	S	I	I	I	I	I	I	I	R	I
BG 35-2	S	–	–	I	–	–	S	R	I	I	–	S
IR2987-13-1	S	I	–	I	I	I	I	R	S	S	R	S
IR3646-8-1-2	S	R	S	–	I	S	I	R	I	S	R	S
IR3839-1	S	S	S	I	I	I	S	I	I	S	R	S
IR3858-6	I	I	S	I	I	I	I	I	I	S	R	S
IR3880-10	S	S	S	–	I	I	I	I	S	S	R	S
IR3880-13-7	S	S	S	–	I	I	I	R	I	I	R	S
IR3880-17	S	–	–	–	I	I	S	R	I	S	R	S
IR3880-29	S	S	S	–	I	I	I	R	I	S	R	S
IR5179-2	S	S	–	–	I	I	S	S	I	S	R	S
IR5260-1	S	S	S	–	I	I	S	I	I	S	R	I
IR5420-1-1-2	S	–	–	I	I	I	S	R	I	S	I	S
IR5429-12-3	S	I	S	S	–	–	S	I	I	–	–	–
IR5716-18-1	S	I	S	–	I	I	S	I	S	S	R	S
IR5873-9-1	I	–	–	–	I	I	I	I	S	I	R	S
IR5929-12-3	R	S	S	S	I	I	I	I	I-S	S	I	S
IR5931-110-1	R	I	S	–	I	I	I	R	S	I	R	S
IR5931-113-1	R	–	–	–	I	I	S	R	I	S	R	S
IR5982-7-6-1	S	S	–	–	I	R	S	I	I	S	R	S
IR6023-10-1-1	I	I	S	I	I	S	I	R	I-S	S	R	S
IR6115-1-1-1	S	S	I	I	I	I	S	I	I	S	R	S
IR7790-18-1-2	I	I	S	–	I	I	S	R	I	S	R	S
IR8073-65-6-1	S	R	S	R	I	I	I	S	I	I	R	I
IR8192-200-3-3-1-1	S	R	S	R	I	I	I	I	I	I	R	I
IR8608-298-3-1-1-2	S	I	–	–	I	I	I	I	I	I	R	I
IR9129-209-2-2-2-3	S	I	S	I	I	I	I	I	I-S	I	R	I
IR9209-48-3-2	S	R	S	S	I	I	I	I	I-S	S	I	I
IR9217-58-2-2	S	R	I	R	I	I	I	I	I	S	I	S
IR9672-140-2-3-2	S	R	S	I	I	–	I	I	I	S	S	I
IR9729-67-3	S	S	S	I	I	I	S	I	I	I	I	I
IR9752-1-2-1	S	S	S	I	I	I	S	I	I	I	I	I
IR9752-71-3-2	I	I	S	I	I	I	I-S	I	I	I	I	I
IR9761-19-1	S	I	S	R	I	I	S	I	I	S	I	I
IR9763-11-2-2-3	S	I	S	I	I	I	S	I	I	I	I	I
IR9764-45-2-2	S	S	S	I	I	I	I	I	I	I	S	I
IR9828-91-2-3	S	I	S	I	I	–	S	R	I	I	R	I
IR9852-22-3	S	R	I	R	I	I	I	R	I	S	I	I
IR10011-16-3	R	–	–	I	–	–	I	R	I	S	R	S
IR10179-2-3-1	I	–	–	R	I	I	S	I	I	S	I	I
IR13146-13-3-3	S	I	I	I	I	–	R	I	I	I	I	I
IR13146-41-3	S	I	S	I	I	I	I	I	I	S	R	S
IR13149-3-2-2	S	I	S	I	I	I	I	I	I	I	R	I
IR13149-19-1	S	I	S	I	I	–	I	I	I	I	R	I
IR13149-23-2	S	I	S	R	I	–	S	I	I	S	I	I
IR13149-71-3-2	S	I	S	I	I	I	I	I	I	S	R	I
IR13240-82-2-3-2-3-1	S	I	S	I	I	I	I	I	I	S	R	I
IR13358-85-1-3	I	S	–	–	I	I	R	R	–	S	R	I
IR13365-253-3-2	I	R	I	R	I	I	I	I	–	S	I	I

Continued on next page

Table 1 (continued)

Variety or line	Disease[a] reaction[b]											
	Bl	LSc	StR	BK	ShB	BS	ShR	NBLS	BLB	RTV	GSV	RSV
IR13419-113-1	S	I	I	I	I	I	I	I	I	S	R	I
IR13423-10-2-3	I	I	I	I	I	I	I	I	I	I	R	I
IR13423-17-1-2-1	S	I	S	I	I	I	I	R	–	S	R	I
IR13426-19-2	I	I	I	I	I	I	I	I	I	S	R	I
IR13427-40-2-3-3-3-3	R	I	I	I	I	I	I	I	I	I	R	I
IR13427-60-1-3-2-2	I	S	S	S	I	I	S	I	I	I	I	I
IR13429-109-2-2-1	I	I	S	I	I	I	I	R	S	S	R	I
IR13429-196-1-2-1-1	I	I	S	I	I	I	I	I	I	I-S	I	I
IR13429-287-3	I	I	S	I	I	I	S	I	I	I	I	S
IR13429-299-2-1-3-1	I	R	S	I	I	I	I	I	I	I	I	I
IR13525-43-2-3-1-3-2	S	I	S	I	I	I	I	I	I	I	I	I
IR13538-48-2-3-2	S	R	S	I	I	I	S	I	I	S	I	I
IR13540-56-3-2-1	S	S	–	–	I	I	R	R	I	I	R	R
IR14632-22-3	S	R	I	I	I	I	I	I	I	S	I	I
IR14753-120-3	S	S	I	I	I	S	I	I	I	S	R	S
IR15314-30-3-1-3	S	I	S	I	I	I	I	I	I	S	I	S
IR15314-43-2-3-3	I	I	S	I	I	I	I	R	I	S	I	I
IR15318-2-2-2-2-2	I	I	–	–	S	I	R	–	I	S	R	I
IR15429-268-1-2-1	R	–	–	I	I	R	I	I	I	S	R	I
IR15496-219-2-3-2	I	R	S	I	–	–	–	–	I	S	I	I
IR15529-256-1	I	–	–	–	I	I	I	R	I	S	–	I
IR17488-2-3-2	I	I	I	I	I	R	R	I	I	S	R	I
IR17494-32-1-1-3-2	S	R	I	I	I	I	I	I	I	S	R	I
IR18189-4-3-1	S	R	I	I	I	–	I	R	I	I	R	I
IR18349-53-1-3-1	S	I	S	R	I	–	R	I	I	I	R	I
IR19660-131-3-3-3-3	S	I	S	I	I	I	R	I	I	I	R	S
IR19661-131-1-3-1-3	I	I	S	I	I	I	I	I	I	S	R	I
IR19661-364-1-2-3	I	R	S	I	S	I	I	I	I	S	R	R
IR19670-206-3-3-3-3	S	R	S	I	S	–	I	I	I	S	R	I
IR19672-140-2-3-2	S	R	–	–	I	I	R	I	I	S	–	I
IR19672-155-2-1-1-3	S	I	S	I	I	–	I	R	I	I	I	I
IR19728-9-3-2-3-3	S	I	S	R	I	I	I	I	–	I	I	I
IR19729-5-1-1-3-2	I	I	I	I	I	I	S	I	I	I	R	I
IR19735-5-2-3-2-1	R	I	–	I	I	I	I	I	I	S	I	I
IR19743-25-2-2-3-1	S	R	S	I	I	I	I	I	I	S	R	I
IR19743-40-3-3-2-3	I	I	I	I	I	I	S	I	I	I	R	I
IR19735-5-2-3-2-1	R	I	–	I	I	I	I	I	I	S	I	I
IR19743-25-2-2-3-1	S	R	S	I	I	I	I	I	I	S	R	I
IR19743-40-3-3-2-3	S	–	S	R	I	I	I	S	I-S	S	R	S
IR19743-46-2-3-3-2	S	–	–	I	I	I	I	S	I	I	R	I
IR19746-28-2-2-3	I	–	–	I	I	I	I	S	I	S	R	I
IR19762-2-3-3	R	–	–	I	I	I	I	I	I	S	R	I
IR19764-23-2-2-1-3	–	–	–	–	I	I	R	R	–	I	R	I
IR19774-23-2-2-1-3	I	–	–	I	I	–	S	R	I	S	R	I
IR19791-12-1-2-2-2	I	–	–	I	I	I	I	S	I	S	I	I
IR19819-31-2-3	R	–	–	R	I	–	S	I	I	S	I	I
IR19819-31-2-3-1-1	S	–	–	–	I	I	I	R	I	I	–	I
IR21912-131-3-3	I	I	I	R	I	I	S	I	I	S	R	I
IR22082-41-2	S	R	I	I	I	–	I	I	I	I	R	I
IR25588-32-2	S	S	S	I	I	–	S	R	I	R	R	I

[a]Bl = blast, LSc = leaf scald, StR = stem rot, BK = bakanae, ShB = sheath blight, BS = brown spot, ShR = sheath rot, NBLS = narrow brown leaf spot, BLB = bacterial leaf blight (PX061), RTV = rice tungro virus, GSV = grassy stunt virus, RSV = ragged stunt virus. [b]R = resistant, I = intermediate, S = susceptible.

their ability to transmit the tungro virus and for their life span on IR34 and TN1 seedlings. Another colony maintained simultaneously on TN1 served as control.

Infective IR34-reared insects tested on IR34 seedlings gradually increased from 35% on the first generation to 88% on the ninth. The TN1-reared insects had consistently less than 40% infectivity

Table 2. Resistance of GEU elite lines and IR varieties to 6 fungal diseases of rice. IRRI, 1981.

Disease	Entries (no.) rated						Total tested	
	Resistant		Intermediate		Susceptible			
	No.	%	No.	%	No.	%	No.	%
Bakanae	118	52.7	89	39.7	17	7.6	224	100
Leaf scald	33	24.6	63	47.0	38	28.4	134	100
Stem rot	0	0	19	24.7	58	75.3	77	100
Sheath blight	0	0	99	0	1	1.0	100	100
Brown spot	3	3.6	77	91.6	4	4.8	84	100
Narrow brown spot	38	37.2	58	56.9	6	5.9	102	100
Sheath rot	3	3.6	76	91.6	4	4.8	83	100

Table 3. Screening for blast resistance. IRRI, 1981.

Source	Entries (no.) rated			Total entries tested
	Resistant (0-2)	Intermediate (3-4)	Susceptible (5-9)	
Hybridization block	62	28	210	300
Elite breeding lines[a]	78	62	251	391
Observational yield trial[a]	38	46	1,181	1,265
Replicated yield trial[a]	18	8	1,029	1,055
Korean lines	942	1,460	4,069	6,471
Drought tolerant materials	215	161	396	772
Germplasm bank[a]	461	332	814	1,607
Pedigree nursery lines	7,639	11,521	42,588	61,748
IRTP[b]	61	71	455	587
International nurseries				
IRBN[a]	226	72	200	498
IRYN-VE, V&M	8	8	54	70
IRON	25	17	203	245
IURYN	9	5	11	25
IRLRON-E&L	14	19	99	132
IRLRYN	1	2	17	20
IURON	21	11	36	68
IRBPHN	14	3	118	135
IRCTN	24	19	66	109
Total	9,856	13,845	51,797	75,498
Percent	13.5	18.3	68.6	100

[a]Tested 2-3 times. [b]International Rice Testing Program.

(Fig. 1). When tested on TN1 seedlings, colonies of infective insects of IR34 averaged 85% and those of TN1, 87%.

Consequently, tungro infection by IR34-reared insects on IR34 seedlings increased from 12% to 35% within 9 generations. However, TN1-reared insects caused consistently lower (11.3% average) tungro infection on IR34 seedlings. TN1 seedlings infected by IR34-reared insects averaged 35% and those by TN1-reared insects, 36%.

Life span of IR34-reared insects gradually increased from 4 to 10 days within 9 generations, whereas that of TN1-reared insects when tested on IR34 remained consistently shorter than 5 days. On TN1 seedlings, both the life spans of TN1- and IR34-reared insects averaged 10 days.

These results indicate that the resistance of IR34 to tungro is influenced by its resistance to the vector and that the resistance of a variety to tungro may change when its resistance is only due to the vector.

SOURCES OF RESISTANCE

Blast tests. Selected breeding lines and their resistance donors were tested in the International Rice

Table 4. Sheath blight screening tests, 1981.

Source	Entries tested (no.)	Entries (no.) rated		
		Resistant	Intermediate	Susceptible
Elite breeding lines	158	0	150	8
Lowland:				
Replicated yield trial	1,024	0	823	201
Observational yield trial	1,066	0	1,001	65
Upland:				
Replicated yield trial	110	0	110	0
Observational yield trial	1,016	0	1,011	5
Hybridization block	688	0	656	32
Hybrid rice	40	0	35	5
Lines from IRTP	85	0	85	0
Germplasm bank	1,327	0	1,285	42
Confirmatory tests				
Elite breeding lines	10	0	10	0
Replicated yield trial	10	0	10	0
Observational yield trial	10	0	10	0
Hybridization block	43	0	43	0
Germplasm bank	9	0	9	0
Upland replicated yield trial	20	0	15	5
Total	5,616	0	5,253	363
%		0	93.5	6.4

Table 5. Wild taxa resistant to rice ragged stunt.

Species	IRRI accession no.
Oryza alta	100967, 101395
Oryza australiensis	101144
Oryza brachyantha	101231, 101232, 101233, 101234, 101235, 101236
Oryza grandiglumis	101405
Oryza latifolia	100962, 100963, 100964, 100966
Oryza malampuzhiensis	100957
Oryza minuta	101081, 101082, 101101, 101123, 101125, 101386, 101387
Oryza officinalis	101114, 101115, 101116, 101121, 101154, 101166, 101399, 101412, 101414, 102125, 102126
Oryza perennis	100582, 103313
Oryza punctata	101408, 101409, 101439
Oryza ridleyi	101453

Blast Nursery (IRBN) from 1975 to 1981. Average ($\bar{X}$) disease reactions were computed using the formula:

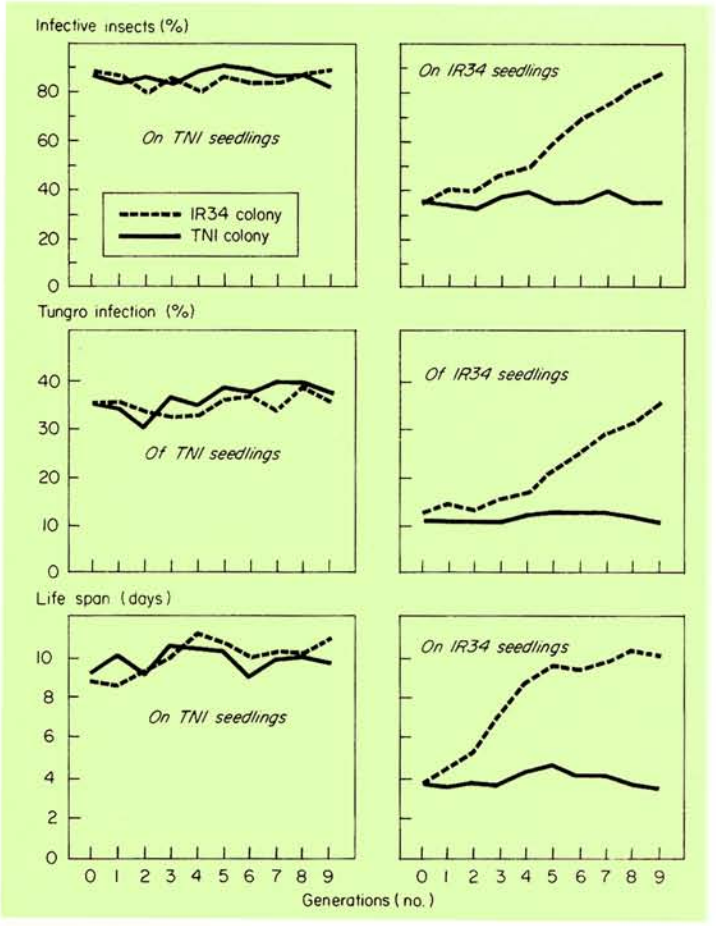
$$\bar{X} = \frac{0(N_0) + 1(N_1) + 2(N_2) + 3(N_3) + 4(N_4) + 5(N_5) + 6(N_6) + 7(N_7) + 8(N_8) + 9(N_9)}{T_N}$$

where N_0 is the number of tests with a score of 0, N_0 is the number of tests with a score of 1, etc. T_N is the total number of tests. The lower the average disease reaction of a line, the higher its resistance. Most of the breeding lines outranked their donor parents in resistance to blast (Table 6).

Inheritance of resistance to bakanae. In a study of the inheritance of resistance to three races of *Gibberella fujikuroi* (Saw.) Ito, progenies of six crosses of IR32, IR44, IR46, IR50, IR7790-18-1-2, and IR9703-41-3-3-1 were inoculated separately with pathogenic races FA-1, FH-1, and FI-1. The seeds were soaked in a spore suspension of the fungus.

The F_1 plants of crosses of resistant and susceptible parents were resistant to the disease, indicating that resistance was dominant. Resistance in IR44/IR50 to races FI-1, FH-1, and FA-1 was apparently controlled by the same duplicating genes (Table 7). In IR44/IR7790-18-1-2, resistance to race FI-1 was governed by duplicating genes, resistance to races FH-1 and FA-1 by a single dominant gene. In IR32/IR44, a single dominant gene controlled resistance to races FI-1, FH-1, and FA-1. In IR44/IR7790-18-1-2, two duplicating genes controlled resistance to FI-1.

Resistance in crosses of IR46 and different susceptible parents varied, depending on the combinations and race used. In IR50/IR9703-41-3-3-1, segregation of F_2 progeny indicated the presence of inhibitory or suppressor genes to races FI-1 and



1. Percentage of infective insects and seedling infection by and life span of tungro-viruliferous *Nephotettix virescens* reared on either TN1 or IR34 plants for 9 generations. IRRI, 1981.

FH-1 and of a single gene to race FA-1.

Inheritance of resistance to blast. To determine the inheritance of resistance to 7 isolates of *Pyricularia oryzae* Cav., seedlings of 15 cross combinations of varieties and breeding lines were inoculated by the injection method.

Inheritance of resistance to blast differed among parents resistant to the same isolate and within parents resistant to different isolates (Table 8). Resistance in IR1905-81-3-1, IR3259-PP5-160-1, and IR3259-PP8-172-7 to races ID-16, IH-1, and II-1 appeared to be controlled by a single dominant gene for each race, but the resistance of IR3259-PP8-172-1 to ID-15 and ID-16 is governed by two complementary genes. The three breeding lines exhibited the existence of two complementary genes for resistance to races IB-45 and ID-15.

F_2 progenies of crosses of resistant parents IR1905-81-3-1, IR3259-PP5-160-1, and IR3259-PP8-172-7 showed that these three parents have the same resistance genes or allelic genes to races IB-45, ID-15, IH-1, and II-1. Resistance in IR3259-PP8-172-7 to race ID-16 showed that it is controlled by two complementary genes. All three breeding lines were susceptible to race IC-2.

Pai-kan-tao was resistant to races IH-1 and II-2. Two complementary genes conferred resistance to race IH-1; duplicate genes controlled resistance to race II-2. There was no allelic relationship between the resistance in Pai-kan-tao and resistant breeding lines IR1905-81-3-1, IR3259-PP5-160-1, and IR3259-PP8-172-7. In crosses of these three resistant breeding lines with Pai-kan-tao, F_2 progenies showed the presence of a suppressor gene against

Table 6. Blast resistance of selected breeding lines, resistance donors and other varieties in International Rice Blast Nursery (IRBN) tests, 1975-1981.

Line	Donor	Tests (no.)	Frequency (%) reaction was rated[a]										Av disease reaction
			0	1	2	3	4	5	6	7	8	9	
IR1905-81-3-1	Tetep	117	10	66	23	11	4	1	1	0	1	0	1.538
IR1905-PP11-29-4-61	Tetep	123	5	67	26	12	8	1	1	3	0	0	1.781
IR1905-PP19-73-2	Tetep	78	5	43	15	8	4	2	0	1	0	0	1.667
IR1905-1-3-3	Dawn	62	0	32	16	7	3	3	1	0	0	0	1.903
IR3259-PP5-160-1	Tetep	51	4	26	12	5	1	3	0	0	1	0	1.804
IR3259-PP11-182-4	Tetep	39	5	22	5	5	0	1	0	0	0	1	1.564
IR3259-PP18-821-2	Tetep	76	4	43	13	10	5	0	0	0	1	0	1.671
IR3271-760-1482	PK203, Dawn	76	4	33	16	13	7	0	2	0	0	1	2.013
IR3273-289-2-1473	PK203	112	4	41	25	13	21	5	2	0	1	0	2.313
IR3273-342-1-6	PK203	80	5	41	15	8	9	1	0	0	1	0	1.800
IR4472-53-10-8-1-2	Dawn	24	0	15	4	3	1	1	0	0	0	0	1.708
IR4547-6-1-3	Tetep, PK203, *O. nivara*	76	4	35	12	7	14	3	0	0	1	0	2.092
IR4547-6-2-4	Tetep, PK203, *O. nivara*	76	4	41	13	7	8	1	0	1	0	1	1.855
IR4547-6-2-5	Tetep, PK203, *O. nivara*	132	9	63	26	15	5	6	6	0	1	1	1.992
IR4547-6-2-6	Tetep, PK203, *O. nivara*	86	5	50	13	8	10	0	0	0	0	1	1.733
IR4547-6-3-2	Tetep, PK203, *O. nivara*	125	8	61	27	17	7	3	1	0	0	1	1.792
IR4547-14-3-1	Tetep, PK203 *O. nivara*	92	4	26	24	8	7	0	1	2	0	0	1.804
IR4547-16-3-2	Tetep, PK203, *O. nivara*	79	4	41	15	5	9	3	0	2	0	0	1.911
IR4547-16-3-4	Tetep, PK203, *O. nivara*	59	0	37	12	5	4	1	0	0	0	0	1.644
IR4547-16-3-7	Tetep, PK203, *O. nivara*	63	0	33	15	7	6	2	0	0	0	0	1.873
IR4547-10180-20-7	Tetep, PK203, *O. nivara*	123	7	50	23	18	11	9	4	0	0	1	2.211
IR5533-13-1-1	Tetep, Carreon	91	5	45	21	13	3	4	0	0	0	0	1.736
IR5533-15-1-1	Tetep, Carreon	91	4	41	25	12	5	1	0	3	0	0	1.901
IR5533-15-1-11	Tetep, Carreon	79	5	43	14	11	3	3	0	0	0	0	1.658
IR5533-56-1-12	Tetep, Carreon	136	9	68	30	10	10	5	2	2	0	0	1.831
IR5533-PP854-1	Tetep, Carreon	120	12	65	24	10	5	0	2	2	0	0	1.575
IR5533-PP855-1	Tetep, Carreon	79	4	44	18	7	2	1	2	1	0	0	1.684
IR5533-PP856-1	Tetep, Carreon	92	9	47	18	13	2	0	1	1	1	0	1.641
IR9559-3-1-1	Tetep, Carreon	79	1	32	15	13	10	5	2	1	0	0	2.342
IR9559-4-1-1	Tetep, Carreon	79	2	43	16	9	5	2	1	0	0	1	1.861
IR9559-PP870-1	Tetep, Carreon	112	2	57	23	17	6	3	1	2	1	0	1.973
IR9660-50-3-1-1	Dawn, Kataktara DA-2	78	4	46	14	6	4	1	0	1	1	0	1.641
IR9660-00951-1	Dawn, Kataktara DA-2	40	4	23	6	2	2	2	0	0	1	0	1.675
IR9669-PP830-1	Carreon	40	4	19	8	5	2	2	0	0	0	0	1.708
IR9669-PP836-1	Carreon	77	4	43	15	8	3	2	1	0	0	1	1.740
IR9669-PP846-1	Carreon	112	7	50	23	19	8	3	1	1	0	0	1.902
B-40		141	1	0	5	2	12	19	35	35	15	17	6.291
Carreon		151	8	64	48	14	8	5	2	2	0	0	1.914
Dawn		119	7	36	26	22	9	6	6	4	0	3	2.613
Fanny		93	0	2	1	3	2	5	3	5	11	61	7.914
Kataktara DA-2		138	8	29	22	28	22	13	7	5	1	3	3.058
KTH-17		144	3	12	15	18	11	24	6	15	13	27	5.194
Kung-shan-wu-shen-ken		32	1	1	0	2	0	2	0	6	3	17	7.375
Taichung T.C.W.C.		98	0	1	1	12	6	9	21	11	19	19	6.378
Tetep		136	11	70	30	13	4	4	1	3	0	0	1.706

[a] On a scale of 1-9: 1.0-3.0 = resistant, 3.1-9.0 = susceptible.

Table 7. F_2 segregation of 6 crosses in response to 3 races of *G. fujikuroi* Saw. IRRI, 1981.

Cross combination	Segregation ratio[a]		
	FI-1	FH-1	FA-1
IR44/IR50	R/R	R/MR	R/R
	15:1	15:1	15:1
IR44/IR7790-18-1-2	R/R	R/S	R/S
	15:1	3:1	3:1
IR32/IR44	S/R	S/R	S/R
	3:1	3:1	3:1
IR46/IR9846-215-3-1	R/R	R/S	R/S
	15:1	13:3	9:7
IR50/IR9703-41-3-3-1	R/S	MR/S	R/S
	13:3	13:3	3:1
IR46/IR9703-41-3-3-1	R/MR	R/S	R/S
	15:1	3:1	3:1

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

race II-1. This inhibited the expression of the dominant resistance gene possessed by IR1905-81-3-1, IR3259-PP5-160-1, and IR3259-PP8-172-7.

The genes for resistance to races IB-45, ID-15, ID-16, IH-1 (isolate PO7-10 and 43), and II-1 of *P. oryzae*, detected in IR3259-PP8-172-7 when it was crossed with susceptible IR442-2-58, segregated independently in the F_2. The genes controlling resistance to IH-1 (isolate P07-10) and II-1, however, appeared to be linked.

The genes for resistance to races IB-45, ID-16, IH-1 (isolates PO7-10 and 43), and II-1 identified in IR1905-81-3-1/IR442-2-58 also showed independent segregation in the F_2 except for those genes responsible for resistance to races IH-1 (iso-

Table 8. F_2 segregation of 15 crosses in response to 7 isolates of *P. oryzae* grouped into 6 international races. IRRI, 1981.

Cross	F_2 segregation ratio[a]					
	IB-45	IC-2	ID-15	ID-16	IH-1[b]	II-1
IR1905-81-3-1/IR3259-PP5-160-1	R/R	S/S	R/R	R/R	R/R	R/R
	1:0	0:1	1:0	1:0	1:0	1:0
IR1905-81-3-1/IR3259-PP8-172-7	R/R	S/S		R/R	R/R	R/R
	1:0	0:1	[c]	57:7	1:0	1:0
IR1905-81-3-1/Pai-kan-tao	R/S	S/S		R/S	R/R	R/R
	45:19	0:1	[c]	3:1	57:7	61:3
IR1905-81-3-1/IR442-2-58	R/S	S/S		R/S	R/S	R/S
	9:7	0:1	[c]	3:1	3:1	3:1
IR1905-81-3-1/IR8	R/S	S/S		R/S	R/S	R/S
	9:7	0:1	[c]	3:1	3:1	3:1
IR3259-PP8-172-7/IR3259-PP5-160-1	R/R	S/S	R/R	R/R	R/R	R/R
	1:0	0:1	1:0	57:7	1:0	1:0
IR3259-PP8-172-7/Pai-kan-tao	R/S	S/S	R/S	R/S	R/R	R/R
	45:19	0:1	9:7	9:7	57:7	61:3
IR3259-PP8-172-7/IR442-2-58	R/S	S/S	R/S	R/S	R/S	R/S
	9:7	0:1	9:7	9:7	3:1	3:1
IR3259-PP8-172-7/IR8	R/S	S/S	R/S	R/S	R/S	R/S
	9:7	0:1	9:7	9:7	3:1	3:1
IR3259-PP8-172-7/Peta	R/S	S/S	R/S	R/S	R/S	R/S
	9:7	0:1	9:7	9:7	3:1	3:1
IR3259-PP5-160-1/Pai-kan-tao	R/S	S/S	R/S	R/S	R/R	R/R
	45:19	0:1	9:7	3:1	57:7	61:3
Pai-kan-tao/IR442-2-58	S/S	S/S	S/S	S/S	R/S	R/S
	0:1	0:1	0:1	0:1	9:7	15:1
Pai-kan-tao/Peta	S/S	S/S	S/S	S/S	R/S	R/S
	0:1	0:1	0:1	0:1	9:7	15:1
IR442-2-58/Peta	S/S	S/S	S/S	S/S	S/S	S/S
	0:1	0:1	0:1	0:1	0:1	0:1
Peta/Nongbaek	S/S	S/S	S/S	S/S	S/S	S/S
	0:1	0:1	0:1	0:1	0:1	0:1

[a]R = resistant, S = susceptible. [b]Isolates 43 and PO7-10 were differentiated in the same race based on the international set of differentials. Both isolates showed similar segregation ratio in the F_2, but they appear to have different genes for pathogenecity; therefore, different genes in the parents control resistance. [c]These crosses were not studied.

late PO7-10) and II-1. Genes for resistance to race ID-15 in IR1905-81-3-1 may segregate independently because this line and IR3259-PP8-172-7 apparently have allelic genes to race ID-15.

In another experiment, susceptible entry 55061 was crossed with resistant breeding lines IR1905-81-3-1, IR5533-PP854-1, and IR4547-4-4-1-2, and Milyang 23 was crossed with IR9669-PP836-1. All the breeding lines were resistant to races IB-45, IC-2, and ID-16, except that IR1905-81-3-1 was susceptible to race IC-2 (Table 9).

Through the injection method, F_2 plants of four cross combinations were separately inoculated with the three races. The F_1 populations of 55061/IR1905-81-3-1 had a segregation ratio of 3 resistant to 1 susceptible to races IB-45 and ID-16. The F_2 progeny of 55061/IR5533-PP854-1 had a 13:3 ratio to races IB-45, IC-2, and ID-16. The F_2 progenies of 55061/IR4547-4-1-2 had a 3:1 ratio to race IC-2 and a 9:7 ratio to race ID-16. The F_2 populations of Milyang 23/IR9669-P836-1 had a 3:1 ratio to race IB-45 and a 15:1 ratio to race ID-16. These results suggest that resistance to various races is conveyed by different genes in the different resistant lines.

Inheritance of resistance to brown spot. In a study to determine inheritance of resistance to isolates Ho-22 and Ho-2 of *Helminthosporium oryzae* in 9 crosses, 30-day-old seedlings were separately inoculated by the injection method with the 2 isolates. The F_1 populations of Sekiguchi Asahi/IR36, IR36/IR14753-120-3, IR9763-11-2-2/IR36, IR9846-215-3/IR36, IR9764-45-2-2/IR36, IR9763-11-2-2-2/IR14753-120-3, IR9764-45-2-2/IR14753-120-3, IR9264-321-3/Sekiguchi Asahi, and IR9264-321-3/IR9846-215-3 were all resistant to isolate Ho-22.

The F_2 progeny of IR9846-215-3/IR36 and IR9764-45-2-2/IR36 segregated into a 3:1 ratio of resistant to susceptible plants for isolate Ho-22, suggesting that resistance is governed by a single dominant gene (Table 10). The segregation of F_2 populations of S. Asahi/IR36 and IR9264-321-3/S. Asahi crosses had a 9:7 ratio of resistant to susceptible plants, indicating that resistance is controlled by two complementary genes. F_2 progeny of other crosses segregated into a 13:3 ratio of resistant to susceptible plants, indicating the presence of inhibitory genes. The F_2 progenies of resistant parents IR36 and IR14753-120-3 were all resistant.

Results also indicated that resistance to brown spot disease can be inherited. All the F_1 and F_2 populations of all crosses were susceptible to isolate Ho-2.

Inheritance of resistance to leaf scald. In a study to determine the mode of inheritance of resistance to leaf scald, an isolate of *Rhynchosporium oryzae* was inoculated, by the clipping method, to plants of 6 cross combinations of rice varieties 45 days after seeding in the greenhouse.

The F_1 population of the cross between resistant

Table 9. F_2 segregation of some crosses between susceptible and resistant parents from different sources in response to 3 races of *P. oryzae*. IRRI, 1981.

Cross	Segregation ratio[a]		
	IB-45	IC-2	ID-16
55061/IR1905-81-3-1	S/R	–	S/R
	3:1	–	3:1
55061/IR5533-PP854-1	S/R	S/R	S/R
	13:3	13:3	13:3
55061/IR4547-4-1-2	–	S/R	S/R
	–	3:1	9:7
Milyang 23/IR9669-PP836-1	S/R	–	S/R
	3:1	–	15:1

[a]R = resistant, S = susceptible

Table 10. F_2 segregation of 9 crosses in response to 2 isolates of *Helminthosporium oryzae*. IRRI, 1981.

Cross	F_2 segregation ratio[a] to	
	Ho-2	Ho-22
Sekiguchi Asahi (S)/IR36	S/S	S/R
	0:1	9:7
IR36/IR14753-120-3	S/S	R/S
	0:1	1:0
IR9763-11-2-2/IR36	S/S	S/R
	0:1	13:3
IR9846-215-3/IR36	S/S	S/R
	0:1	3:1
IR9764-45-2-2/IR36	S/S	S/R
	0:1	3:1
IR9763-11-2-2-2/IR14753-120-3	S/S	S/R
	0:1	13:3
IR9764-45-2-2/IR14753-120-3	S/S	S/R
	0:1	
IR9264-321-3/Sekiguchi Asahi	S/S	R/S
	0:1	9:7
IR9264-321-3/IR9846-215-3	S/S	R/S
	0:1	13:3

[a]R = resistant, S = susceptible.

varieties and susceptible IR36 showed resistant reactions, indicating that resistance is dominant. Progenies of cross combinations between resistant varieties Suntang Biringin, Melot, Tjele, and Montje Wowo and susceptible variety IR36 segregated into a Mendelian ratio of 3 resistant to 1 susceptible, suggesting the presence of a single dominant gene for resistance (Table 11). All plants in the F_2 population of crosses among susceptible parents IR36, Kolai, and Rama were susceptible.

PATHOGENIC VARIABILITY

Races of *Pyricularia oryzae*. Two sets of blast differentials were used to determine the pathogenic races and the frequency of their occurrence at IRRI. Forty-nine isolates were inoculated to the two sets of differential varieties and the races classified according to the reactions of the varieties. Six races were categorized (Table 12). The most prevalent race was IH-1, with 39 (79.6%) isolates, followed by IG-1, 4(8.2%), and II-1, 3 (6.1%). Races IA-127, IC-19, and IG-2 had one isolate each.

Nine races were classified according to the reactions of new Japanese differentials (Table 13). Races 002 (24.5%), 403 (20.4%), and 007 (16.4%) predominated. Race 003 (12.3%) ranked fourth and races 006 (10.2%) and 407 (10.2%), fifth in frequency of occurrence. Varieties Fukunishiki, Yashiro-mochi, and Pi No. 4 showed resistant reactions to all races identified.

Variability of some *Helminthosporium oryzae* **isolates.** In preliminary tests on the pathogenic variability of 50 isolates of *Helminthosporium oryzae* from 8 Philippine provinces, cultivars from the germplasm collections and elite breeding lines were grown in plastic trays containing fertile soil in the greenhouse. Four weeks after seeding, 20 isolates (spore density 40,000 — 45,000/ml) were inoculated separately.

Inoculated plants were left inside the inoculation chambers for at least 24 hours, then transferred to greenhouse benches for symptom development. Ten days after inoculation, test plants were evaluated for disease reaction.

Initial results indicated marked variation in reactions of the test varieties as well as variations in pathogenicity among the isolates (Table 14). Further tests are being conducted to select varieties that can be used as a tentative set of differentials for race grouping.

Variability of *Xanthomonas campestris* pv. *oryzae. Homogeneity and heterogeneity strains.* The variation of 70 Philippine *Xanthomonas campestris* pv. *oryzae* strains belonging to 2 races, all virulent to IR8, was evaluated on the basis of lesion production in IR8, IR20, and IR1545. Homogeneous groups of each race were based on length of lesions caused by the strains of each race on the test varieties.

There was significant interaction between strains and cultivars. Based on the reactions of the three cultivars, the virulence of the strains of each race varied. On IR8, the strains were sorted into two groups each on race I (Fig. 2C, D) and race II (Fig.

Table 11. F_2 segregation of 6 crosses in response to an isolate of *Rhynchosporium oryzae*. IRRI, 1981.

Cross[a]	Segregation ratio	X^2	P
IR36 (S)/Suntang Biringin (R)	3:1	0.0048	95-90
IR36 (S)/Melot (R)	3:1	1.4032	30-20
IR36 (S)/Tjele (R)	3:1	0.8728	50-30
IR36 (S)/Montje Wowo (R)	3:1	0.03516	80-70
IR36 (S)/Kolai (S)	0:1	–	–
IR36 (S)/Rama (S)	0:1	–	–

[a]S = susceptible, R = resistant.

Table 12. Occurrence of *Pyricularia oryzae* races on international differential varieties at IRRI, 1981.

Race	Isolates		Reaction[a]							
	No.	Frequency (%)	Raminad Strain 3	Zenith	NP-125	Usen	Dular	Kanto 51	Sha-tiao-tsao	Caloro
IA-127	1	2.0	S	R	R	R	R	R	R	S
IC-19	1	2.0	R	R	S	R	S	S	R	S
IG-1	4	8.2	R	R	R	R	R	R	S	S
IG-2	1	2.0	R	R	R	R	R	R	S	R
IH-1	39	79.6	R	R	R	R	R	R	R	S
II-1	3	6.1	R	R	R	R	R	R	R	R

[a]R = resistant, S = susceptible.

Table 13. Occurrence of *Pyricularia oryzae* races on new Japanese differential varieties at IRRI, 1981.

Race	Isolates		Reaction[a]								
	No.	Frequency (%)	Shin 2 *(Pi-k)*	Aichi-asahi *(Pi-a)*	Ishikare-shiroke *(Pi-i)*	Kanto 51 *(Pi-k)*	Tsuyuake *(Pi-m)*	Fukunishi *(Pi-z)*	Yashiro mochi *(Pi-ta)*	Pi No. 4 *(Pi-ta²)*	Toride 1 *(Pi-z¹)*
002	12	24.5	R	S	R	R	R	R	R	R	R
003	6	12.3	S	S	R	R	R	R	R	R	R
006	5	10.2	R	S	S	R	R	R	R	R	R
007	8	16.4	S	S	S	R	R	R	R	R	R
037	1	2.0	S	S	S	S	S	R	R	R	R
402	1	2.0	R	S	R	R	R	R	R	R	S
403	10	20.4	S	S	R	R	R	R	R	R	S
406	1	2.0	R	S	S	R	R	R	R	R	S
407	5	10.2	S	S	S	R	R	R	R	R	S

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

4A, B). Unrelated variance groups of the strains were observed on IR20 (Fig. 3, 4) and IR1545 (Fig. 2A, B; 4C, D).

This suggests that the virulence of each strain was very distinct on the cultivars, indicating race differentiation. Variance groups of race-I strains, less virulent to IR20, were more homogeneous than those that were avirulent to the same variety (Fig. 3A, B). However, IR20-virulent strains were more variable (Fig. 3C, D). On IR1545, all strains seemed less variable because races I and II strains were avirulent to this variety.

Virulence of field population. In the study of the virulence of field population of *Xanthomonas campestris* pv. *oryzae*, isolates differed in virulence regardless of test variety or year (Fig. 5). The isolates were classifield into three of the four race groups. However, for 3 years, most of the isolates at IRRI have resembled, in virulence, race group II. The determination of predominantly virulent isolates would provide a basis for selecting varieties with resistance genes.

Isolates from Isabela and IRRI. Fifty isolates, 25 collected from Isabela in 1974 and 25 from IRRI in 1980, were evaluated for virulence on the basis of reactions of 4 IRRI differential varieties. The isolates were classified by the patterns of reaction in the varieties.

Of the Isabela isolates, 4% caused reaction pattern 1 (all 4 varieties were susceptible); 56%, reaction pattern 2; 16%, reaction pattern 3; and 24%, reaction pattern 4 (Table 15). Similarly, 4% of the IRRI isolates caused reaction pattern 1; 56%, reaction pattern 2; 36%, reaction pattern 4; and 5%, reaction pattern 5 (all 4 varieties resistant).

The majority of the Isabela isolates were grouped under reaction pattern 2, and most of the IRRI isolates, under reaction pattern 3. These two groups represent the predominant virulence of the field population at each location.

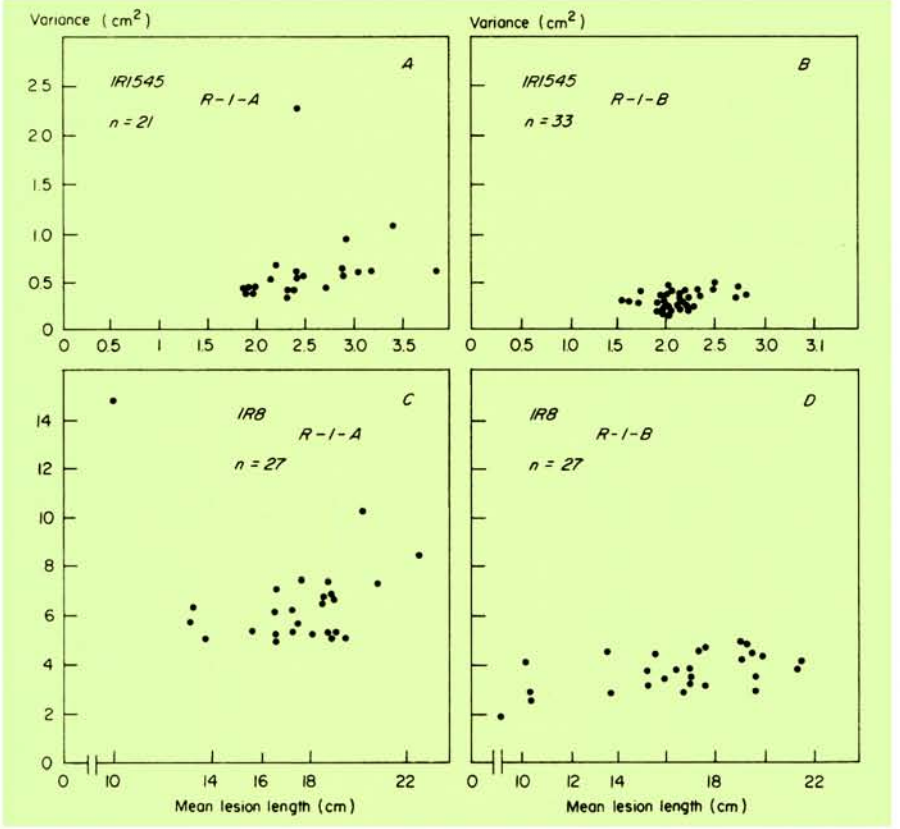
INTERNATIONAL COLLABORATIVE RESEARCH PROJECT

IRRI-Tropical Agriculture Research Center. *Race group of* **Xanthomonas campestris** *pv.* **oryzae** *in Indonesia and Bangladesh.* Isolates from Indonesia and Bangladesh were inoculated on 10 differential cultivars of Japan and IRRI to determine their

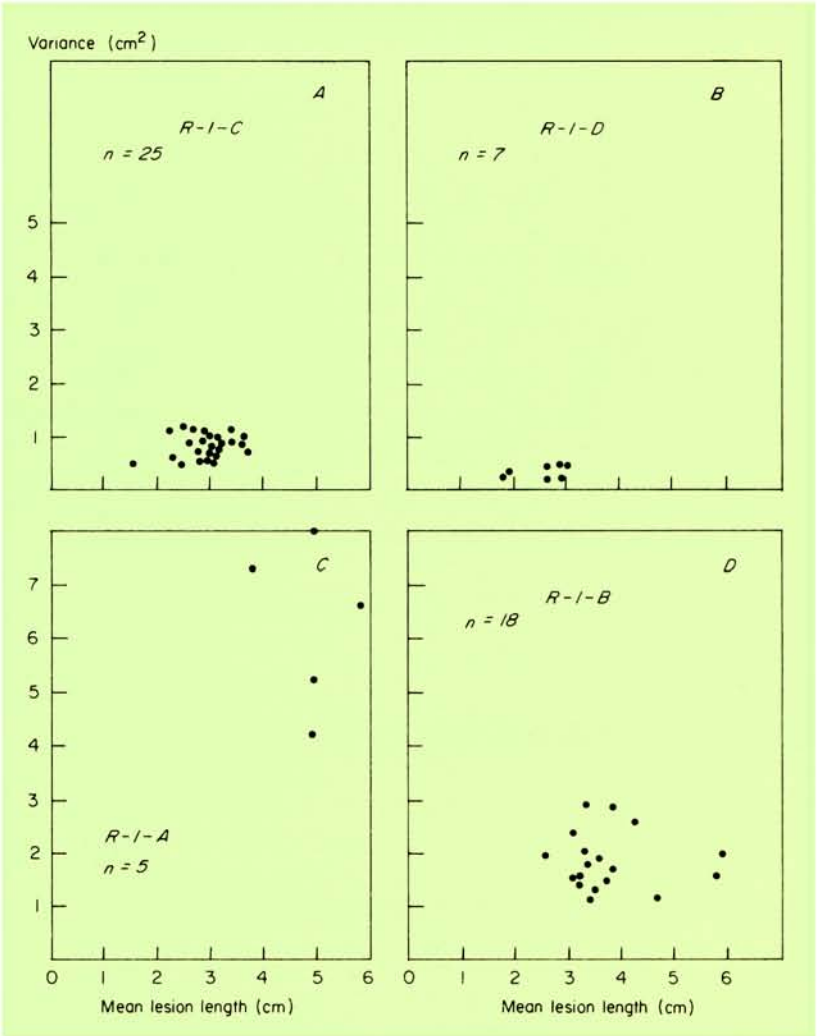
Table 14. Reactions to 20 isolates of *Helminthosporium oryzae* of 7 selected rice varieties from the germplasm collection. IRRI, 1981.

Isolate number	Reaction[a]						
	Kanto	Asahi	Norin 12	Eratio	Utri meah	Blue Rose	Kencana
1	R	R	R	R	R	S	S
2	R	R	R	R	R	R	S
3	S	S	S	R	S	S	S
4	R	S	I	S	S	S	S
5	R	R	R	R	R	R	S
6	S	R	R	S	S	R	S
8	R	R	R	R	S	R	S
9	R	R	I	R	R	S	S
11	R	R	R	R	I	R	S
12	R	R	R	R	R	R	R
13	R	S	R	S	S	R	S
15	R	R	R	I	S	I	S
16	–	R	R	S	S	S	S
17	R	R	R	R	S	R	R
18	R	R	R	R	R	R	S
19	R	R	R	R	S	I	S
20	R	R	S	S	S	S	S
21	S	I	S	S	S	S	S
22	R	S	S	S	S	S	S
23	R	R	R	R	R	R	R

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



2. Virulence variation of *Xanthomonas campestris* pv. *oryzae* race 1 isolates on 2 rice cultivars differing in resistance. IRRI, 1981.



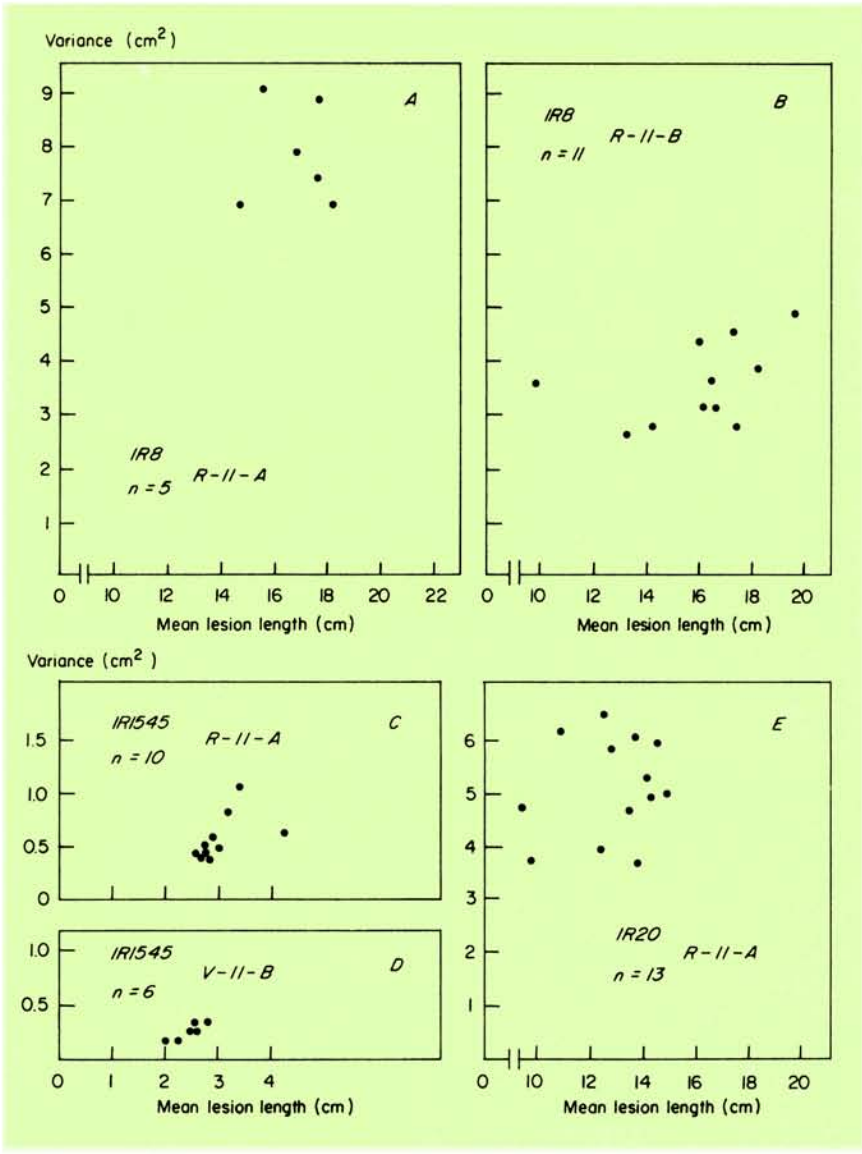
3. Virulence variation of *Xanthomonas campestris* pv. *oryzae* race 1 strains on IR20. IRRI, 1981.

race group or pattern. The isolates from Indonesia were classified into eight race groups (Table 16). Of the 40 isolates tested, 65.0% were categorized in group A (corresponding to Philippine race III), 17.5% in Group B (Philippine race I), and 5.0% in Group C (Philippine race IV).

The 20 isolates from Bangladesh showed a different race pattern from that of isolates from Indonesia and were classified into 16 race patterns. Of the 20 isolates tested, 20% were in race group L and 10% in race group R. One isolate from each country was classified into different race groups.

The virulence of the different isolates was determined on the 10 IRRI differential varieties. Virulence indices ranged from 1.3 to 5.8. Six Indonesian isolates had a virulence index of 5.2; only 1 isolate from Bangladesh did. One isolate from Bangladesh had a 5.8 virulence index. These results suggest that Bangladesh isolates are more virulent than Indonesian isolates. Among the Bangladesh isolates, 14 showed variable results that need confirmation.

Susceptibility indices of the Japanese and Philippine differential varieties were computed against Indonesia and Bangladesh isolates. The varieties differed in susceptibility to the isolates. Varieties Tetep and Kogyoku were susceptible to Indonesian isolates but highly resistant to Bangladesh isolates. Wase Aikoku, IR20, and Java 14 were highly resistant to the isolates tested. Cas 209 was the most

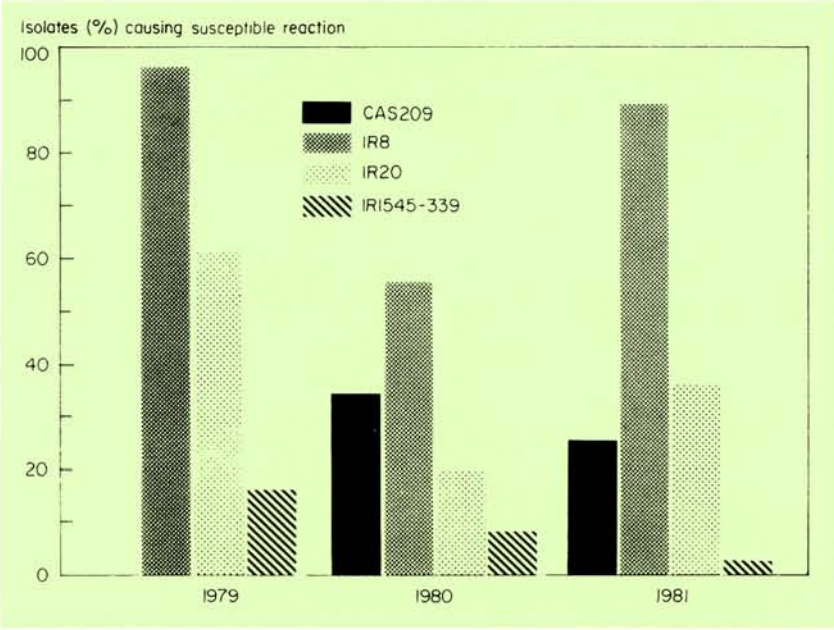


4. Variation of *Xanthomonas campestris* pv. *oryzae* race 2 strains on 3 rice cultivars differing in resistance. IRRI, 1981.

susceptible variety.

IRRI-Chinese Academy of Agricultural Sciences. The International set of differentials (the IRRI and the Japanese sets) for the International Bacterial Blight Collaborative Research Project and the Chinese set of differentials were used separately to evaluate the virulence of the South China pathotypes at Guangdong and that of the Philippine races at IRRI. From the reactions of the IRRI and the Japanese differential varieties, five representative South China pathotypes appear to be similar to pathotypes of the Philippine races, except that Kogyoku, a variety susceptible to the four Philippine races, is resistant to South China pathotypes I and II (Table 17). Cas 209 was susceptible to all of the South China pathotypes, but was resistant to Philippine race II.

Although the South China pv. *oryzae* isolates from Guangdong were identified and classified into five pathotypes, these isolates could be grouped as only three pathotypes when their virulence is compared with isolates in the Philippine races.



5. Frequency distribution for 3 years at IRRI farm of *Xanthomonas campestris* pv. *oryzae* field population (isolates) with specific virulence to differential varieties. IRRI, 1981.

Table 15. Reactions of 4 Philippine differential varieties to *Xanthomonas campestris* pv. *oryzae* isolates collected from Isabela and IRRI.

Reaction pattern	Virulence index	Frequency (%)	Reaction[a]			
			IR8	IR20	Cas 209	IR1545-339
			Isabela isolates			
1	7.0	4.0	S	S	S	S
2	5.5	56.0	S	S	S	R
3	4.0	16.0	S	S	R	R
4	4.0	24.0	S	R	S	R
5	–	–	–	–	–	–
			IRRI isolates			
1	7.0	4.0	S	S	S	S
2	–	–	–	–	–	–
3	4.0	56.0	S	S	R	R
4	4.0	36.0	S	R	S	R
5	1.0	4.0	R	R	R	R

[a]Based on a rating scale of 1-9: 1.0-3.0 = R (resistant), 3.1-9.0 = S (susceptible). Means of 3 replications.

South China pathotypes I and II cannot be matched with any Philippine race; pathotypes III and IV correspond to Philippine race I, and pathotype V, the most virulent, may correspond to Philippine race IV (Table 18).

All the 211 pv. *oryzae* isolates belong to group B. This group or pathotype appears to be widely distributed in Guangdong, South China.

IRRI-Thailand. Selected Thailand pv. *oryzae* strains, collected in 1974-1977, were comparable in virulence to the Philippine strains tested earlier (Table 19).

Of the 37 strains collected in Thailand in 1978, 11 represented pv. *oryzae* groups I, II, and III. They differed in length of lesions produced on IRRI differential varieties. Two strains were avirulent to

Table 16. Race groups, frequency, and virulence indices of *Xanthomonas campestris* pv. *oryzae* isolates from Indonesia and Bangladesh and resistance of differential varieties.

Isolate	Frequency (%)	Virulence index	Reaction[a]									
			Japanese					Philippine				
			Kinmaze	Kogyoku	Tetep	Wase Aikoku 3	Java 14	IR8	IR20	IR1545	DV85	Cas 209
Indonesia												
A	65.0	4.6	S	S	S	R	R	S	S	R	R	S
B	17.5	4.0	S	S	S	R	R	S	R	R	R	S
C	5.0	4.6	S	S	S	R	R	S	R	S	R	S
E	2.5	4.0	S	S	S	R	R	S	R	S	R	R
F	2.5	4.0	S	S	S	R	R	R	S	R	R	S
H	2.5	5.2	S	S	S	S	S	S	R	R	R	S
I	2.5	2.8	S	R	R	S	R	R	R	R	R	S
J	2.5	3.4	S	S	S	R	R	R	R	R	R	S
Bangladesh												
K	5.0	3.4	S	R	R	R	R	S	R	S	R	S
L	5.0	4.6	R	R	S	R	R	S	S	S	S	S
M	20.0	5.2	S	S	R	R	R	S	S	S	S	S
N	5.0	5.8	S	S	S	S	S	S	R	S	R	S
O	5.0	4.5	S	S	R	S	S	S	R	S	R	S
P	5.0	3.4	R	R	R	R	R	S	R	R	S	S
Q	5.0	1.6	R	R	R	R	R	R	R	S	R	S
R	10.0	2.8	R	R	R	R	R	R	S	S	R	S
S	5.0	4.6	S	S	R	R	S	S	R	S	R	S
T	5.0	4.0	S	R	S	R	R	S	R	S	S	S
U	5.0	5.2	S	S	S	R	R	S	R	S	S	S
V	5.0	4.0	S	R	R	R	R	S	R	S	S	S
W	5.0	3.4	S	R	S	R	R	S	R	R	R	S
X	5.0	4.0	S	R	R	R	R	S	R	S	S	S
Y	5.0	5.2	S	S	R	S	S	S	R	S	R	S
Z	5.0	4.6	S	S	R	R	R	S	R	S	S	S
			Mean susceptibility index									
			6.0	4.5	4.0	2.25	2.25	5.75	2.25	5.0	3.0	6.75

[a] R = resistant, S = susceptible.

Table 17. Relationship of South China *Xanthomonas campestris* pv. *oryzae* pathotypes to Philippine races, based on the reactions of 3 sets of differential varieties.[a]

Differential variety	Resistance gene[b]	Reaction[c]								
		South China pathotype[d]					Philippine race[e]			
		I	II	III	IV	V	I	II	III	IV
Japanese set										
Kinmaze	none	S	S	S	S	S	S	S	S	S
Kogyoku	*Xa-1, Xa-kg*	R	R	S	S	S	S	S	S	S
Tetep	*Xa-1, Xa-2*	S	S	S	S	S	S	S	S	S
Wase Aikoku 4	*Xa-3*	R	R	R	R	R	R	R	R	R
Java 14	*Xa-1, Xa-3, Xa-kg*	R	R	R	R	R	R	R	R	R
IRRI set										
IR8	?	S	S	S	S	S	S	S	S	S
IR20	*Xa-4*	R	R	R	R	S	R	S	S	S
IR1545-339	*xa-5*	R	R	R	R	S	R	R	R	S
DV85	*xa-5, Xa-7*	R	R	R	R	R	R	R	R	R
Cas 209	?	S	S	S	S	S	S	R	S	S

Continued on next page

Table 17 continued

Differential variety	Resistance gene[b]	Reaction[c]								
		South China pathotype[d]					Philippine race[e]			
		I	II	III	IV	V	I	II	III	IV
Chinese set										
TN1	none	S	S	S	S	S	S	S	S	S
Bao-Tai-Ai	?	S	S	S	S	S	S	S	S	S
IR26	*Xa-4*	R	R	R	R	S	R	S	S	S

[a]Inoculated by the clipping method at maximum tillering stage. [b]? = resistance gene has not yet been identified. [c]Mean of 3 replications; each replication with 10 leaves used for disease reading; based on a rating scale of 0-9: 0 to 3.0 = R (resistant); 3.1 to 9.0 = S (susceptible). [d]Test conducted in Guangdong, China. [e]Test conducted in IRRI, Philippines.

Table 18. Comparative virulence of South China *Xanthomonas campestris* pv. *oryzae* pathotypes and Philippine races to 3 sets of differential varieties.

Differential variety	Resistance gene[a]	Reaction[b]								
		South China pathotype					Philippine race			
		I	II	III	IV	V	I	II	III	IV
Japanese set										
Kinmaze	none	S	S	S	S	S	S	S	S	S
Kogyoku	*Xa-1, Xa-kg*	R	R	S	S	S	S	S	S	S
Tetep	*Xa-1, Xa-2*	S	S	S	S	S	S	S	S	S
Wase Aikoku 3	*Xa-3*	R	R	R	R	R	R	R	R	R
Java 14	*Xa-1, Xa-3, Xa-kg*	R	R	R	R	R	R	R	R	R
IRRI set										
IR8	?	S	S	S	S	S	S	S	S	S
IR20	*Xa-4*	R	R	R	R	S	R	S	S	S
IR1545-339	*xa-5*	R	R	R	R	S	R	R	R	S
DV85	*xa-5, Xa-7*	R	R	R	R	R	R	R	R	R
Cas 209	?	S	S	S	S	S	S	R	S	S
Chinese set										
TN1	none	S	S	S	S	S	S	S	S	S
Bao-Tai-Ai	?	S	S	S	S	S	S	S	S	S
IR26	*Xa-4*	R	R	R	R	S	R	S	S	S

[a]? = resistance gene has not yet been identified. [b]R = resistant, S = susceptible.

Table 19. Virulence of selected Thailand *Xanthomonas campestris* pv. *oryzae* strains on the Philippine differential varieties.

Strain	Virulence group	Lesion length[a] (cm)				Strain mean
		IR8	IR20	IR1545	DV85	
TB7621	0	3.0 b	2.1 bc	1.8 b	2.4 a	2.3
TB7724	0	0.8 bc	0.9 c	1.3 b	1.2 a	1.0
	Group mean	1.9	1.5	1.5	1.8	1.6
TB7612	I	11.8 a	1.5 bc	1.4 b	1.1 a	4.2
TB7617	I	14.0 a	3.5 bc	2.0 b	2.1 a	5.4
	Group mean	12.9	3.0	1.7	1.6	4.8
TB7536	II	18.6 a	7.7 ab	2.3 b	2.6 a	7.8
TB7538	II	19.7 a	9.4 a	3.0 b	3.1 a	8.8
TB7410	II	19.1 a	11.7 a	5.4 ab	1.7 a	9.5
TB7615	II	20.4 a	10.4 a	5.0 ab	4.2 a	10.0
	Group mean	19.4	9.8	3.9	2.9	8.8

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

Table 20. Specific virulence of Thailand *Xanthomonas campestris* pv. *oryzae* strains to rice differential varieties.

Strain	Virulence group	Lesion length (cm)						Strain mean
		IR8	IR20	IR1545	DV85	RD7	RD9	
TB7807	0	1.4	1.4	2.1	2.2	1.1	1.0	1.5
TB7833	0	1.4	1.3	2.0	1.7	2.6	2.0	1.8
	Group mean	1.4	1.3	2.0	1.9	1.8	1.5	1.7
TB7808	I	30.2	4.5	2.7	3.1	5.6	25.6	11.9
TB7831	I	24.2	2.7	1.9	3.0	4.7	28.7	10.9
TB7822	I	24.3	5.3	1.5	3.2	5.6	30.0	11.6
	Group mean	26.2	4.2	2.0	3.1	5.3	27.9	11.4
TB7814	II	23.4	8.6	3.6	4.8	18.3	25.2	14.0
TB7822	II	24.8	8.6	4.3	5.3	19.0	32.3	15.7
TB7841	II	29.0	6.0	3.6	5.0	23.3	30.4	16.2
	Group mean	25.7	7.7	3.8	5.0	20.2	29.3	15.3
TB7803	III	23.5	18.5	4.9	5.3	18.9	24.3	15.9
TB7821	III	20.8	16.3	3.0	4.0	19.5	26.4	15.0
TB7805	III	16.0	15.0	6.6	6.2	18.9	20.5	13.9
	Group mean	20.1	16.5	4.6	5.2	19.1	23.7	14.9

all varieties, including very susceptible IR8 and RD9. The other strains were virulent to IR8 and RD9 and less virulent to IR1545 and DV85. Virulence to IR20 (having the *Xa-4* gene for resistance) and to RD7 varied. Group II strains were very virulent to RD7, but less virulent to IR20. Group I strains were less virulent to both varieties. Group III strains were virulent to both varieties (Table 20).

Genetic evaluation and utilization (GEU) program

Insect resistance

Entomology, Plant Breeding, and Chemistry Departments

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GERMPLASM EVALUATION

Entomology Department

Evaluation of the germplasm collection continued. Varieties identified in 1981 brought the total number of varieties selected for resistance to 8 pests to almost 3,000 (Table 1). Testing of the entire germplasm collection for green leafhopper (GLH) resistance is near completion; more than 1,200 varieties with resistance have been identified.

Of the more than 42,000 varieties tested for brown planthopper (BPH) biotype 1, more than 300 are resistant. In 1981, most of the Assam Rice Collection was evaluated and several varieties were found to be resistant to BPH biotypes 1, 2, and 3 (Table 2).

With increasing severity of the whitebacked planthopper (WBPH), the search for additional sources to be used as donors in the breeding program continued. Of 3,132 varieties screened, 15 (0.5%) were found to have resistance (Table 3). The resistant varieties are from India, Sri Lanka, Bangladesh, and Australia.

Screening for leaffolder resistance intensified. Of 2,200 germplasm collection entries tested in the greenhouse, 26 were selected as resistant or moderately resistant (Table 4). Three varieties from India (Kamalbhog, Karpur Kanti, and Kataribhog) were resistant.

For the first time varieties were screened for armyworm (*Mythimna separata*) resistance. IR varieties IR5 to IR54 have moderate differences in susceptibility to the armyworm (Table 5). IR34 and IR52 were the least susceptible and had low damage ratings in two subsequent tests.

None of the selected IR varieties screened against swarming caterpillar *Spodoptera mauritia*, were resistant, but there were differences in susceptibility. IR34 and IR52 had the lowest damage ratings.

Table 1. Germplasm collection varieties screened and selected for resistance through 1981.

Insect	Accessions	
	Tested (no.)	Selected (no.)
Brown planthopper		
Biotype 1	42,355	363
2	15,068	258
3	16,402	267
Whitebacked planthopper	39,965	282
Green leafhopper	45,292	1,268
Zigzag leafhopper	1,959	401
Yellow stem borer	23,595	65
Striped stem borer	15,000	21
Whorl maggot	40,000	5
Leaffolder	5,901	54

Table 2. Damage caused by 3 brown planthopper (BPH) biotypes to germplasm from the Assam Rice Collection. IRRI greenhouse, 1981.

Variety	IRRI acc. no.	BPH biotype[a]		
		1	2	3
ARC 11321	40947	3	5	5
ARC 12176	41016	5	5	5
ARC 14395	41541	3	5	5
ARC 14453	41566	3	5	3
ARC 14465	41569	3	5	5
ARC 14515	41580	3	3	5
ARC 14548	41598	3	5	5
ARC 14559	41603	3	5	5
ARC 14664	41672	1	5	5
ARC 14668	41676	3	5	5
ARC 14669	41677	3	5	5
ARC 14670	41678	5	5	5
ARC 14671	41679	3	5	5
ARC 14740	41732	3	5	5
ARC 14764	41739	5	5	5
ARC 14774	41747	3	3	5
ARC 14807	41759	5	5	5
ARC 15242	41978	5	5	5
ARC 15285	41997	1	5	3
ARC 15286	41998	1	5	3

[a] 1-3 = resistant, 5 = moderately resistant.

Table 3. Germplasm collection varieties selected for resistance to the whitebacked planthopper. IRRI greenhouse, 1981.

Variety	IRRI acc. no.	Origin
Sindurmukhi	46678	India
Teenpakhia	46736	India
W398	46787	India
Pokkalian	47407	Sri Lanka
Chengri	49172	Bangladesh
Ratoi	49256	Bangladesh
C.P. 12	49539	India
Cross 1	49544	Australia
Cuttack 13	49564	India
Hansraj	49681	India
Vellathan	50240	India
Vellayatham	50241	India
Desi Munji	50740	India
Desi Munji	50742	India
Horana Wee	50987	Sri Lanka

Table 4. Reaction of selected germplasm collection entries against the rice leaffolder. IRRI greenhouse, 1981.

Variety	IRRI acc. no.	Origin	Rating[a]
Kamalbhog	46020	India	3
Karpur Kanti	46048	India	3
Kataribhog	46076	India	3
Hanskal	45756	India	5
HS19/Taichu 65 (VKM 12)	45813	India	5
IB Rose/Latisail	45848	India	5
Jatadhanya	45880	India	5
Jathakatke	45890	India	5
Jessoa	45893	India	5
Jessoa	45895	India	5
Jhinga	45905	India	5
Jhingasail	45906	India	5
Kakowa	45955	India	5
Karpur Kanti	46049	India	5
Karpursail	46050	India	5
Kartikbad	46051	India	5
Karticgeti	46052	India	5
Kartic Kalma	46053	India	5
Kartiksail	46061	India	5
Katalgaria	46075	India	5
Kataribhog	46077	India	5
Kataribhog	46078	India	5
Katihibadal	46082	India	5
Katke	46086	India	5
Katki	46091	India	5
Kaurdhan	46092	India	5

[a]Based on a 0-9 grading system: 3 = resistant, 5 = moderately resistant. Av of 10 replications.

Table 5. Damage ratings of IR-variety seedlings infested with *M. separata*. IRRI, 1981.

Variety	Rank	Mean[a]	Rating[b]
IR5	12	6.4 cdefg	–
IR8	13	6.2 defg	–
IR20	1	9.0 a	S
IR22	10	6.8 cdef	–
IR24	6	7.0 cde	–
IR26	3	8.6 ab	S
IR28	15	6.0 efgh	–
IR29	5	7.6 bcd	–
IR30	18	5.8 efgh	–
IR32	15	6.0 efgh	–
IR34	25	4.6 h	–
IR36	20	5.6 efgh	–
IR38	11	6.6 cdefg	–
IR40	6	7.0 cde	–
IR42	4	7.8 abc	S
IR42	6	7.0 cde	–
IR44	20	5.6 efgh	–
IR45	15	6.0 efgh	–
IR46	24	5.2 gh	–
IR48	18	5.8 efgh	–
IR50	6	7.0 cde	–
IR52	23	5.4 fgh	–
IR54	13	6.2 defg	–
IET 6073	20	5.6 efgh	–
IR1552	1	9.0 a	S
Grand mean	–	6.6	

[a]Damage rating (1-9 scale) (averaged over 5 replications). Separation of means by Duncan's multiple range test at the 5% level. [b]S = not significantly different from the most susceptible entry at the 5% level.

SCREENING THE WILD RICE COLLECTION

Entomology Department

The wild rice collection is being screened to identify genes for resistance not found in *Oryza sativa*. More than 200 wild-rice accessions have been screened against 9 major rice pests (Table 6). *Oryza officinalis, O. minuta,* and *O. latifolia* had the largest numbers of resistant accessions, especially against the different hopper species. More than 50% of the wild rices were resistant to zigzag leafhopper and green leafhopper. No accession was resistant to whorl maggot or caseworm.

Some accessions were resistant to all hopper species tested (Table 7). All accessions resistant to two or more hopper species were from India and Sri Lanka.

Thirty accessions from Asia, Africa, and Central America were resistant to the yellow stem borer (Table 8).

Accessions of *O. nivara, O. rufipogon, O. officinalis, O. minuta*, and *O. punctata* collected in Southeast Asia and Kenya were resistant to the striped stem borer (Table 9).

Some accessions were resistant (rated 3) or moderately resistant (rated 5) to both yellow and striped stem borers (Table 10). *O. punctata* (accession 101417) from Kenya had a 3 rating against both species.

RESISTANCE IN IR VARIETIES

Entomology Department

Varieties IR5 to IR54 were evaluated for resistance to some of the major rice insect pests in Asia (Table 11). Variety IR50, recently named by the Philippine Government, has multiple resistance to BPH, GLH, and striped stem borer and moderate resistance to the yellow stem borer.

In addition to being studied for resistance to

Table 6. Wild rices resistant to insect pests. IRRI, 1981.

Species	Tested	Accessions (no.) Resistant to										
		BPH biotype			GLH	WBPH	ZLH	YSB	SSB	LF	WM	CW
		1	2	3								
O. alta	1	1	1	1	1	0	1	1	0	0	0	0
O. barthii	4	3	1	3	3	0	1	0	0	0	0	0
O. eichingeri	6	4	6	4	5	6	4	5	0	0	0	0
O. latifolia	17	13	2	4	16	7	17	3	0	0	0	0
O. minuta	29	28	28	28	28	28	28	7	3	0	0	0
O. nivara	33	11	9	10	14	2	7	0	0	0	0	0
O. officinalis	37	37	34	36	36	33	37	6	2	0	0	0
O. paraguaensis	1	1	1	1	1	1	1	0	0	0	0	0
O. perennis	6	1	1	1	1	0	1	0	0	0	0	0
O. punctata	12	8	11	6	11	5	11	6	1	0	0	0
O. ridleyi	2	2	0	0	2	2	2	2	0	0	0	0
O. rufipogon	14	0	0	0	2	1	2	0	0	1	0	0
O. stapfii	1	0	0	0	0	0	1	0	0	0	0	0
Natural hybrids:												
O. sativa/O. nivara	13	0	0	0	0	0	2	0	0	0	0	0
O. sativa/O. rufipogon	23	0	0	0	1	0	4	0	0	0	0	0
O. nivara/O. rufipogon	18	3	2	2	4	1	6	0	1	0	0	0
Unnamed *Oryza* sp.	7	0	0	0	0	0	1	0	0	1	0	0
Total		113	96	96	125	86	126	30	7	2	0	0
Tested (no.)		231	231	231	229	230	228	230	227	226	226	204
Resistant (%)		48.9	41.6	41.6	54.6	37.4	55.3	13.0	3.1	0.9	0	0

[a]Ratings of 1-3 only. BPH = brown planthopper, GLH = green leafhopper, WBPH = whitebacked planthopper, ZLH = zigzag leafhopper, YSB = yellow stem borer, SSB = striped stem borer, LF = leaffolder, WM = whorl maggot, CW = caseworm.

Table 7. Wild rices closely related to *Oryza sativa* with resistance to different hopper species. IRRI, 1981

Species	IRRI acc. no.	Origin	Resistance
O. nivara	102164	India	BPH[a], GLH, WBPH, and ZLH
O. nivara	102179	India	BPH, GLH, WBPH, and ZLH
O. nivara/O. rufipogon	101998	Sri Lanka	BPH, GLH, WBPH, and ZLH
O. nivara	102163	India	BPH, GLH, and WBPH
O. nivara	102165	India	BPH, GLH, and WBPH
O. perennis	100211	India	BPH, GLH, and ZLH
O. nivara/O. rufipogon	102168	India	BPH, GLH, and ZLH
O. nivara	102169	India	BPH, GLH, and ZLH
O. nivara	102178	India	BPH, GLH, and ZLH
O. nivara	102166	India	BPH and GLH
O. nivara	102167	India	BPH and GLH
O. nivara	102175	India	BPH and GLH
O. nivara	102176	India	BPH and GLH

[a]Includes all biotypes of brown planthopper (BPH). GLH = green leafhopper, WBPH = whitebacked planthopper, ZLH = zigzag leafhopper.

hoppers and stem borers, the germplasm collection is being evaluated to identify varieties with resistance to WBPH, zigzag leafhopper, and leaffolder. Resistance identified has been incorporated into breeding lines.

Resistance to green leafhopper and whitebacked planthopper in parents of IR varieties. The resistance to GLH and WBPH of some varieties used as parents in the IRRI breeding program was evaluated through the seedling bulk test. Several

Table 8. Wild rices resistant to yellow stem borer (ratings of 1 and 3 only). IRRI, 1981.

Species	IRRI acc. no.	Origin
O. ridleyi	100820	Japan
O. ridleyi	100821	Japan
O. punctata	100937	Ghana
O. officinalis	100947	India
O. officinalis	100948	India
O. officinalis	100953	India
O. punctata	100954	India
O. latifolia	100966	Panama
O. officinalis	100973	Philippines
O. minuta	101083	Philippines
O. minuta	101086	Philippines
O. minuta	101089	Philippines
O. minuta	101092	Philippines
O. minuta	101094	Philippines
O. minuta	101096	Philippines
O. minuta	101128	Philippines
O. officinalis	101151	Malaysia
O. alta	101395	US
O. punctata	101417	Kenya
O. eichingeri	101418	Uganda
O. eichingeri	101421	Uganda
O. eichingeri	101422	Uganda
O. eichingeri	101424	Uganda
O. eichingeri	101426	Uganda
O. punctata	101430	Uganda
O. punctata	101434	Tanzania
O. punctata	101439	Ghana
O. latifolia	101443	Morocco
O. officinalis	102382	Indonesia
O. latifolia	102481	Nicaragua

Table 9. Wild rices resistant to striped stem borer (ratings of 1 and 3 only). IRRI, 1981.

Species	IRRI acc. no.	Origin
O. nivara/O. rufipogon	102168	India
O. officinalis	100878	Thailand
O. minuta	101079	Philippines
O. minuta	101129	Philippines
O. minuta	101141	Philippines
O. officinalis	101154	Malaysia
O. punctata	101417	Kenya

varieties had high resistance to the GLH; Ptb 18 had a rating of 1 (Table 12). No variety was highly resistant to the BPH but Fortuna, HR 21, and SLO 17 were moderately resistant.

Resistance to whitebacked planthopper in IR varieties. Although damage ratings in the seedling bulk test and nymphal survival were similar for all varieties, there were distinct differences in population growth and honeydew excretion (Fig. 1). On IR36, hoppers had a low population growth; on IR20, high growth. This finding supports observations of high WBPH populations on IR20, and low populations on IR36 in the field.

Comparative resistance in IR and traditional varieties. The loss of low levels of resistance in breeding for high yields in the modern varieties and the various changes in cultural practices that accompany growing of high yielding varieties have been suggested as the reasons for recent outbreaks of BPH and other rice insect pests. In 1981, levels of BPH resistance in traditional varieties Peta and Intan and IR varieties were compared, using population development of BPH as the measure of susceptibility. BPH populations on IR20, which has no major gene for resistance, were similar to those on Peta and Intan (Fig. 2). IR36 and IR50, which have genes for BPH resistance, had lower insect populations than the traditional varieties. These varieties are being evaluated for resistance to additional insect pests.

Resistance in varieties having the same major gene for whitebacked planthopper resistance. Varieties identified as having the same major genes *Wbph 1* and *Wbph 2* were screened using the seedling bulk test. Differences in resistance were assumed to be due to minor gene differences. Most of the *Wbph 1* gene varieties were resistant or moderately resistant to the WBPH, but differed in levels of resistance (Table 13). T 1432 and NP 97 were the most resistant, with a rating of 3; Sathra 265 had a rating of 7 and variety 18 a rating of 8. N 22, which has been used extensively in the IRRI breeding program, had a rating of 6. Differences in levels of resistance were more distinct among *Wbph 2* gene varieties (Table 14). Chempan was highly resistant, ARC 13349 was susceptible.

GREEN LEAFHOPPER RESISTANCE AND TUNGRO VIRUS INFECTION IN IR VARIETIES

Entomology Department

Varieties IR5 to IR54 were tested for level of GLH resistance and degree of tungro infection. An insect resistance ratio (RR) was calculated using three parameters (seedling damage rating, percentage survival, and population growth):

$$RR = \frac{\text{damage rating of TN1}}{\text{damage rating of test variety}} \times \frac{\text{\% survival on TN1}}{\text{\% survival on test variety}} \times \frac{\text{population growth on TN1}}{\text{population growth on test variety}}$$

To determine the percentage of tungro infection, 100 GLH were caged on virus-infected TN1 plants in the middle of 2.2- × 1.2-m field plots. Inoculation was for 24 hours.

In the seedling bulk test, 2 varieties were susceptible, 15 moderately resistant, and 6 resistant (Table 15). Insect survival and population growth differed significantly among varieties of the same age and at different plant ages within the same variety. Insect survival usually decreased with plant age. On IR5 and IR8, GLH had about 80% survival on 15-day-old plants but less than 10% on 60-day-old plants (Fig. 3).

Population growth was low on most varieties at all plant ages (Fig. 4). IR22 and IR46 had high populations on 60-day-old plants.

The RR indicated that, in addition to IR30 and IR40, sister lines IR28, IR29, and IR34, IR50, IR52, and IR54, which have Gam Pai as one of their resistant parents, were the most resistant to the GLH and had low virus infection. Yield was highest in IR50 and IR54.

Correlation of green leafhopper resistance and tungro virus infection in varieties with different genes for resistance. Levels of GLH resistance in seven rice varieties with different genes for resistance were determined in greenhouse studies. The relationship between GLH resistance and degree of tungro infection was determined in the greenhouse and in the field. The varieties with known genes in the study were Pankhari 203 (*Glh 1*), ASD7 (*Glh 2*), IR8 (*Glh 3*), Ptb 8 (*Glh 4*), ASD8 (*Glh 5*), TAPL #796 (*Glh 6*), and Moddai Karuppan (*Glh 7*). IR29 was the resistant check and TN1 the susceptible check.

There was a distinct difference in seedling preference among varieties. Moddai Karuppan was the most preferred; Pankhari 203, ASD7, and ASD8, the least preferred (Fig. 5).

Survival of males and females at 5 days after infestation was highest on Ptb 8 and Moddai Karuppan (Fig. 6). Survival of females was lowest on ASD7 and Pankhari 203; survival of males was lowest on IR8 and ASD7.

Pankhari 203 and ASD7 had the least GLH eggs (Table 16). Egg hatchability was equally high on all varieties.

Survival of nymphs ranged from 0% on ASD7 to 76% on Moddai Karuppan (Table 17). Population growth was highest on Moddai Karuppan and lowest on ASD7, IR8, and ASD8.

In the greenhouse, tungro infection was highest in IR8, Ptb 8, and Moddai Karuppan and lowest in Pankhari 203 (Fig. 7). In the field, tungro infection in free-choice and no-choice plots was almost identical and similar to that in the greenhouse (Fig. 8). Tungro infection was high in Moddai Karuppan, Ptb 8, and IR8 and low in Pankhari 203.

In general, there was a close relationship between level of resistance to GLH in the greenhouse tests

Table 10. Wild rices with some level of resistance (ratings of 3 and 5 only) to yellow and striped stem borers. IRRI, 1981.

Species	IRRI acc. no.	Origin	Rating	
			Yellow stem borer	Striped stem borer
O. latifolia	100172	Guatemala	5	5
O. officinalis	100181	Burma	5	5
O. latifolia	100890	India	5	5
O. officinalis	100947	India	3	5
O. officinalis	101074	Philippines	5	5
O. minuta	101079	Philippines	5	3
O. officinalis	101121	Philippines	5	5
O. minuta	101129	Philippines	5	3
O. minuta	101133	Philippines	5	5
O. officinalis	101137	Philippines	5	5
O. minuta	101141	Philippines	5	3
O. punctata	101417	Kenya	3	3
O. nivara/O. rufipogon	102116	Cambodia	5	5

Table 11. Resistance of IR varieties to insect pests.[a] IRRI, 1981.

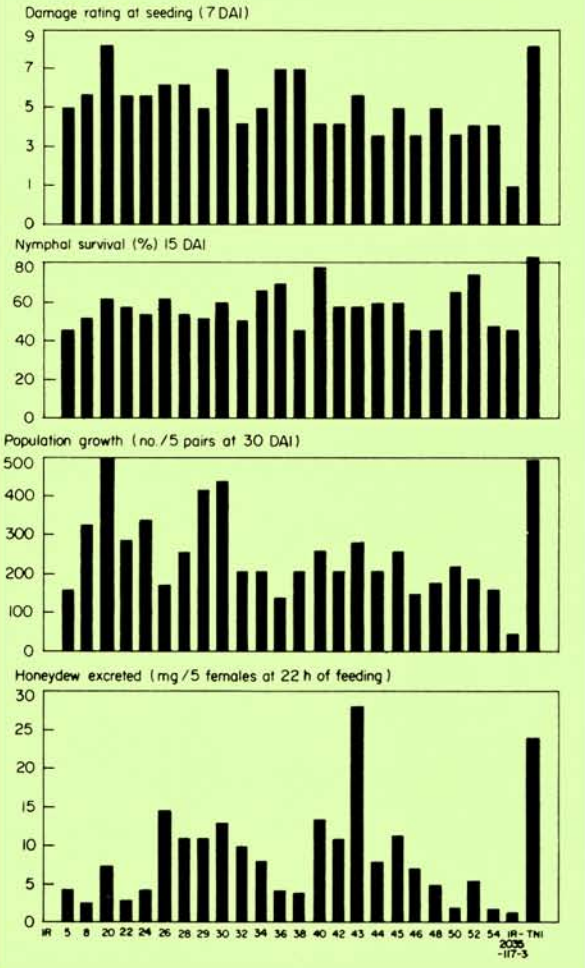
Variety	Brown planthopper biotype			Green leafhopper	Whitebacked planthopper	Zigzag leafhopper	Yellow stem borer	Striped stem borer	Leaf folder	Case-worm	Whorl maggot
	1	2	3								
IR5	S	S	S	MR	S	S	S	S	S	S	S
IR8	S	S	S	MR	S	S	S	S	S	S	S
IR20	S	S	S	MR[d]	S	S	MR	R	S	S	S
IR22	S	S	S	S	S	S	S	S	S	S	S
IR24	S	S	S	MR	S	S	S	S	S	S	S
IR26	R	S	R	MR	S	S	S	MR	S	S	S
IR28	R	S	R	R	S	S	S	S	S	S	S
IR29	R	S	R	R	S	S	S	S	S	S	S
IR30	R	S	R	R	S	S	S	MR	S	S	S
IR32	R	R	MR[c]	MR	S	S	S	MR	S	S	S
IR34	R	S	R	R	S	S	S	MR	S	S	S
IR36	R	R	MR[c]	MR	S	S	MR	R	S	S	S
IR38	R	R	MR[c]	MR	S	S	S	MR	S	S	S
IR40	R	MR	S	MR	S	S	MR	R	S	S	MR
IR42	R	R	S	MR[d]	S	S	S	MR	S	S	S
IR43	S	S	S	MR	S	S	S	MR	S	S	S
IR44	R	R	MR[c]	MR	S	S	S	R	S	S	S
IR45	R	S	R	MR	S	S	S	S	S	S	S
IR46	R	S[b]	R	MR[d]	S	S	S	S	S	S	S
IR48	R	R	S	MR	MR	S	S	S	S	S	S
IR50	R	R	MR[c]	R	S	S	MR	R	S	S	S
IR52	R	R	MR[c]	R	MR	S	S	MR	S	S	S
IR54	R	R	S	S	S	S	MR	MR	S	S	S

[a]Based on replicated experiments. Hopper resistance based on greenhouse evaluation of seedlings; yellow and striped stem borer resistance based on a screenhouse evaluation of 40- to 70-day-old plants; leaffolder and caseworm resistance based on the reaction of 30- and 11-day-old plants in the greenhouse; whorl maggot resistance based on field observations at 30 days after transplanting. Varieties rated, on the basis of standard evaluation system, 1-3 are considered resistant (R), 5-7 moderately resistant (MR), and 9 susceptible (S). [b]IR46 has field resistance to biotype 2. [c]Reaction to biotype 3 is occasionally susceptible and often resistant. [d]Occasional susceptible reactions. Least resistant of the IR varieties, except IR22, which is highly susceptible.

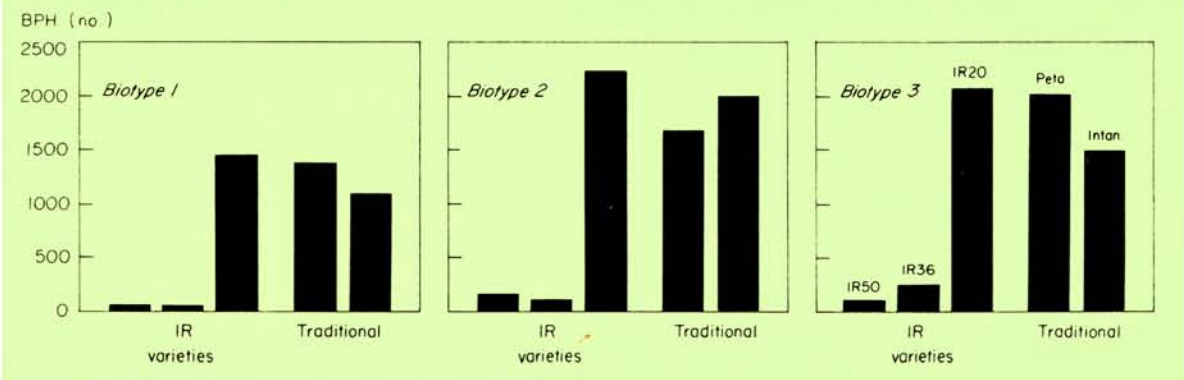
Table 12. Resistance of IR parents to green leafhopper (GLH) and whitebacked planthopper (WBPH). IRRI, 1981.

Variety	IRRI acc. no.	Damage rating[a] at 7 DAT	
		GLH	WBPH
Benong	13530	7	7
Bluerose	00151	7	7
BPI 121	15762	3	7
Century Patna 231	00134	7	9
CO 18 (Vellai Kar)	06331	7	9
CPSLO	06993	7	9
Dee-geo-woo-gen	00123	9	9
Fortuna	00139	7	5
GEB 24 (Kitcheli Samba)	05909	5	7
Gam Pai	00831	3	7
HR 21	00663	5	5
Latisail	08340	3	7
Mudgo	06663	7	5
NMS4	00171	5	5
Nam Sagui 19	11462	5	7
Ptb 18 (Evarapandi)	06105	1	7
Ptb 21 (Thekkan)	06113	3	5
Peta	00035	3	7
Rexoro	00143	5	7
Sinampaga	03966	7	7
Supreme Bluerose	01739	7	7
SLO 17	00637	5	5
Sigadis	00611	3	7
Texas Patna	00144	7	7
Tsai-yuan-chon	00126	7	7
TN1	00105	9	9
TKM6	00237	3	7
Tetep	11115	7	7
Tangkai Rotan	00031	7	7
IR29 (R. check for GLH)	–	1	–
IR2035-117-3 (R. check for WBPH)		–	3

[a]Av of 3 replications. 1-3 = resistant, 5-7 = moderately resistant, and 9 = susceptible.



1. Resistance of IR varieties to whitebacked planthopper, DAI = days after infestation. IRRI, 1981.



2. Brown planthopper (BPH) biotypes 1, 2, and 3 populations on modern IR varieties and traditional varieties in the Philippines. Populations represent the progeny of 5 pairs (♂ and ♀) of 3-day-old adults at 25 days after infestation. IRRI, 1981.

Table 13. Plant damage ratings for varieties with *Wbph 1* gene for resistance to whitebacked planthopper exposed to 2nd-instar nymphs. IRRI, 1981.

Variety	Damage rating[a] at		
	6 DI	7 DI	8 DI
N 22	4	6	6
N32	6	6	6
Litighawar	4	4	4
Sonpattar 45	3	3	4
Bnasphul	4	4	4
P580	4	5	5
Senawee	4	4	4
W128	3	5	6
SM234	2	4	4
T1432	3	3	3
Sufaida 176	3	4	4
Tirisurkhi 251	4	5	6
Jhinuwa	4	5	6
Sathra 265	4	4	5
Sukhuel	6	7	7
Muskhan	2	2	2
Ziriyowaian 245	2	4	5
CI 6037-4	2	3	4
S39 JKW	4	5	5
NP 97	2	3	3
76 S	3	4	5
18	6	7	8
39	3	5	5
78	5	6	6
24A	5	6	6
180	5	6	6
213B	3	4	4
267	3	4	4
293	3	4	4
IR2035-117-3 (*Wbph 1 & 2*) (R check)	4	4	4
TN1 (S check)	9	9	9

[a]Av of 3 replications. 1-3 = resistant, 5-7 = moderately resistant, 9 = susceptible. DI = days after infestation.

Table 14. Plant damage ratings for varieties with *Wbph* 2 gene for resistance to whitebacked planthoppers exposed to 2nd-instar nymphs. IRRI, 1981.

Variety	Damage rating[a] at		
	6 DI	7 DI	8 DI
ARC 10239	4	4	4
Cheriya Chittari	2	2	3
Chempan	1	1	2
Sinnanayan	4	5	5
ARC 13349	9	9	9
MGL 1	4	6	6
Bam 3	6	6	6
A 1	3	3	4
Chuvanna Kumbulum	2	2	3
Colombo (*Wbph 2* + 1 rec.)	4	4	4
IR2035-117-3 (*Wbph 1 & 2*) (R check)	1	2	2
TN1 (S check)	9	9	9

[a]Av of 3 replications. 1-3 = resistant, 5-7 = moderately resistant, 9 = susceptible. DI = days after infestation.

and degree of tungro infection in the greenhouse and in the field. Seedling preference, survival, and population growth were most closely related to tungro infection both in the greenhouse and in the field (Table 18). That close relationship indicates the importance of GLH resistance in tungro virus control.

Green leafhopper feeding and tungro virus infection in IR varieties. Although the GLH feeds substantially on resistant varieties, it does not survive. Biochemical evidence that the GLH feeds on the phloem in a susceptible variety and on the xylem in a resistant variety was reported earlier (Research highlights for 1980). In 1981, further studies were done to determine whether GLH-transmitted tungro virus would be inoculated equally into insect-resistant and susceptible varieties.

Viruliferous GLH were placed on 100 plants each of insect-susceptible IR22, moderately-resistant IR8 and IR42, and highly resistant IR29. Insect-feeding activity was equal on all varieties (Fig. 9). However, tungro infection was 98% on susceptible variety IR22, 78% on IR8, and 44% on IR40, which are moderately resistant, and only 14% on highly resistant IR29. The basic portion of honeydew excreted by the insect feeding on IR22 was high; that on moderately resistant varieties, low; and that on highly resistant IR29, absent. The presence of basic honeydew indicates that the insect had been feeding in the phloem; the presence of acidic honeydew indicates xylem feeding. The high amount of basic honeydew from insect-susceptible IR22 and the lack of basic honeydew from insect-resistant IR29 indicate that feeding in the phloem might be necessary for tungro inoculation and development within the plant. Viruliferous hoppers feeding in the xylem, as in the case of an insect-resistant variety, do not efficiently transmit the tungro virus, and the virus does not develop subsequently in the plant.

BROWN PLANTHOPPER BIOTYPES

Entomology and Plant Breeding Departments

Genetic variability *(Entomology).* BPH *Nilaparvata lugens* has been considered a plastic species with a wide genetic variability. Because of its plasticity, it develops resistance to insecticides rapidly and, through selection, overcomes the resistance

Table 15. Resistance of IR varieties to green leafhopper at different growth ages, tungro infection, and yield. IRRI, 1981.

Variety	Damage rating[a]	Resistance ratio[b]			Tungro infection[c] (% plants)	Yield[c] (t/ha)
		30 DS	45 DS	60 DS		
IR5	6	17	3281	2404	80 abc	0.084 k
IR8	6	157	253	8812	91 a	0.157 k
IR20	6	21	20	31	40 e	0.343 ijk
IR22	8	4	8	2	96 a	0.273 jk
IR24	3	176	743	172	72 bcd	0.181 k
IR26	4	71	274	146	90 a	0.651 k
IR28	3	4331	41583	55854	5 f	3.687 c
IR29	3	1968	41583	4295	4 f	2.466 ef
IR30	3	157	222	72	9 f	2.798 de
IR32	6	38	37	12	84 abc	0.091 k
IR34	3	2099	1891	18618	12 f	4.093 bc
IR36	6	20	224	29	50 de	2.007 fg
IR38	5	31	12	41	70 bcd	0.659 ijk
IR40	5	1499	249	113	11 f	2.901 de
IR42	6	8	32	10	89 ab	0.263 jk
IR43	4	237	234	258	82 abc	0.543 ijk
IR44	6	50	36	38	53 de	1.413 gh
IR45	4	310	2250	829	90 a	0.150 k
IR46	8	9	12	2	82 abc	1.071 hi
IR48	6	11	–	–	68 cd	0.988 hij
IR50	3	52668	–	–	3 f	5.202 a
IR52	4	28	–	–	8 f	3.500 cd
IR54	4	39501	–	–	4 f	4.721 ab
TN1	9	–	–	–	89 ab	0.000 k

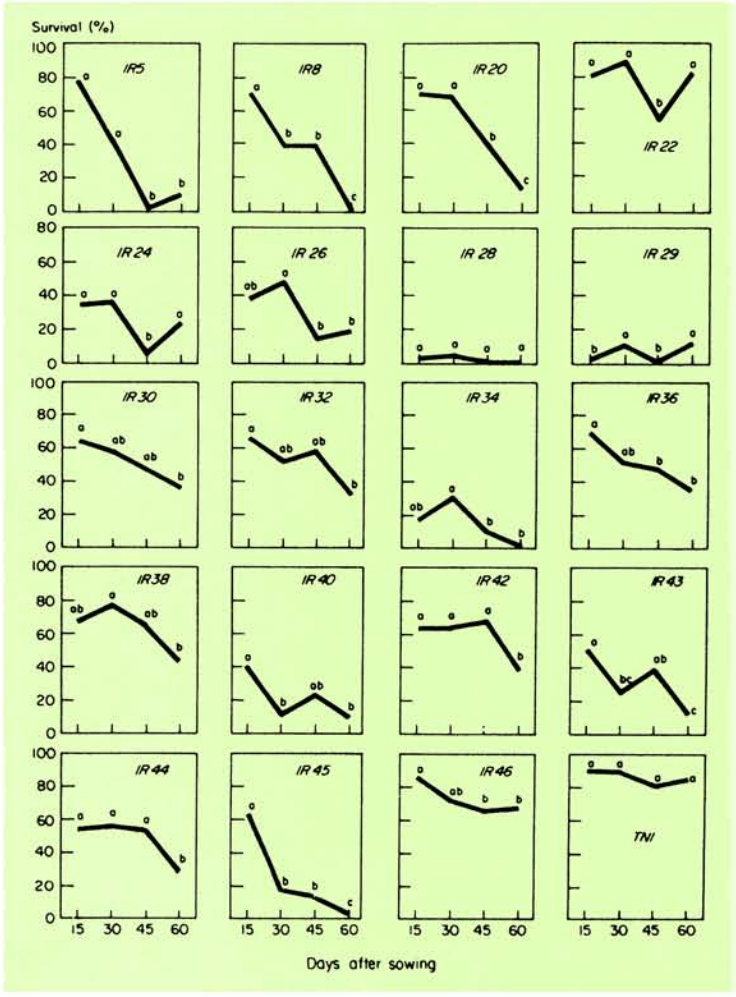
[a]Mean of 3 replications in the seedling bulk test. 1-3 = resistant, 5-7 = moderately resistant, 9 = susceptible. [b]DS = days after seeding. Mean of 3 replications. [c]Separation of means in a column by Duncan's multiple range test at the 5% level.

factor in resistant varieties. The genetic variability is exemplified by the various color forms in the species. Three color forms were isolated from culture — predominant brown, black, and red. These forms differ in ability to damage and to survive and multiply on resistant varieties (Fig. 10). The red forms build up a high population on Mudgo, with the *Bph 1* gene for resistance, and ASD7, with *Bph 2* gene for resistance. The black and brown forms have low populations on these varieties.

Biotype selection *(Entomology).* Because of the genetic variability within the species, a small proportion of individuals are able to feed on and damage a variety that is resistant to other individuals in the same population. When a resistant variety is planted over a wide area, these virulent individuals increase, becoming predominant after several generations. To keep ahead of the biotype selection process, scientists must be able to evaluate breeding lines for resistance to a particular biotype before it becomes predominant in the field. In this way, varieties with genes for resistance to a particular biotype can be released as soon as a current variety becomes susceptible because of a shift in the insect biotype.

With the technique shown in Figure 11, biotypes can be selected in the greenhouse, and breeding lines screened against them. A test of this technique was done with IR36, a brown planthopper-resistant variety now grown throughout Indonesia, Philippines, and the southern portion of Vietnam. Using the scheme, a biotype that kills IR36 in the seedling stage has been selected and IR breeding lines are being evaluated for resistance to it. Lines IR13543, with the *Bph 3* gene, and IR13240, with the *bph 4* gene, are resistant to the biotype 3 that kills IR36, and to biotypes 1 and 2. The majority of elite IR breeding lines evaluated in 1981 are resistant to the three biotypes (Fig. 12).

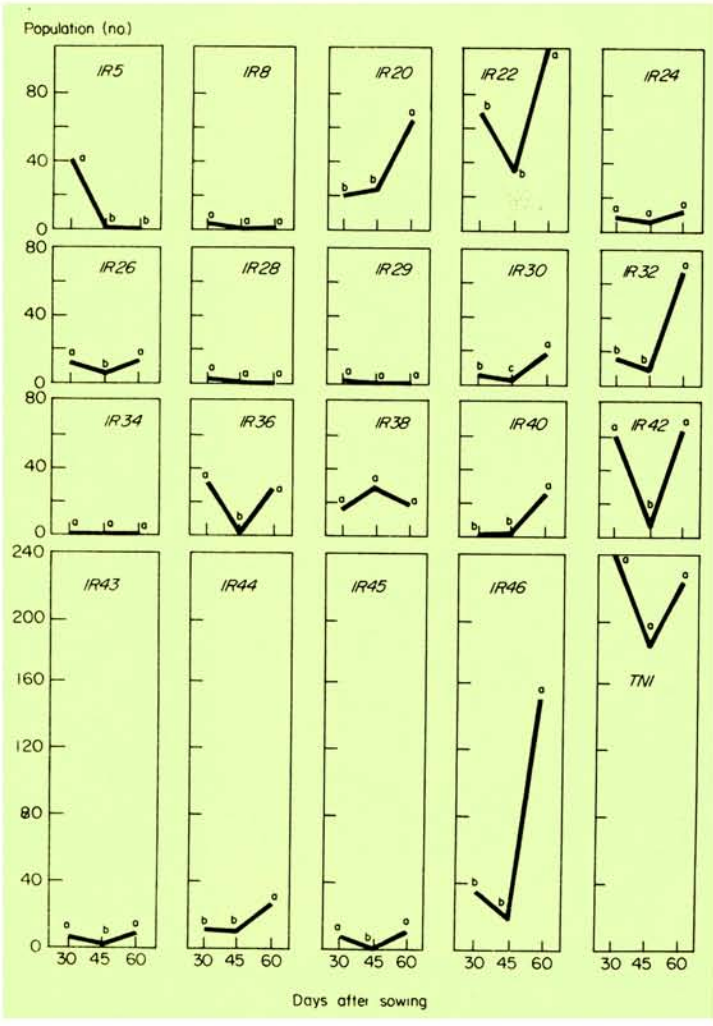
Cytogenetic variations in BPH biotypes 1 and 2 *(Entomology).* Chromosome number, morphology, and behavior are often used as complemen-



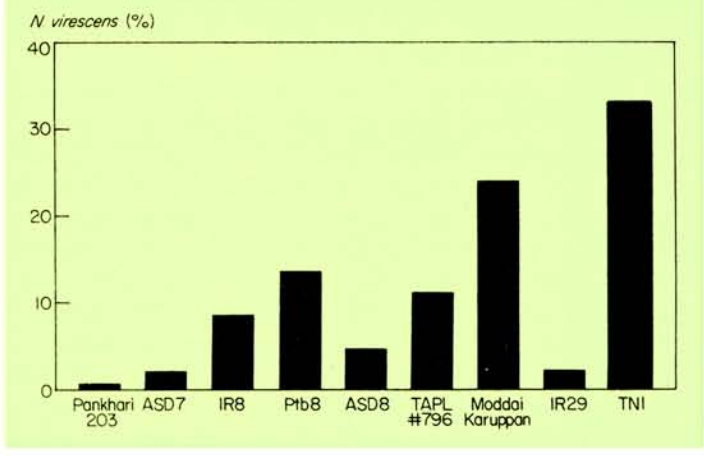
3. Survival of green leafhopper nymphs on IR varieties. First-instar nymphs were placed on the plants at 4 different dates after sowing; survival was recorded 15 days after infestation. IRRI, 1981.

tary taxonomic indicators in a number of species complexes. Sex chromosomes are especially useful in cytotaxonomy because they may show marked to subtle differences within a genus or species. In 1981, cytological investigations of the meiotic chromosomes of the BPH biotype 1 and 2 populations, maintained as stock cultures at IRRI for several years, showed that the first meiotic division was reductional and the second division equational for all components of the species' genome. The male diploid number was 2n = 30, consisting of 14 bivalent autosomal pairs and XY sex chromosomes. Thus, *Nilaparvata lugens* has an XY sex-determining mechanism, the males heterogametic (14 π + XY), or producing 2 types of secondary spermatocytes, and the females homogametic (14 π + XX), producing only type of secondary oocytes.

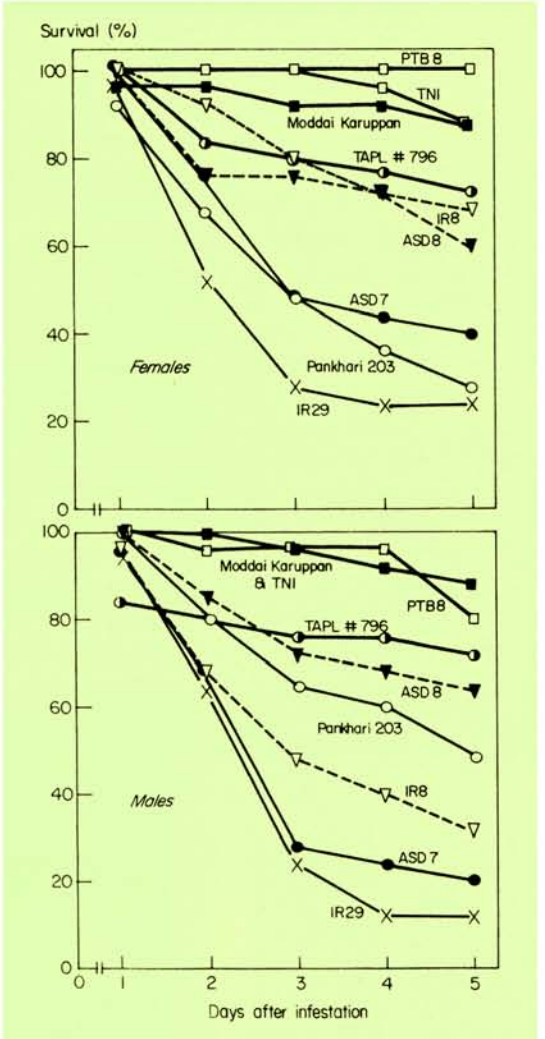
Chromosomal behavior during metaphase I featured clustering of highly condensed and shortened autosomes at the equatorial portion of the reproductive cell, and separation of the highly heterochromatic, unequally synapsed sex chromosome from the autosomal grouping. The clustering of autosomes is due mainly to intrachiasmatic and interchiasmatic matrices between the homologous bivalent chromosomes and among the tetrads or homologues.



4. Growth of green leafhopper populations on IR varieties. Five pairs (♂ and ♀) were placed in a cage with 4 hills at different days after sowing; populations were recorded 30 days after infestation. IRRI, 1981.



5. Preference, 1 day after infestation, of 2d-instar *N. virescens* nymphs for rice varieties with different genes for resistance (% insects on variety). IRRI, 1980.



6. Survival of *N. virescens* adult females and males on rice varieties with different genes for resistance. IRRI, 1980.

Table 16. Number of *N. virescens* eggs laid and hatchability of varieties with genes for resistance. IRRI, 1980.

Variety[a]	Eggs laid[b] (no.)	Egg hatchability[b] (%)
Pankhari 203	28.0 e	95.7 a
ASD7	35.2 de	97.2 a
IR8	89.2 bc	98.4 a
Ptb 8	102.0 b	97.2 a
ASD8	136.0 b	96.2 a
TAPL #796	118.2 b	99.5 a
Moddai Karuppan	133.4 b	99.1 a
IR29	52.2 cd	95.0 a
TN1	321.8 a	96.4 a

[a]Thirty-day-old plants. [b]Av of 5 replications with 5 adults/replication. Separation of means in a column by Duncan's multiple range test at the 5% level.

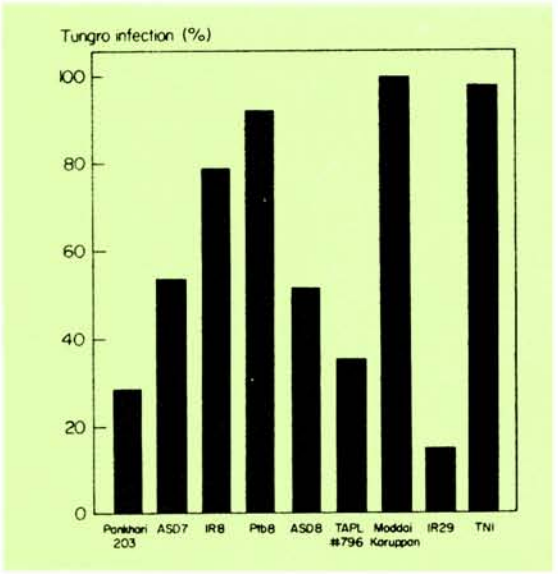
Table 17. *N. virescens* nymphal survival[a] and reproduction[b] on varieties with genes for resistance. IRRI, 1980.

Variety	Survival[c] (%)	Progeny[d] (no./female)
Pankhari 203	22.5 c	3.1 d
ASD7	0.0 e	0.0 d
IR8	15.0 cd	0.1 d
Ptb 8	32.5 c	17.4 b
ASD8	20.0 cd	0.4 d
TAPL #796	32.5 c	5.0 c
Moddai Karuppan	67.5 b	49.1 a
IR29	7.5 de	0.3 d
TN1	35.0 a	79.4 a

[a]Av of 4 replications; 10 first-instar nymphs were used for infestation per replication. Data taken 15 days after infestation. [b]Mean of 4 replications. [c]Thirty-day-old plants were used. [d]Separation of means by Duncan's multiple range test at the 5% level.

A total of 218 and 200 metaphase I stages in testicular cells from 60 newly emerged males each of BPH biotypes 1 and 2 were examined. In biotype 1, 147 (68%) cells showed complete aggregation of sex chromosomes with autosomes, while the rest of the cells showed a slight separation of sex chromosomes from the autosomes. In biotype 2, almost 100% of the observed metaphase I chromosomes of testicular cells manifested complete isolation of the sex chromosomes from the autosomal groupings. The sex chromosomes are more isolated from autosomes in biotype 2 than in biotype 1. The extent of chromosome clustering also was higher in biotype 2 than in biotype 1 (Fig. 13, 14). The occurrence of chromosomal aberrations as loose pairings of paired homologous bivalents as well as fragmentations or chromosomal deletions were more frequent among the chromosomes of biotype 1 than among those of biotype 2. Further cytogenetic studies are in progress.

International collaborative project on BPH biotypes *(Entomology).* Reactions of differential varieties to BPH feeding in tests conducted throughout Asia showed that the South Asian BPH population is distinct from the Oceania, East Asia, and Southeast Asia population. Within India, there may be slight differences in the Hyderabad, Coimbatore, and Pantnagar populations (Table 19).



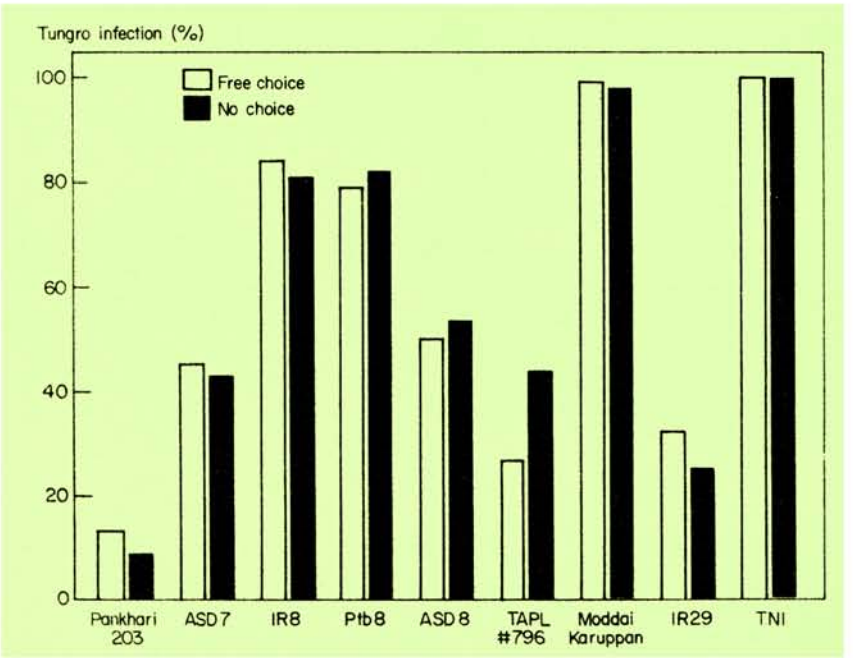
7. Tungro virus-infected plants in rice varieties with different genes for *N. virescens* resistance. Five hoppers that had fed on virus-infected plants were placed on 14-day-old seedlings, 20/pot, in the greenhouse. Virus infection was recorded 21 days after infestation. IRRI, 1980.

Four distinct BPH biotypes can be recognized in Asia. The wild-type populations in East and Southeast Asia and Oceania belong to biotype 1. Biotype 2 became predominant in the Solomon Islands, Indonesia, Philippines, and Vietnam after IR26 was widely grown. Biotype 3 is being maintained in the laboratory in the Philippines. Biotype 4 occurs in India, Bangladesh, and Sri Lanka.

At Pantnagar in India, all BPH-resistant varieties have been classified susceptible. Varieties with *Bph 1* gene are resistant to biotypes 1 and 3, varieties with *bph 2* gene are resistant to biotypes 1 and 2. Varieties with *Bph 3* and *bph 4* genes are resistant to most biotypes, possibly except the Pantnagar (India) population.

Donor sources (Babawee, Balamawee, and Sinna Sivappu) and advanced breeding lines IR13240 and IR17494 were resistant or moderately resistant at all sites except Pantnagar.

Resistance of IR breeding lines to BPH biotypes *(Entomology and Plant Breeding).* Because of the



8. Tungro virus infection in rice varieties with different genes for *N. virescens* resistance. In the free-choice treatment, viruliferous hoppers were placed in fiberglass screen cages containing one field plot of all varieties. In the no-choice treatment, each cage contained one field plot of a single variety. One hundred hoppers that had fed on virus-infected plants were released in the center of each plot 5 days after transplanting. Virus infection was recorded 30 DT. IRRI, 1980.

Table 18. Correlation between tungro virus infection and insect resistance. IRRI, 1980.

Insect resistance	Correlation coefficient[a]	
	Tungro infection in greenhouse	Tungro infection in field
Seedling preference	0.799**	0.807**
Oviposition rate	0.601	0.644
Survival of nymphs	0.664	0.645
Survival of adults (♂)	0.680*	0.566
Survival of adults (♀)	0.864**	0.786*
Population growth	0.702*	0.717*

[a]Significance at the 5% level, * = 0.666 and significance at the 1% level, ** = 0.798.

possible selection for a BPH biotype capable of destroying widely grown IR36 and other varieties having the *bph 2* gene (biotype 3), breeding lines with multiple resistance to biotypes 1, 2, and 3 are being developed. In GEU elite lines screened in the 1981 dry season, 40% were resistant to all 3 biotypes (RRR); in the wet season, 50% were resistant (Fig. 12). Only about 10% were susceptible to all 3 biotypes (SSS).

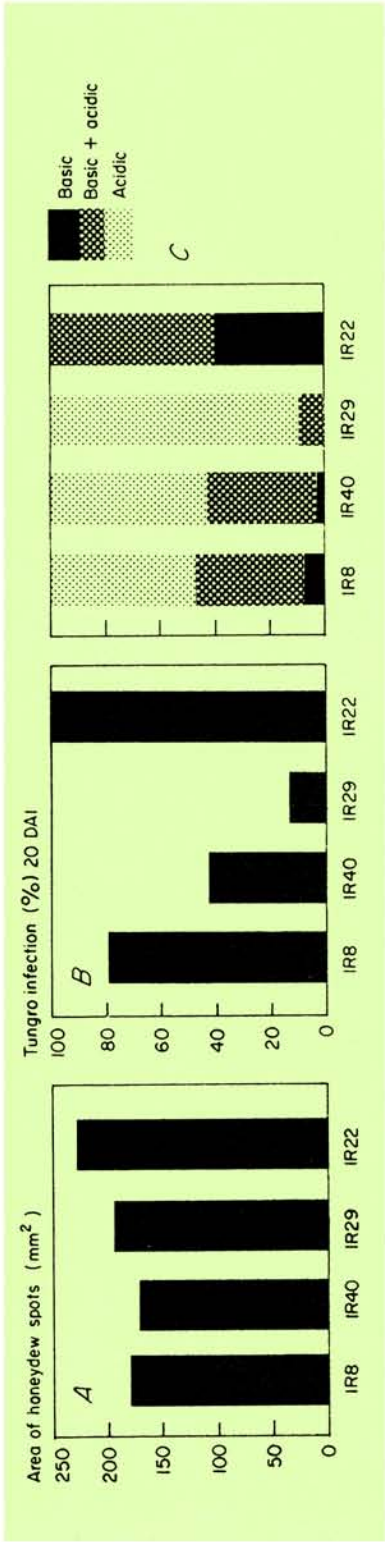
MECHANISMS OF INSECT RESISTANCE

Entomology and Chemistry Departments

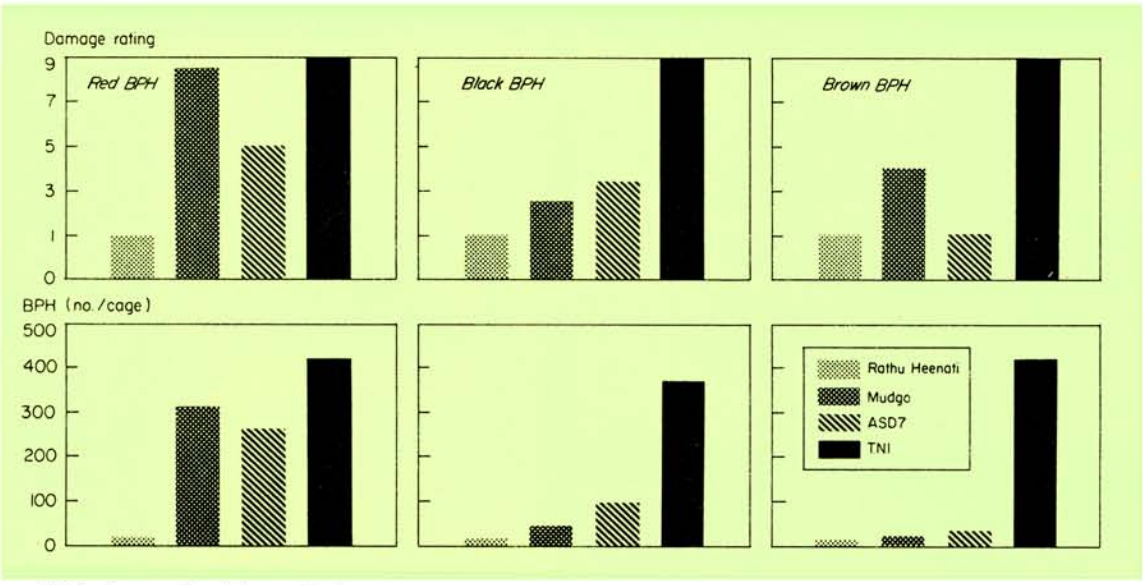
Resistance of wild rices to BPH *(Entomology).* Wild rices are possible sources of new genetic resistance to rice insects. In the screening of about 200 wild-rice accessions for resistance to major rice insects at IRRI, several had resistance to biotypes 1, 2, and 3. These accessions were retested to confirm the resistance. Several varieties had high levels of resistance to all three biotypes (Table 20).

In feeding studies, honeydew excretion was low on the resistant varieties (Table 21). The small amount of honeydew excreted on resistant varieties produced a pale-colored spot on bromocresol green-treated filter paper, indicating that the hopper was feeding in the xylem. This is similar to the feeding of the GLH on resistant varieties (Annual report for 1980).

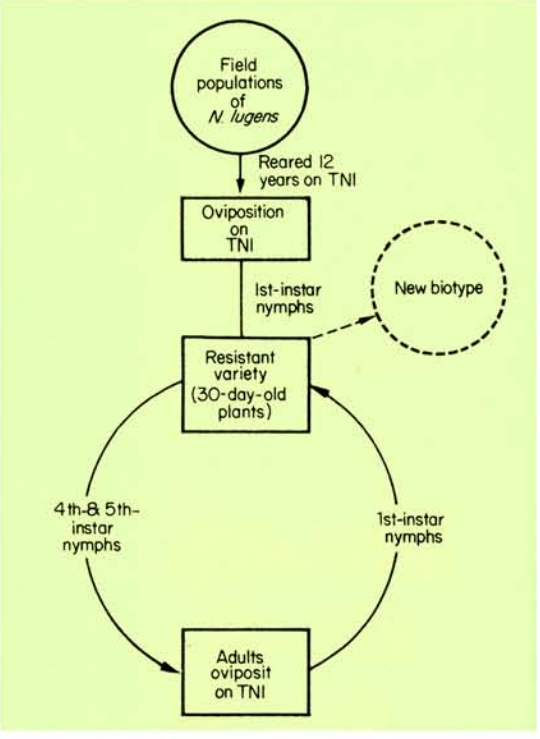
Because of the low feeding activity and lack of nutrients in the xylem, hopper development was retarded on resistant varieties (Table 22). In resistant *O. punctata*, the BPH population was only 18 at 20 days after infestation. Most of the few survi-



9. Two tungro-viruliterous green leafhopper (GLH) adults were allowed to feed on plants of 4 varieties for 22 h. The area of honeydew on bromocresol green-treated filter paper for the varieties was about the same, but tungro infection, 20 days after inoculation (DAI) feeding, was low for IR29, which is GLH resistant. Resistance is also shown in the high percentage of acidic honeydew, indicating that the hoppers were feeding in the xylem rather than in the phloem. IR22 is a susceptible variety. IRRI, 1981.

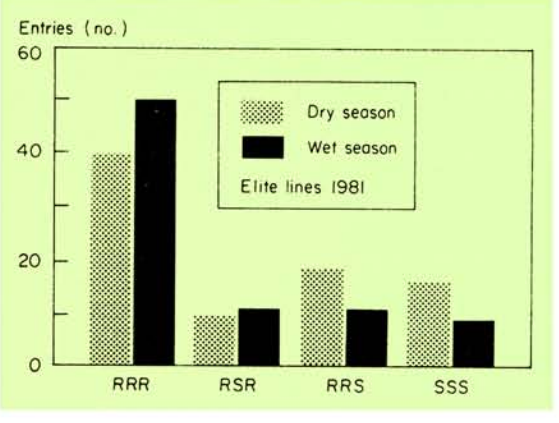


10. Resistance of varieties to 3 BPH color strains. IRRI, 1981.



11. Schemata for selecting biotypes that feed on and destroy resistant varieties.

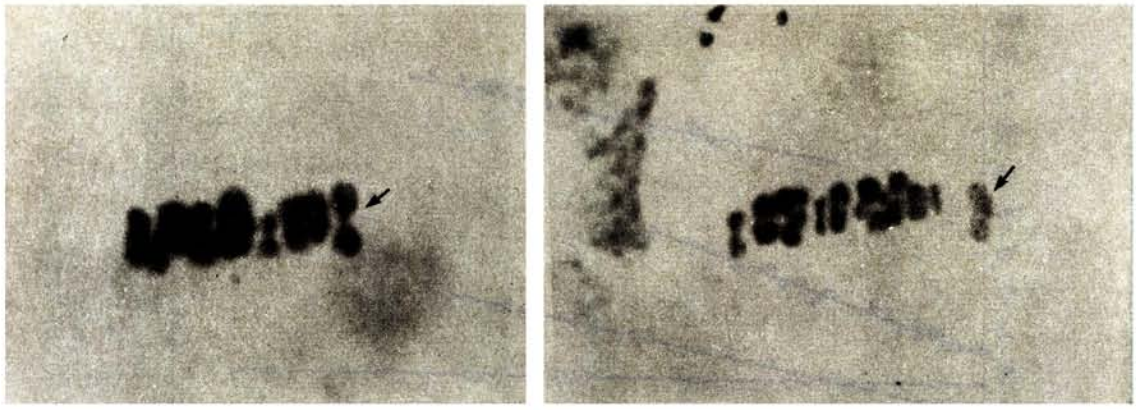
vors were in the 4th instar and none had become adults. In susceptible *O. perennis*, the population was 567. Most were in the 5th instar and 35 had become adults.



12. Resistance of IRRI elite breeding lines to 3 brown planthopper biotypes, based on the seedling bulk screening test for plant damage. Letters indicate reactions to biotypes 1, 2, and 3 (R = resistant and S = susceptible). IRRI, 1981.

Studies on preference indicated that highly resistant varieties were not preferred. *O. minuta* from the Philippines had only 2 insects/10 seedlings; susceptible *O. rufipogon* from Cuba had 80 insects/10 seedlings.

Tolerance for BPH attack *(Entomology).* Using tolerance as one of several strategies to cope with the BPH biotype problems is being considered. Tolerance refers to the ability of a variety to grow and produce grain or to repair injury in spite of supporting an insect population approximately equal to one that destroys a susceptible variety.



13. Metaphase I chromosomes in testicular cells of brown planthopper biotype-1 males. Sex chromosomes are pointed out by arrows. IRRI, 1981.

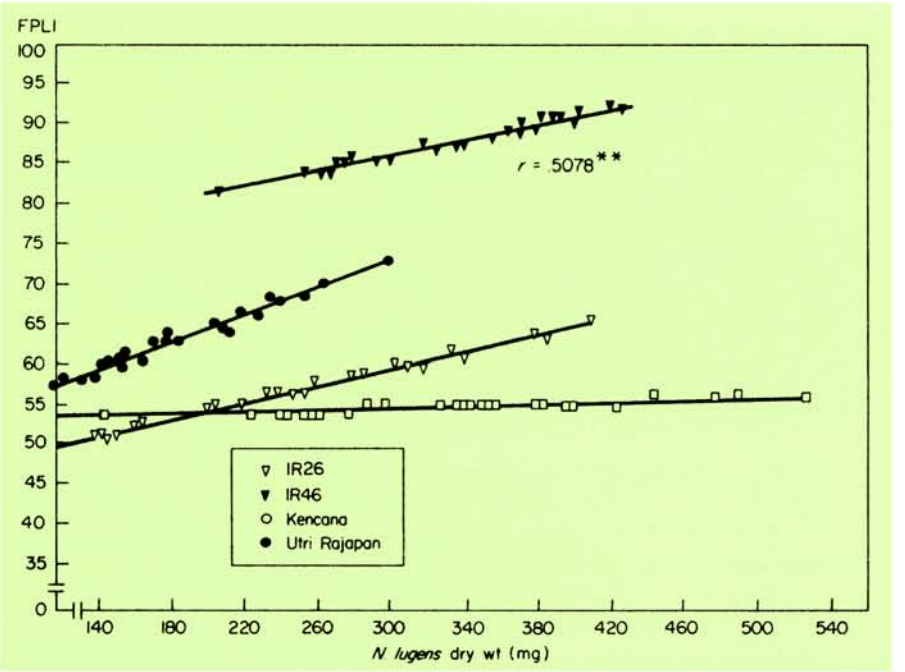
Because tolerance exerts no selection pressure on the insect, it does not cause a shift in the biotype, and the variety retains its tolerance. But tolerance alone does not decrease the insect population. The objective is to combine tolerance with the antibiosis controlled by major genes, which provide a high level of resistance. In such a variety, a biotype that can overcome the antibiosis controlled by a major gene could become predominant. But that would not be a catastrophe, because the tolerance mechanism would allow the variety to produce some grain in spite of high insect populations. Such a variety would allow scientists to detect a shift in the biotype in farmers' fields and to replace the variety with another that is resistant to the new biotype



14. Metaphase I chromosomes in a testicular cell of a brown planthopper biotype-2 male. Sex chromosome is pointed out by arrow. IRRI, 1981.

Table 19. Brown planthopper biotypes based on response of varieties.

Biotype	Response
Philippine biotype 1, China, Japan, Korea, Malaysia, Taiwan, China (field), and Thailand	• Resistant or moderately resistant: IR26, ASD7, Rathu Heenati, Babawee, Ptb 33 • Susceptible: ARC 10550, TN1
Philippine and Vietnam biotype 2, Solomon Islands	• Resistant: ASD7, Rathu Heenati, Babawee, Ptb 33 • Susceptible: IR26, ARC 10550, TN1
Philippine biotype 3 and Taiwan, China biotype 3	• Resistant: IR26, Rathu Heenati, Babawee, Ptb 33 • Susceptible: ASD7, ARC 10550, TN1
Bangladesh and Hyderabad, India	• Resistant or moderately resistant: Rathu Heenati, Babawee, Ptb 33, ARC 10550 • Susceptible: IR26, ASD7, TN1
Coimbatore, India	• Resistant: Babawee, Ptb 33, ARC 10550 • Susceptible: Rathu Heenati, IR26, ASD7, TN1
Pantnagar, India	• Susceptible: IR26, ASD7, Rathu Heenati, Babawee, Ptb 33, ARC 10550, TN1



15. Regression on functional plant loss index (FPLI) vs *N. lugens* dry weight. IRRI, 1981.

Table 20. Selected wild rice varieties screened for resistance to the brown planthopper.[a] IRRI, 1981.

Variety	IRRI acc. no.	Origin	Damage rating[b]		
			Biotype 1	Biotype 2	Biotype 3
O. perennis	100844	Madagascar	9	9	8
O. punctata	101409	Ghana	2	3	3
O. punctata	100954	Japan	1	1	2
O. punctata	100937	China	2	2	1
O. minuta	101081	Philippines	1	2	1
O. rufipogon	100184	Cuba	8	8	8
O. rufipogon	100910	Thailand	5	4	4
O. latifolia	100914	Mexico	2	3	2
O. latifolia	100956	India	2	3	3
O. latifolia	100964	Guatemala	3	3	3
O. latifolia	100962	Guatemala	2	2	3
O. nivara	102165	India	2	3	3
O. officinalis	101155	Malaysia	1	1	1
TN1			9	9	9
IR26			3	8	3
ASD7			3	3	7

[a]Modified bulk screening test. [b]Means of 3 replications. 1 = no damage, 9 = all plants dead.

Table 21. Honeydew excretion of BPH biotype 2 on wild rice varieties. IRRI, 1981.

Variety	IRRI acc. no.	Resistance	Honeydew area[a] (mm^2)		
			Blue color[b]	Pale color[c]	Total
O. perennis	100844	S	852.0 a	7.8 c	859.8 a
O. rufipogon (Cuba)	100184	S	638.6 ab	12.6 bc	651.2 ab

Continued on opposite page

Table 21 continued

Variety	IRRI acc. no.	Resistance	Honeydew area[a] (mm²)		
			Blue color[b]	Pale color[c]	Total
O. punctata	100954	R	6.2 c	47.6 ab	53.8 c
O. latifolia	100962	R	50.0 c	27.6 abc	77.6 c
O. rufipogon (Thailand)	100910	MR	152.0 c	65.2 a	217.2 c
O. nivara	102165	R	100.6 c	27.5 abc	128.1 c
TN1		S	735.6 ab	12.2 bc	747.8 ab
ASD7		R	146.8 c	44.2 abc	191.0 c
IR26		S	514.2 b	25.0 bc	539.2 b

[a]Five replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Blue spots produced by honeydew bromocresol green-treated filter paper indicate a basic reaction because the insect is feeding in the phloem. [c]A pale color on the filter paper indicates an acidic reaction due to xylem feeding.

Table 22. Growth of BPH biotype 2 populations on selected wild rice varieties.[a] IRRI, 1981.

Variety	IRRI acc. no	Resistance	Insects[b] (no.)				
			3rd instar	4th instar	5th instar	Adult	Total
O. perennis	100844	S	102.2 abc	212.4 a	216.8 a	35.4 a	566.8 a
O. rufipogon (Cuba)	100184	S	36.2 bcd	62.0 a	199.8 a	27.8 a	325.8 a
O. punctata	100954	R	5.6 d	10.8 b	2.0 d	0.0 b	18.4 c
O. latifolia	100962	R	34.0 bc	43.4 a	13.6 c	0.2 b	91.2 b
O. rufipogon (Thailand)	100910	MR	104.8 ab	158.6 a	281.2 a	20.6 a	565.2 a
TN1		S	49.2 cd	163.6 a	321.4 a	18.6 a	552.8 a
ASD7		R	79.6 ab	133.0 a	22.4 c	1.6 b	236.6 b
IR26		S	218.2 a	222.2 a	160.4 ab	18.2 a	619.0 a

[a]Three pairs (female and male) of BPH biotype 2, 3 days after emerging on IR26 variety, were released in each cage. Observations made 20 days after infestation were on adults. [b]Av of 5 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

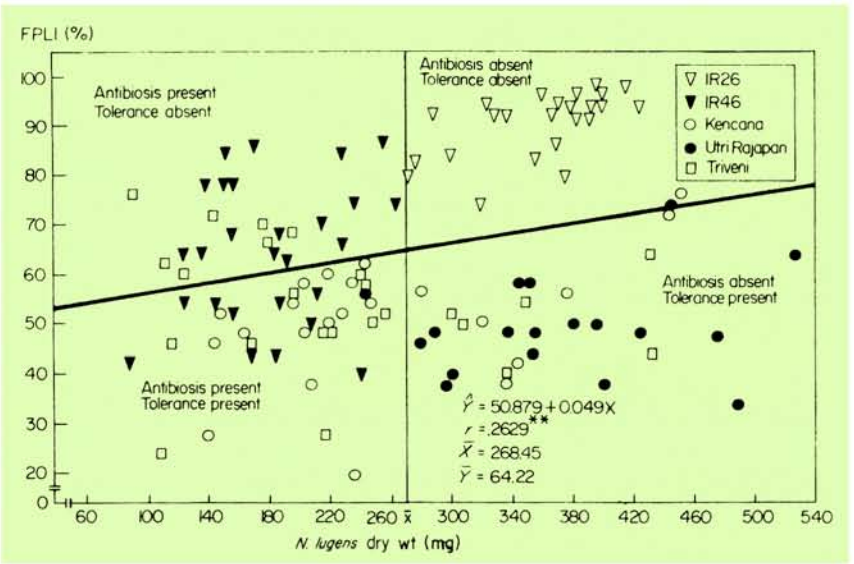
before severe losses are incurred.

The lack of a technique to identify and measure levels of tolerance has been a constraint to breeding for tolerance. In 1980, the variety Triveni was reported to have some levels of tolerance. In 1981, Utri Rajapan was identified, by different techniques, as a variety with high levels of tolerance. To measure tolerance, the dry weight of insects produced by the plants and the functional plant loss index were used.

$$\text{Functional plant loss index (FPLI)} = 1 - \frac{\text{dry wt of infested plants}}{\text{dry wt of uninfested plants}} \times 1 - \frac{\text{av plant damage score}}{9} \times 100$$

A variety that produces an insect population with a dry weight equal to that of a susceptible variety is considered to have no antibiosis (antibiosis decreases the population). Utri Rajapan produced the same dry weight of insects as IR26, which is susceptible to BPH biotype 2. However, the FPLI of Utri Rajapan (55%) was much lower than that of IR26 (90%), even though the two varieties maintained similar insect populations (Fig. 15). The other moderately resistant varieties (IR46, Kencana, and Triveni) had lower FPLIs than IR26 because of the combination of both tolerance and antibiosis.

The tolerance index in Utri Rajapan (1.0) was significantly higher than that in other moderately resistant varieties. The regression estimates for FPLI in test varieties on BPH dry weight were highly significant, with a steep slope for IR26 ($r = 0.5076^{**}$) and a flat slope for Utri Rajapan (Fig. 15). The pooled regression of all the varieties was also highly significant ($r = 0.2629^{**}$) (Fig. 16). This regression separates the components of antibiosis and tolerance in the varieties. Utri Rajapan has high tolerance and no antibiosis while IR46,



16. Identification of components of resistance to brown planthopper (*Nilaparvata lugens*) using paper dry weight (antibiosis indicator) and functional plant loss index (FPLI) (tolerance indicator) in some moderately resistant rice varieties. IRRI greenhouse, 1982.

Kencana, and Triveni have tolerance and antibiosis. IR26 is susceptible, with neither antibiosis nor tolerance.

Biochemical bases of stem borer resistance *(Chemistry and Entomology).* The study of volatile oils from plants of varieties resistant (TKM6, Taitung 16) and susceptible (Rexoro) to striped stem borers continued. Volatile oils from the steam distillation of TKM6, Taitung 16, and Rexoro (control) were fractionated by elution on an activated magnesium silicate column with organic solvents of increasing polarity. Bioassays based on mortality from the topical application on four insect pests and one disease organism indicated some separation of insecticidal activities. However, gas chromatography-mass spectrometry of the TKM6 and Rexoro crude oils and their chromatographic fractions at the Laboratory of Chemical Evolution, University of Maryland at College Park, showed the complexity of these partially purified oils and solids. At least 11 component compounds were identified.

The oviposition-deterrent compound previously identified by Tropical Products Institute (TPI, London) was readily assayed from the direct ether extract of fresh TKM6, Rexoro, and Taitung 16 plants ground with dry ice and injected into a gas chromatograph, using the analytical method developed by TPI. A survey of this compound in the fractions of TKM6 and Rexoro oils showed that its elution was in one specific fraction. As expected, the level of this oviposition deterrent compound in both fresh plants and volatile oils was higher in TKM6 than in Rexoro.

Biochemical bases of brown planthopper resistance *(Entomology and Chemistry).* In 1981, nutritional and allelochemic differences were evaluated in rice varieties with different genes for BPH biotype 1 resistance: Mudgo (*Bph 1* gene), ASD7 (*bph 2* gene), Rathu Heenati (*Bph 3* gene), Babawee (*bph 4* gene), Ptb 33 (2 genes), and moderately resistant ARC 6650 (genetic composition of which has not yet been studied). TN1, with apparently no gene for resistance, was the susceptible check.

No major differences in total amino acid composition, free amino acids, and total sugars and starch were observed among the test varieties. Only Rathu Heenati and Ptb 33 had lower amino acid compositions than susceptible TN1.

The allelochemics of resistant and susceptible varieties were obtained by steam distillation of their leaf sheaths, followed by diethyl ether extraction. Topical application of the extract of the resistant varieties caused a significantly higher mortality of BPH adult females than did topical application of the extract of TN1 (Table 23). The

Table 23. Toxicity of steam distillate extracts of susceptible and resistant (R) rice varieties topically applied to newly emerged, brachypterous BPH biotype-1 females. IRRI, 1981.[a]

Variety	Corrected mortality (%) 24 h after topical application to each insect of extract at	
	10 μg/0.1 μg acetone	20 μg/0.1 μg acetone
TN1 (susceptible check)	14.9 a	31.8 a
Mudgo (R)	37.3 bc	59.2 bcd
ASD7 (R)	35.4 bc	56.4 bc
Rathu Heenati (R)	29.9 bc	63.9 bc
Babawee (R)	34.4 bc	58.9 bc
Ptb 33 (R)	40.9 c	70.8 d
ARC 6650 (R)	26.8 bc	51.7 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level; av of 4 replications, 10 insects/replicate.

Table 24. Toxicity of steam distillate extract of rice varieties susceptible and resistant (R) to 1st-instar BPH biotype-1 nymphs. IRRI, 1981.[a]

Variety[b]	Mortality (%) 24 h after caging on tillers sprayed with extract at	
	0.5 mg[c]	1.0 mg[c]
TN1 (susceptible check)	0.0 a	40.2 a
Mudgo (R)	10.0 ab	70.2 b
ASD7 (R)	15.8 bc	61.1 b
Rathu Heenati (R)	20.8 bcd	73.3 b
Babawee (R)	24.3 cd	71.1 b
Ptb 33 (R)	32.1 d	70.1 b
ARC 6650 (MR)	34.6 d	51.5 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level; av of 4 replications; 10 1st-instar nymphs/replicate. [b]R = resistant, MR = moderately resistant. [c]Per 30-year-old TN1 plant.

mortality of first-instar nymphs caged on TN1 tillers sprayed with the extract of resistant varieties was significantly higher than that of nymphs caged on tillers sprayed with the extract of TN1 (Table 24). The extract from 60-day-old resistant plants was more toxic than that from 30-, 45-, or 100-day-old resistant plants. However, toxicity from the susceptible variety remained low at all plant growth stages.

In a multichoice phagostimulation test, 10% sucrose solution incorporated with the steam distillate extract of the susceptible variety stimulated greater ingestion of the sucrose solution by BPH females than did sucrose solution alone or sucrose solution incorporated with the extract of resistant varieties (Table 25). In another multichoice test,

Table 25. Relative intake of sucrose solution incorporated in parafilm sachets with steam distillate extract of susceptible and resistant (R) rice varieties simultaneously offered for feeding to brachypterous BPH biotype-1 females. IRRI, 1981.[a]

Variety	Solution ingested daily[b] (mg/20 ♀♀)
TN1 (susceptible check)	12.0 a
Mudgo (R)	4.6 bcd
ASD7 (R)	12.5 a
Rathu Heenati (R)	2.4 cd
Babawee (R)	6.5 bc
Ptb 33 (R)	0.6 d
ARC 6650 (R)	7.9 b
Sucrose (control)	6.3 bc

[a]0.1 mg of extract per parafilm sachet incorporated with 0.5 ml of 10% sucrose solution and offered to newly emerged females. [b]Separation of means by Duncan's multiple range test at the 5% level; av of 4 replications.

Table 26. Settling response of BPH biotype 1 females in a test cage simultaneously offered TN1 plants sprayed with steam distillate extract of susceptible or resistant (R) varieties. IRRI, 1981.[a]

Plant extract sprayed	Insects settled after 24 h[b] (%)
Control (acetone)	33.6 a
TN1 (susceptible check)	17.0 ab
Ptb 33 (R)	10.3 bc
ARC 6650 (R)	4.9 c

[a]Separation of means by Duncan's multiple range test at the 5% level; av of 4 replications, 50 insects/replicate. [b]Response was calculated on basis of total insects released in a cage.

Table 27. Leaffolder moth eggs laid on rice varieties.[a] IRRI, 1981.

Variety	Damage rating[b]	Eggs laid[c] (no.)	Larval survival[d] (%)
TN1	9.0	38.3 a	55.0 abc
GEB 24	3.7	21.3 ab	48.3 bc
W1263	3.7	37.3 a	51.7 abc
Peta	6.3	36.0 a	46.7 bc
Intan	4.3	27.7 a	48.3 bc
IR4707-106-3-2	4.3	31.0 a	50.0 bc
IR20	6.3	25.0 ab	51.7 abc
IR36	5.7	26.7 a	70.0 ab
IR50	5.7	20.7 ab	71.7 a
TKM6	3.0	12.0 b	40.0 c

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]1-3 = resistant, 4-6 = moderately resistant, 7-9 = susceptible. [c]Potted plants of all varieties were equal to 35-day-old potted plants of all the varieties simultaneously exposed for 48 h to ovipositing moths in a cage. [d]Twenty 1st-instar larvae were placed on a variety in a pot and survival was recorded at 17 days after infestation.

more BPH females settled and fed on TN1 tillers sprayed with TN1 extract and on acetone-sprayed tillers than on tillers sprayed with the extract of resistant Ptb 33 or ARC 6650 (Table 26).

Gas chromatographic analyses of steam distillate extracts of resistant and susceptible varieties showed distinct qualitative and quantitative differences among their volatiles. These fingerprints of the steam distillate volatiles illustrate basic chemotaxonomic differences between the BPH-susceptible and -resistant rice varieties.

Resistance to leaffolder *(Entomology).* The mechanisms of resistance in cultivars GEB 24, W1263, IR4707-1-6-3-2, and TKM6 with moderate levels of resistance (Table 27); traditional varieties Peta and Intan, and modern varieties IR20, IR36, and IR50 were studied. TKM6 had the lowest damage rating, was less preferred for oviposition, and caused lower larval survival than the other varieties. Further studies indicated that levels of resistance in GEB 24 and TKM6 increased between 30 and 60 days' plant age (Table 28).

Table 28. Damage ratings of rice varieties exposed to leaffolder larvae at 3 plant ages. IRRI, 1981.

Variety	Damage rating[a]		
	30 days old	45 days old	60 days old
TN1	9.0 a	9.0 a	9.0 a
GEB 24	6.6 b	5.0 ab	3.5 b
TKM6	6.3 b	3.9 b	3.2 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. 1-3 = resistant, 4-6 = moderately resistant, 7-9 = susceptible.

Genetic evaluation and utilization (GEU) program

Nutritional value

Chemistry, Plant Breeding, Plant Physiology, and Statistics Departments

EVALUATION TRIALS **78**
- Protein content of promising lines **78**
- Tracer and histochemical studies **78**
- Detached-panicle system **78**
- Sulfur amino acids and sulfur-deficient soils **79**
- Rice/wheat hybrid and higher lysine rice **79**

FEEDING TRIALS **80**
- Protein quality of milling fractions **80**
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OTHER NUTRIENTS **82**
- Nutrient content of washing and cooking water **82**
- Fatty acids of rice and corn oils **82**

Chemistry, Plant Breeding, Plant Physiology, and Statistics Departments

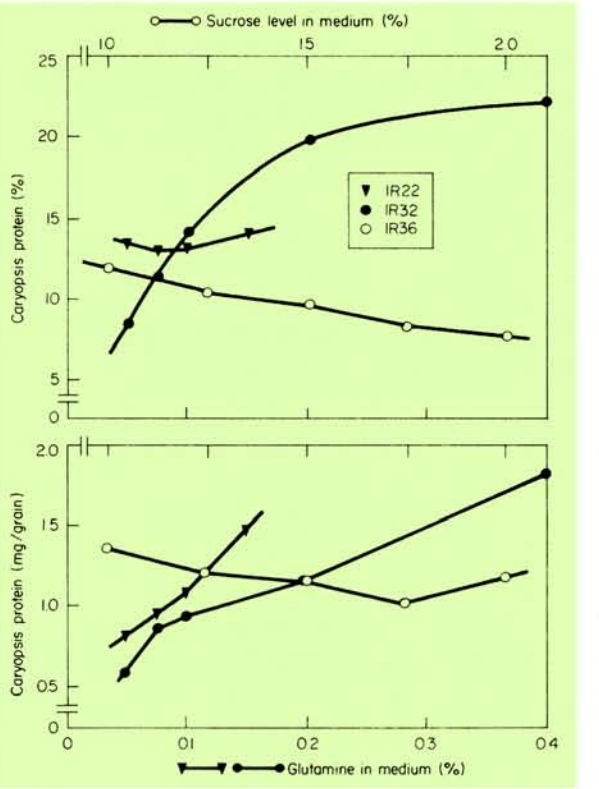
Protein content of promising lines *(Chemistry, Plant Breeding, and Statistics).* Analysis of the protein content of brown rice and milled rice of promising (elite) lines continued. Protein content was at least maintained in the elite lines, taking into consideration the variability due to environmental factors. Milled rice of the promising selection IR9752-71-3-2 showed high protein content (10.4%) in both dry- and wet-season crops.

Tracer and histochemical studies *(Chemistry and Plant Breeding).* A cooperative study with the Botany Department, University of Durham, England, on factors limiting nutrient translocation into the developing rice grain used rices supplied by IRRI. Translocation was found to occur through the dorsal vascular bundles of the caryopsis, through the pigment strand, circumferentially into the nucellus surrounding the aleurone layer, through the many plasmodesmata in nucellus cell walls.

The rate-limiting step was probably the passage of nutrients from the nucellus to the aleurone layer and subsequent subaleurone layer, which do not have connecting plasmodesmata. Electron microscopy showed that mitochondria lined the outer periclinal cell walls, indicating the need for active transport of nutrients through these walls. The water from translocation was probably removed through the pigment strand into the xylem, then into the hull for evaporation.

Detached-panicle system *(Chemistry).* Earlier studies have shown that increasing the glutamine level in the nutrient medium for detached rice panicles results in a drastic increase in the protein of the developing grain, particularly if the sucrose level was kept constant at 1.0% (Annual reports for 1977 and 1978) (Fig. 1). When the sucrose-glutamine ratio was kept constant at 10, the percentage protein did not change as much, but protein weight per grain increased, indicating that both nutrients are translocated into the developing grain at parallel rates.

To complete the study, the effect of sucrose level on protein accumulation in developing grains of IR36 was measured during 10 days in detached



1. Effect of sucrose and glutamine levels in liquid medium on the caryopsis protein of developing grains (IR22 at sucrose-glutamine ratio of 10, IR32 at constant 1% sucrose level, IR36 at constant 0.06% glutamine level). Detached-panicle culture, IRRI, 1977-81.

panicle culture with the glutamine level held constant at 0.06%.

In general, percentage and weight of caryopsis protein decreased as sucrose level in the medium increased from 1.0 to 1.75% (Fig. 1). The correlation coefficient between sucrose level in the medium and percentage protein in the grain was -0.93^{**} ($n = 15$). A corresponding field sample had 10.7% protein and 1.51 mg protein/caryopsis. Grains in the detached-panicle samples approached the field sample in free amino acids (0.24-0.36% vs 0.34% leucine) but had less free sugars (1.1-1.3% vs 3.7% glucose). In contrast, hulls and stems in the detached panicles were richer in free sugars (5-13% vs 2%) and free amino acids (0.7-1.4% vs 0.3%) than they were in the field samples.

Free sugars and free amino acid levels in developing grains, hulls, and stems of IR36 were compared in detached panicles cultured in a complete liquid medium containing 0.075% glutamine and 1.0 or 1.5% sucrose and in field samples. Free

sugars in developing grain were higher in the field samples than in the detached-panicle samples (3.9% vs 1.8-2.8%). The reverse was true for hulls (2.0% vs 3.1-4.3%) and stems (2.4% vs 4.5-5.6%). In contrast, the field samples had consistently lower free amino acid levels than the detached-panicle samples in developing grains, 0.47% vs 0.61-0.70%; in hulls, 0.27% vs 0.40-0.46%; and in stems, 0.24% vs 1.0-1.1%. Detached panicles had lighter grain weight and less protein per grain than the field samples but the two samples had similar percentage protein. The results suggest a greater barrier to sucrose translocation into developing grain than to glutamine translocation.

Dry matter accumulation of 5 other rices and IR36 was studied for 7 days in detached-panicle culture, using 0.075% glutamine and 1.0 and 1.5% sucrose in the nutrient media. With these rices, percentage protein again was lower in 1.5% sucrose than in 1.0% sucrose, with a correspondingly heavier grain weight in four cases. Protein (mg/grain) either remained the same or was lower at 1.5% sucrose. Only in the two higher protein rices IR480-5-9 and IR2153-338-3 were the protein levels per grain higher in detached-panicle samples than in field samples of comparable age.

The results indicate that, although protein accumulation in the detached-panicle system was determined mainly by the free amino acid level in the nutrient medium, increases in the sucrose level had a depressing effect on protein accumulation in the developing grain.

However, the detached-panicle system is not directly comparable to the intact panicle, because the whole vascular bundle is exposed to the nutrient medium instead of just the phloem. Hulls and culms showed abnormally high nutrient levels, although the developing grain tended to have lower free sugars than the field samples. The fine-grain samples Bom Dia and Kalajira showed slow growth in 1.0% sucrose.

Amino acid composition of the developing grain in IR36 detached panicles showed the usual negative relationship between protein content and lysine content of protein in brown rice. With an increase in protein content from 7.8 to 11.3%, the lysine content dropped from 5.0 to 4.2%. The field sample had 10.1% protein and 4.2% lysine in protein.

Sulfur amino acids and sulfur-deficient soils *(Chemistry)*. Studies in other cereals and legumes demonstrated that the amounts of sulfur-containing amino acids cystine and methionine may be lower in the seed proteins produced in sulfur-deficient soils. Although the levels of these amino acids are high in rice protein, their reduction may adversely affect the protein quality of rice-legume diets, because the excess cystine and methionine of rice proteins compensate for the deficiency in sulfur amino acids of legume proteins.

However, our preliminary screening of brown rice grown in sulfur-deficient soils in Indonesia and Bangladesh, with and without sulfur amelioration, showed no adverse effect of soil sulfur deficiency on the total content of cystine and methionine in brown-rice protein. Mean total sulfur amino acids in 4 Indonesian samples (7-12% protein) was 4.9% of brown-rice protein with sulfur treatment and 5.2% without. In Bangladesh BR3 rice (7-8% protein), total sulfur amino acids were 5.1% of brown-rice protein, with and without sulfur treatment.

Rice/wheat hybrid and higher lysine rice *(Chemistry and Plant Physiology)*. Seeds of a rice/wheat hybrid from China were analyzed for seed properties. The caryopses had incomplete hulls and were somewhat curved, and some had slight grooves at the dorsal and ventral sides. Milled grain had 4.1% lysine at 10.8% protein, which is typical of rice. Sodium dodecyl sulfate (SDS)-polyacrylamide gel electrophoresis of 0.5% SDS-0.6% β-mercaptoethanol soluble proteins gave molecular weight (MW) patterns closer to the 3 subunits of rice glutelin than to wheat gluten. The milled grain had 25% amylose, intermediate starch gelatinization temperature, and medium gel. Cracking hardness was lower than for milled rice.

Overall, the sample was closer to rice than to wheat. Examination of additional samples showed the presence of grooves in 15-35% of the caryopses. Proteins extracted from cylindrical and grooved grains had similar SDS-polyacrylamide gel electrophoretic patterns.

A higher lysine strain, MA 13, was obtained from PI 353705 (similar to Assam 5) tissue cultures derived from anthers screened against the inhibitor *S*-2-aminoethyl-*L*-cysteine at the Cell Culture and Nitrogen Fixation Laboratory, Beltsville Agricultural Research Center, USDA. Analysis of second

and later generations of the MA 13 mutant seeds at IRRI showed that it had higher lysine content in both brown and milled rice than the PI 353705 parent (Table 1). But the 0.6% increase was lower than the 1 percentage point required for effective screening of higher lysine content.

The protein of MA 13 was similar to that of its parent in solubility fractions and subunit MW on SDS-polyacrylamide disc gel electrophoresis. Its seed was lighter than that of its parent.

FEEDING TRIALS

Chemistry Department

Protein quality of milling fractions. A nitrogen balance study of diets of brown, undermilled, and milled IR32 rice with casein (2:1 nitrogen contribution) was done with six preschool children in cooperation with the Nutritional Evaluation Laboratory (NEL), Food and Nutrition Research Institute (FNRI), Manila, in 1980. At a daily nitrogen intake of 250 mg/kg body weight, apparent nitrogen digestibilities and retention were similar for the three diets. An earlier study (1977) by FNRI using rice-milk diets at 200 mg N/kg body weight showed poorer digestibility and retention of brown rice than of milled rice.

The balance study was repeated with 4 children at an intake of 200 mg N/kg body weight. The three samples still showed similar apparent digestibilities (65.0-66.7%) and retention (29.4-32.4%). The casein control diets had higher digestibility (76.0-77.1%) but comparable retention (31.8-36.4%). These data show that the nutritional advantages of brown rice over milled rice are mainly its higher vitamin B and protein contents, not higher protein quality.

Ash contents of the freeze-dried diets were casein I, 0.96%, brown rice casein, 1.44%; undermilled rice casein, 0.88%; milled-rice casein, 0.72%; and casein II, 0.98%. Neutral detergent fiber contents were casein I, 1.9%; brown-rice casein, 3.2%; undermilled rice casein, 2.5%; milled-rice casein, 1.8%; and casein II, 2.2%. These data are consistent with the higher ash and fiber content of brown rice relative to milled rice (Annual report for 1980).

Nitrogen balance in growing rats fed the milling bran and polish byproducts of IR32 showed their lower digestibility, higher biological value, and resultant net protein utilization relative to brown and milled rices (Table 2). In spite of higher fat content, the byproducts also had lower digestible energy (% and kcal/g), because of high fiber, trypsin inhibitors, and phytin levels. Because of their higher protein contents, bran and polish had higher utilizable protein (NPU × protein content/100) than brown and milled rices. Poor digestibility may be due to the thicker cell walls and protein-phytin complexing, since bran had higher fiber but lower phytin than polish. The higher biological value of bran and polish protein probably reflected their higher lysine content than brown- and milled-rice protein.

Protein requirement of adults. The protein

Table 1. Grain properties of the higher lysine rice strain MA 13 obtained from PI 353705 tissue cultures derived from anthers screened against the inhibitor *S*-2-aminoethyl-*L*-cysteine at USDA, Beltsville. IRRI 1981.

Property	1st sample ex USDA		2nd sample		
	PI 353705 (USDA)	MA 13[a] (USDA)	PI 353705 (USDA)	MA 13[b] (USDA)	MA 13[b] (IRRI)
Brown rice					
Wt (mg/grain)	20.5	12.5	17.6	16.5	14.1
Lysine (g/16.8 g N)	4.3	4.6	4.1	4.7	4.5
Calculated protein[c] (%)	8.1	10.9	9.7	12.7	9.2
Protein per seed (mg)	1.7	1.4	1.7	2.1	1.3
Lysine per seed (mg)	0.071	0.063	0.070	0.098	0.058
Milled rice					
Lysine (g/16.8 g N)	3.9	4.3	–	4.5	4.6
Calculated protein[c] (%)	6.8	10.6	–	11.1	7.2

[a]Second generation. [b]Third generation. [c]Based on % recovered N x 5.95.

Table 2. Mean nitrogen and energy balance of 5 growing rats and selected properties of IR32 brown rice and its milling fractions.[a] National Institute of Animal Science (Copenhagen) and IRRI, 1980-81.

Property	Brown rice	Bran	Polish	Milled rice
True digestibility (%)	96.9 b	78.8 d	82.5 c	98.4 a
Biological value (%)	68.9 b	86.6 a	86.3 a	67.5 b
Net protein utilization (%)	66.7 bc	68.3 b	71.2 a	66.4 c
Digestible energy (%)	94.3 b	67.4 d	73.3 c	96.6 a
Protein (% N x 6.25)	8.7 c	16.8 a	13.4 b	8.3 d
Lysine (g/16 g N)	3.80 c	5.78 a	5.04 b	3.55 d
Neutral detergent fiber (%)	2.6 c	20.7 a	19.1 b	0.8 d
Crude fat (%)	2.4 c	27.2 a	19.8 b	0.7 d
Phytin P (%)	0.06 c	0.90 b	1.10 a	0.02 c
Energy value (kcal/g wet basis)	3.90 c	4.94 a	4.45 b	3.80 c

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

requirements of 7 female adult Filipinos, 22-35 years of age, consuming local rice-based diets was verified at the NEL as part of the UN University World Hunger Program research network on protein-energy requirements. The study used 40 ± 2 kcal and 1.12 g protein/kg body weight for 12 weeks. About 40% of the dietary nitrogen was contributed by rice and 40% by animal source. About 20-25% of the dietary energy was from fat.

A 5-day cycle menu was used. Amino acid composition of the five menus were at least 95% of FAO/WHO pattern. Based on a daily intake of 185 ± 4 mg N/kg (1.12 g protein), apparent digestibility was 148 ± 4 mg N (80%) and apparent retention was 14 ± 3 mg N (8%). Nitrogen balance was 10 ± 3 mg N, assuming 5 mg N/kg for integumental and unaccounted-for losses.

Of five subjects given 40 kcal/kg body weight, three maintained initial weights, 1 lost 0.38 kg, and 1 gained 0.79 kg. Of two subjects given 42 kcal/kg body wt, one gained 0.31 kg and the other 0.77 kg during the study. Serum protein and its fractions, urea N and creatinine excretion, were maintained at initial satisfactory levels. Although the current allowance of 1.12 g protein/kg body weight was verified as adequate for Filipino female adults, it cannot be considered too generous, particularly for those who perform manual work.

An additional study was made to check if the recommended level of 1.12 g protein/kg body weight daily would still give good nitrogen retention if energy intake was reduced 15% (34 kcal/kg). (The 1978 mean energy intake of Filipinos was 88.6% of recommended intake.)

Four subjects from the earlier study lost 2.2 kg in 12 weeks. The weight loss was most rapid during the first 2 weeks. Simultaneously, nitrogen balance dropped. Subjects had their lowest negative nitrogen balance at the end of the first week. Nitrogen excretion gradually improved so that before the end of the third week, subjects were in nitrogen equilibrium. Thereafter, mean nitrogen balance was positive.

The basal metabolic rate of subjects decreased 5-18% and they tried to minimize their activities. Creatinine excretion also decreased. The capability of the subjects to maintain a positive nitrogen balance despite inadequate energy intake indicated that the body uses its energy stores before it uses protein for energy.

Digestibility of rice-mungbean diet. A study at the NEL examined the protein requirements of 5 Filipino children 22-29 months old given rice-mungbean diets at 4 levels of dietary protein (1.0, 1.25, 1.5, and 1.75 g/kg body wt; one third of the protein from whole mungbean and 38.4% from milled rice). The mean nitrogen requirement for maintenance, calculated using the multiple-level confidence band method, was 1.0 g/kg body weight. The safe level of intake for 97.5% of preschool children has been projected as 1.39 g protein/kg body weight. This requirement was much higher than with a rice-fish diet, where the protein requirement was 0.70 g and the safe level was 1.0 g.

High fecal N losses were obtained, generally higher than urinary N. At an intake of 152 mg N/kg, all subjects, except one, were in negative balance. Above 152 mg N/kg, all were in positive

nitrogen balance.

Although energy intake was kept at 100 kcal/kg body weight, subjects lost weight at intake levels of 200 mg N/kg and above. However, weight gains were realized at the lowest nitrogen intake level. Loss of weight was accompanied by increased fecal weight and volume.

Earlier studies with rice-dehulled mungbean diets at the FNRI gave 67-76% apparent digestibility at 200-240 mg N intake/kg, against the 57-62% for rice-whole mungbean diets in this study (Annual report for 1975). But apparent nitrogen retention was comparable, at 22-23% in the first study, and at 22-28% in the current study.

Because the major difference between the two diets was the use of whole mungbean instead of dehulled mungbean, the mungbean seed coat must be the source of poorer digestibility. This was probably due to phenolics located in the seed coat of legumes rather than to higher levels of dietary fiber or trypsin inhibitors, since the difference in dietary fiber content of whole and dehulled bean was only 4.2% (8.4% vs 4.2%) and the trypsin inhibitor level in boiled mungbean was very low due to heat inactivation. Tannins in seed coat have been identified as a cause of poor digestibility of whole legume seeds at the Institute of Nutrition of Central America and Panama at Guatemala City and at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan.

However, varietal differences in tannin content of mungbean have been reported by AVRDC. Toasting the mungbean effectively removes the seedcoat. And most commercial mungbean weaning formulations use dehulled beans.

OTHER NUTRIENTS

Chemistry Department

Nutrient content of washing and cooking water. Because a Manila medical group wanted to investigate the use of *am* (decanted rice concoction or water) in the treatment of acute gastroenteritis or diarrhea, the nutrient content of washing and cooking water of C4-63G, IR36, and IR42 milled rice were studied.

Water from 2 washings of 50 g rice (1:1 by weight with water) and the drainings from boiling rice at 1:10 by weight with water to optimum cooking time (18-23 minutes) were used.

Table 3. Mean nutrient content of cold rice washing water and rice cooking water for 3 milled rices. IRRI, 1981.

Property	Nutrient extracted (% of milled rice)		
	Washing	Gruel	Total
Solids	1.28	8.08	9.36
Total carbohydrates (glucose)	0.64	8.02	8.66
Crude protein	0.18	0.22	0.40
Total lipids	0.62	0.44	1.06
Free sugars (glucose)	0.18	0.10	0.28
Free amino acids (leucine)	0.02	0.02	0.04
Sodium	0.004	0.004	0.008
Potassium	0.024	0.028	0.052
Calcium	0.002	0.001	0.003
Magnesium	0.004	0.001	0.005
Phosphorus	0.040	0.012	0.052
Iron	0.0002	0.0002	0.0004

Cold washing water alone extracted mainly the lipid (fat), free sugars, and loose starch granules from milled rice (Table 3). The cooking water further extracted polysaccharides, principally starch, and lipids. Extracted minerals were minimal, reflecting the low mineral content of milled rice.

Mechanisms by which rice gruel can cure diarrhea have been debated. The recent suggestion is that starch-like carbohydrates, because of their lower osmolarity, tend to draw less fluid out of the body into the gut than a similar amount of glucose or sucrose.

Fatty acids of rice and corn oils. The fatty acid composition of a sample of local rice bran cooking oil was compared with those of two local brands of corn salad oil. Based on gas chromatography of fatty acid methyl esters, rice oil principal fatty acids were 17% palmitic, 35% oleic, and 40% linoleic, with 2% lauric and 3% linolenic acids. The rice bran oil was darker and more turbid than the corn oils. The corn oil fatty acids were 13% palmitic, 28-30% oleic, and 51-52% linoleic, with 3% linolenic and only trace lauric acid.

The corn oils had more essential unsaturated fatty acids (54-55% linoleic and linolenic) than the rice oil sample (43%). Lauric acid may have been derived from coconut oil contamination during rice oil refining.

Genetic evaluation and utilization (GEU) program

Drought resistance

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

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HYBRIDIZATION AND SELECTION

Plant Breeding Department

This year's program focused on hybrids needed by collaborating programs in drought-prone areas. In all, 148 single crosses, 111 double crosses, and 78 multiple crosses were made — 16 designed for rainfed-wetland areas of Thailand, 105 for drought-prone rainfed-dryland areas of north-central India, 11 for Brazil, and 5 for the International Institute for Tropical Agriculture (IITA) in Nigeria.

IRRI sent 159 F_2 bulk populations to India, 9 to Brazil, and 50 to Mexico.

During the wet season, 218 F_2 bulk populations were grown in dryland nurseries and 33 in wetland nurseries. A modified bulk method was used to select the F_2 plants grown in dryland nurseries.

In pedigree nurseries, 5,948 F_3-F_6 lines were grown in the dry season and 1,654 were carried over to the wet season. A high brown planthopper incidence on the IRRI farm reduced the nurseries to only 390 lines at the end of the year.

VARIETAL SCREENING

Agronomy and Plant Breeding Departments

Screening at vegetative stage *(Agronomy).* Of 4,358 rices seeded 21 January to be screened for drought resistance at the vegetative stage in rainfed dryland and shallow wetland, and deepwater culture, 4,247 had satisfactory stand establishment. These included materials from previous drought tests, the International Rice Testing Program (IRTP), the Germplasm Evaluation and Utilization (GEU) program, and the Germplasm Bank (GB).

The experimental field was sprinkler irrigated after seeding, then every 4-6 days until 30 days after seedling emergence. At that time, soil moisture stress was imposed. Each entry was scored for drought resistance when soil moisture tensions (SMT) at 20-cm soil depth reached 2 bars (18 March) 5 bars (4 April), and 10 bars (24 March). The 1980 Standard Evaluation System for rice (SES) 0-9 scale was used (0 = no symptoms of soil moisture stress and 9 = all plants apparently dead). To measure drought recovery ability, the experimental field was sprinkler irrigated at 10 bars SMT and scored for recovery 16 days later (20 April) using the SES scale (1 = 90-100% plants fully recovered; 9 = 0-19% plants fully recovered).

At 2 bars SMT, 92% of the entries scored 3-5, only 5% scored 1-2, and 3%, 6-7 (Fig. 1). At 5 bars SMT, 33% scored 4 and 36% scored 5. At 10 bars, 50% of the entries scored 7. Distribution of drought recovery scores was similar to that at 2 bars SMT (Fig. 2).

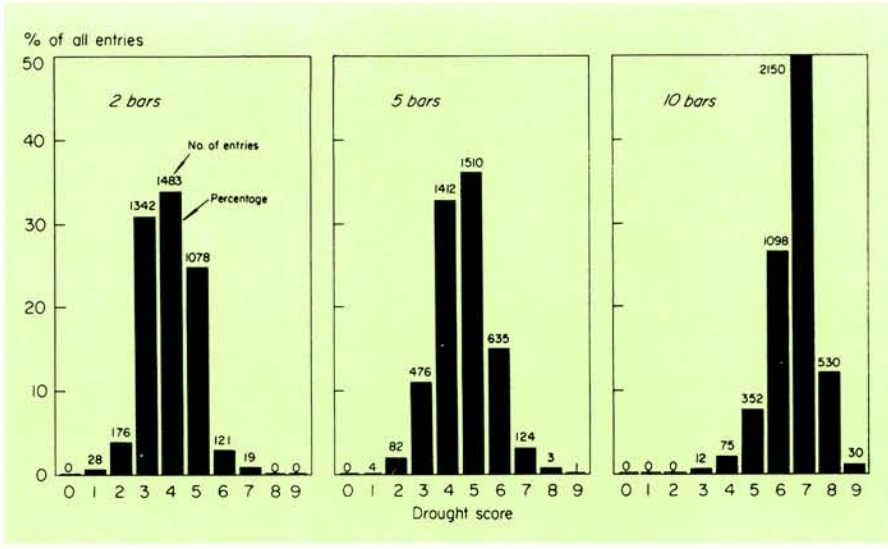
Eighty-seven entries had better drought resistance scores than the checks Salumpikit and IR442-2-58 (Table 1). Only 12 entries including 10 IRRI selections and 2 accessions from the Khmer Republic (Anlong Phnom) and Thailand (KU 86) scored 3. KU 86's drought resistance scores have been similar to or better than those of Salumpikit in IRRI dry-season field screenings since 1977. Among the rices with drought resistance scores of 4 were 40 IRRI lines and 16 deepwater rice accessions from Thailand.

Of the 50 IRRI lines with scores of 3 and 4, 31 were progeny of crosses involving a deepwater variety as parent or ancestor, confirming earlier reports that deepwater rices, notably Nam Sa-gui 19, are very good contributors of genes for drought resistance.

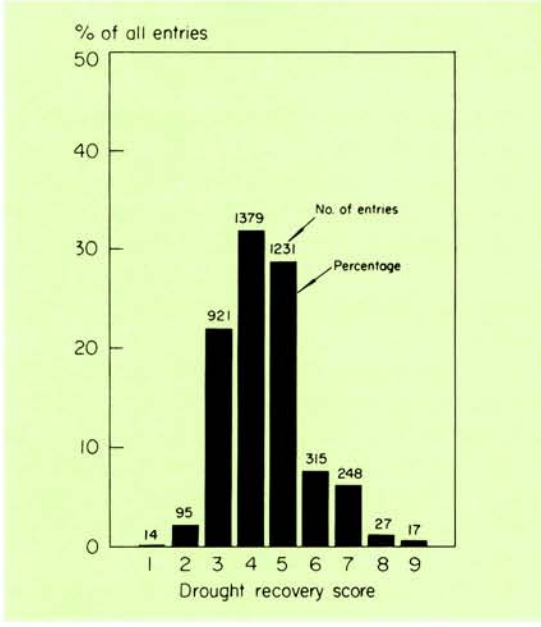
These findings confirm that it is not safe to select for drought resistance at 2 bars SMT. Of 28 entries that scored 1 at 2 bars SMT, only 4 still scored 1 at 5 bars SMT, and these 4 scored 5 at 10 bars SMT. IR13204-3-3-3-2-1 and IR24760-24-2 were among the best 12 entries at 10 bars SMT.

Screening at reproductive stage *(Plant Breeding).* About 4,434 accessions and breeding lines from the dryland and wetland nurseries were screened in dryland culture. Only 520 could be scored at the reproductive growth stage. Five accessions had a score of 3 — Khao Pick (Acc. 235256), Khao Pick Khao (Acc. 23528), and Khao Tam (Acc. 23538) from Laos; Chakula (Acc. 37035) from Bangladesh; and Burik (Acc. 44370) from the Philippines.

Another 1,113 breeding lines were screened in rainfed-wetland culture. Only 616 entries could be scored at the reproductive stage, 10 of which had a score of 4. Those were HB entries: M1-48, Ai-Yeh-Lu, Chiang Tsenf Tao Ju, Ching Hsi 17, Chu-Cheng, Dumsiah 81, Leng Kwang, Mal Siraz, and IR4570-74-2-2. One TOX line developed at the



1. Frequency distribution of rice drought reaction scores at 2, 5, and 10 bars soil moisture tension in field screening for drought resistance at IRRI, 1981 dry season.



2. Frequency distribution of rice drought recovery scores from 10 bars soil moisture tension in field screening for drought resistance at IRRI, 1981 dry season.

IITA, TOX 95-3-1-1-3, had a score of 3. Most of them are early maturing (100-110 days) lines that could have partly escaped serious stress. M1-48 was a resistant check variety in earlier drought tests.

Developing a screening method to detect genetic variability in drought resistance at reproductive stage *(Agronomy)*. Work over the last 3 years has indicated that water stress is generally much more destructive during the reproductive period than during the vegetative period. The occurrence of a relatively mild, short-duration water stress at or near flowering can reduce the number of fertile spikelets drastically, reducing grain yield to a fraction of its potential.

Dependable field screening procedures for vegetative stage response to drought have been used at IRRI for a number of years. A reliable method to compare genotypic responses to water stress at the reproductive period would be equally valuable.

A major constraint in developing such a drought screening method is the rice crop's particular sensitivity to stress at flowering. Genotype response is highly influenced by the timing of the stress in relation to its flowering date. That makes it difficult to distinguish whether superior drought resistance is due to escape (such as relatively early or late maturity) or to drought-resistance characteristics per se. Valid interpretation of screening results is dependent on ensuring that all entries being compared flower simultaneously, or on using an analytical method to remove the confounding effects due to the variation in flowering dates among the entries, or on both.

A field trial in the dry season tested possible methods for obtaining useful genotypic comparisons for reproductive stage drought resistance. Elements of both simultaneous flowering and a discrete analytical method were incorporated. Selected entries were grown under sprinkler irrigation

Table 1. Outstanding selections in field screening for drought resistance at the vegetative stage. IRRI, 1981 dry season.

Entry	Acc. no.	Origin	Drought score[a]			Recovery score[b]
			2 bars	5 bars	10 bars	
IR5853-213-6-1		IRRI	2	2	3	2
IR13204-3-3-3-2-1		IRRI	1	2	3	1
IR18599-68-2-1		IRRI	2	2	3	2
IR21048-30-3		IRRI	2	2	3	2
IR21178-21-3		IRRI	2	3	3	2
IR24760-24-2		IRRI	2	2	3	1
IR24760-58-1		IRRI	2	2	3	2
IR24760-69-2		IRRI	2	2	3	4
IR24761-35-3		IRRI	3	3	3	2
IR24761-156-3		IRRI	3	3	3	2
Anlong Phnom	22724	Khmer Rep.	2	2	3	4
KU 86	15027	Thailand	2	2	3	3
Salumpikit (T ck)	5423	Philippines	3	3	5	3
IR442-2-58 (T ck)		IRRI	4	5	6	3
IRAT 9 (S ck)	28506	Ivory Coast	5	7	8	7
IR20 (S ck)		IRRI	5	6	8	5

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

on an aerobic dryland site at the new IRRI farm. Entries were grouped by maturity class (early or late) and seeded on one of nine consecutive dates (at 3-day intervals) in an attempt to induce simultaneous flowering. Three check varieties (IR52, IR36, and Kinandang Patong) were seeded on all dates so that plots of each would be flowering simultaneously with all entries for direct comparisons.

Full irrigation to meet pan evaporation was applied until late panicle development. During the flowering period, a line source moisture gradient was applied for 21 days to create 5 moisture environments across the plots of each entry. The microclimatic conditions and plant water stress levels between the extreme environments (1 = wet and 5 = dry) are compared in Figure 3.

The staggered plantings helped concentrate flowering within a 14-day period. However, because flowering dates are not predictable with a high level of precision, the range was still greater than would be necessary for direct genotypic comparisons.

Two methods of analysis were developed in the attempt to normalize responses to account for variation in flowering date. In the first method, the drought-resistance parameters were compared between each entry and the simultaneously flowering plots of the check varieties. Figure 4 illustrates the yields of materials that flowered simultaneously on four different dates.

IR6115-1-1-1 had higher yields over the range of environments than the IR52 check that flowered on the same date (16 April). The entries that flowered on 19 April responded similarly to IR52. Those that flowered on 21 and 26 April were inferior.

The simultaneous check analysis has these constraints: A considerable number of check plots are required to cover the range in flowering dates (9 plantings/replication in this case), consuming considerable field area and management time. Some entries may flower outside the range of the check plantings.

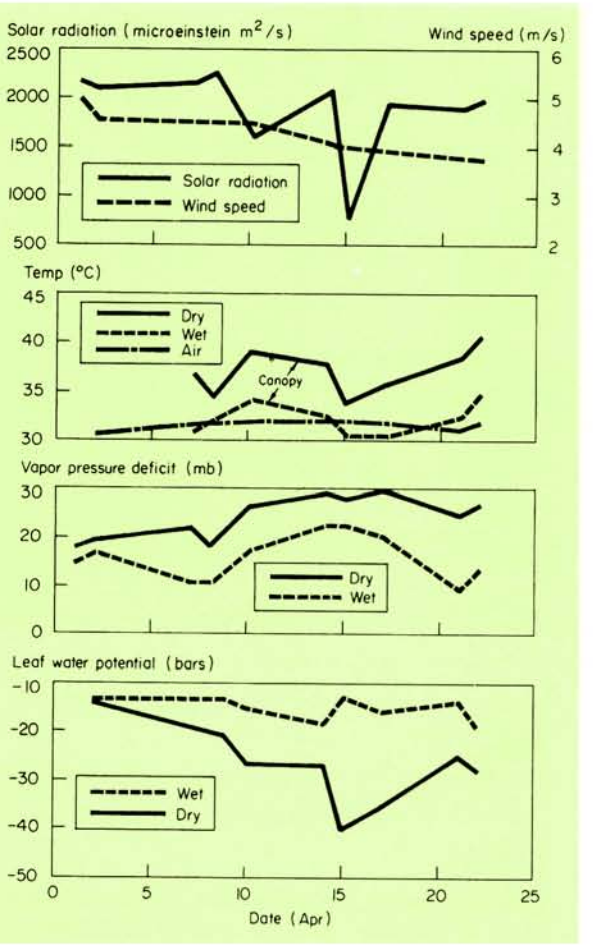
A second method of analysis used a regression approach that incorporated all the trial data. The drought resistance parameter was regressed against date of flowering. The regression estimated the expected response for any particular flowering date. The amount of deviation of each entry from the expected response may be interpreted as its level of superiority or inferiority for that character.

That approach is shown in Figure 5. Mean grain yields for environments 1 through 3, representing relatively mild water stress, are graphed against date of flowering. The linear regression was highly significant, with an estimated reduction in yield of 5 g/m^2 for each day beyond 5 April that flowering

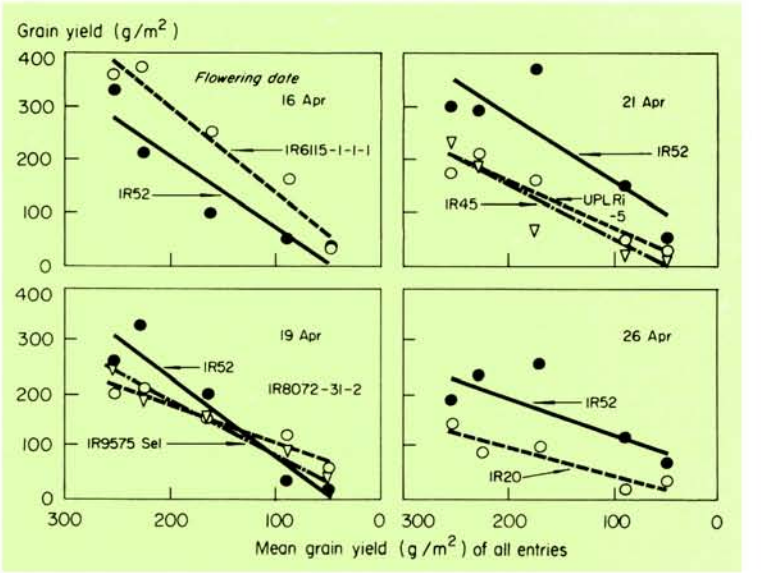
occurred. The entries showing the largest positive deviations between actual and estimated yields were IR6115-1-1-1 and IR52. They had superior productivity, yet flowered during the maximum stress period. The entries with the largest negative deviations, indicating poorest performance, were IR45 and IR20. Data for environments 4 and 5, representing severe drought stress (mean yields less than 150 g/m^2) are given in Figure 5B. Relative performances among entries were similar for both sets of environments.

The analysis also was used to interpret observations made on flowering delay as a result of water stress (Fig. 6, 7). Flowering in environment 5 was delayed from 2 to 12 days after flowering in environment 1. In the late group, IR9995-96-2 and IR9669 Sel. were outstanding in their ability to exsert panicles and flower under severe stress (Fig. 6). In the early group, IR52, RP1158-111-1, and KMP 34 were superior (Fig. 7).

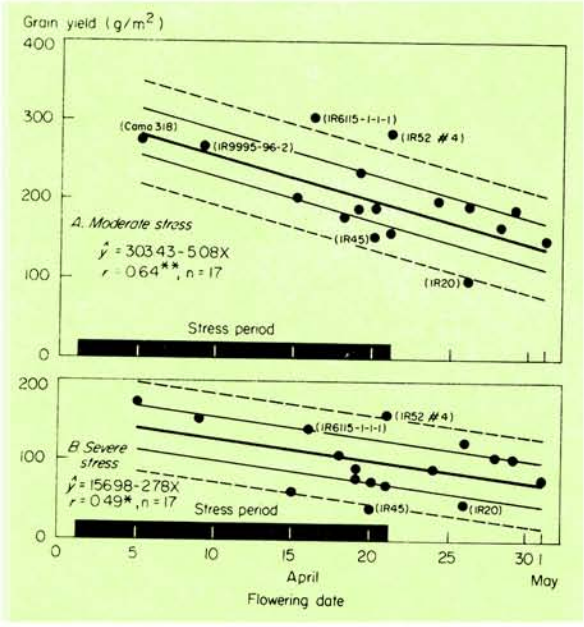
Each entry was rated for flowering delay and for grain yield, depending on the size of its deviation from estimated performance. The parallel lines above and below the regression line in Figures 5, 6, and 7 correspond to the rating scale. The scale is given in Table 2 and results are summarized in Table 3. This general approach is being refined so that larger scale screening can be done.



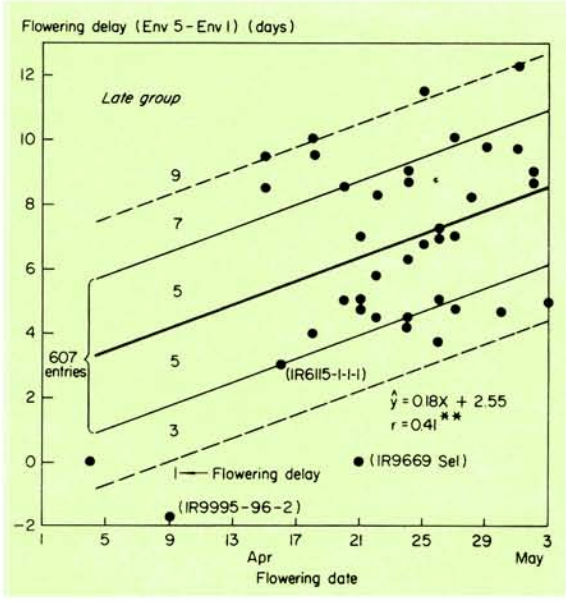
3. Crop microclimatic conditions during drought-stress treatments at the productive stage, 1981 dry season. Wet = environment 1, dry = environment 5.



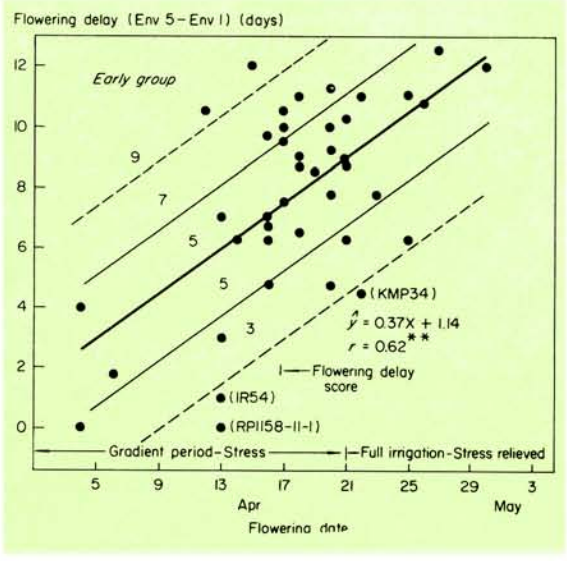
4. Grain yields in 5 reproductive drought-stress environments of genotypes flowering simultaneously with IR52. IRRI, 1981 dry season.



5. Grain yields of a set of cultivars grown under reproductive drought stress, plotted against flowering date. IRRI, 1981 dry season.



6. Flowering delay under reproductive drought stress, plotted against flowering date, of a set of relatively late-maturing cultivars. IRRI, 1981 dry season.



7. Flowering delay under reproductive drought stress, plotted against flowering date, of a set of relatively early-maturing cultivars. IRRI, 1981 dry season.

FIELD EVALUATION OF RAINFED DRYLAND RICES

Agronomy Department, IRTP, and Plant Breeding Department

Breeding lines *(Plant Breeding)*. Replicated yield trials were divided into two groups to accommodate new promising entries from the observational trials. The first group (A) consisted of 30 entries that had outstanding yield performances in earlier replicated yield trials. Those entries were replicated four times. The second group (B) consisted of 80 entries, most of them advanced from observational yield trials. The plots were replicated twice.

Yield trials were conducted at three locations. Only Group B was planted at the less fertile site of IRRI near the railway because of limited space.

At the farmer's field location in Santo Tomas, two periods of drought stress — 22 July-5 August and 17 August-7 September — occurred at the vegetative, panicle initiation, and grain-filling stages (Fig. 8). Grain yields ranged from 0.1 to 2.0 t/ha for Group A (CV 43.2%) and 0.05 to 1.3 t/ha for Group B (CV 48.0%).

The highest yields in the Group A were 2.0 t/ha from IR3839-1 and 1.5 t/ha from IR5873-20-1, significantly better than the yield from the recommended early check UPL Ri-7 (1.1 t/ha). These two lines had average drought reaction scores of 4 at the reproductive stage.

The good performance of IR5873-20-1, which could be attributed to its high drought resistance and good recovery ability, was also observed at

IRRI farm. This line, like IR5, had delayed flowering during stress. As soon as moisture was replenished, panicles immediately exserted and the grain began to fill.

Some lines, such as IR10011-16-3 and IR10110-23-1, also had higher drought resistance levels and good recovery ability.

Table 2. Rating scale for reproductive drought resistance screening. IRRI, 1981.

Sign of deviation from regression	Level of deviation from regression (%)	Rating
+	Highest 10%	1
+	Upper 10-40%	3
+	Lowest 60%	5
–	Highest 60%	
–	Upper 10-40%	7
–	Lowest 10%	9

In the Group B trial, lines that produced more than 1 ton of rice were IR3880-29 (1.3 t/ha), IR5260-1 (1.2 t/ha), IR5962-29-4-3 (1.1 t/ha), and IR9669 selection (1.2 t/ha). The first three lines have drought resistance at both the vegetative and reproductive stages. IR9669 selection has high drought resistance at the vegetative stage and good recovery ability.

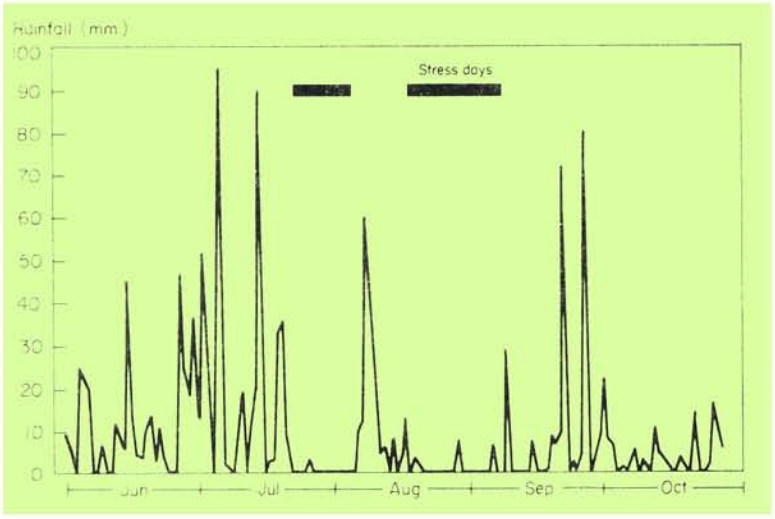
The traditional check variety Kinandang Patong produced only 0.2 t/ha. Although its drought resistance was quite high in previous years, its ability to recover after severe moisture stress was very poor.

Under prolonged drought, most of the taller entries yielded higher than most of the semidwarfs. The correlation coefficient between grain yield and plant height was positive ($r = 0.45^{**}$). As in the past, moisture stress greatly reduced the plant height of semidwarfs, and such reduction was

Table 3. Grain yields, flowering delay, and comparative ratings of 25 entries in the drought resistance trial at the reproductive stage. IRRI dryland farm, 1981 dry season.

Entry	Environments 1-3[a]		Environments 4-5[b]		Flowering delay[c]		Sum of ratings
	Yield (g/m²)	Rating	Yield (g/m²)	Rating	Days	Rating	
Late-maturity group							
IR6115-1-1-1	305	1	141	4	3.00	4	9
IR52	284	1	159	1	4.75	5	7
Gama 318	275	5	174	3	3.50	5	13
IR9995-96-2	267	5	153	4	-1.75	1	10
IR2061-522-6-9	191	5	73	6	5.00	5	16
IR9575 Sel.	189	5	92	5	10.00	8	18
IR8072-31-2	179	7	108	5	4.00	5	17
UPL Ri 5	162	7	71	6	5.00	5	18
IR45	154	7	42	9	8.50	6	22
IR20	101	9	46	7	3.75	3	19
Early-maturity group							
IR9752-71-3-2	314	5	227	4	0.00	3	12
C1064-5	296	3	130	4	6.75	5	12
IR52	289	4	105	5	1.00	1	10
IR9782-111-2-1-2	282	1	148	1	4.75	3	5
IR36	264	5	114	5	3.00	3	13
IR3839-1	243	5	109	4	10.50	7	16
CR222	237	5	116	4	9.50	6	15
BG 35-2	226	5	81	5	11.00	7	17
IET 1444	224	5	109	4	6.50	5	14
IR9410-80	220	5	74	5	6.75	5	15
MW10	156	7	74	5	12.00	9	21
IR5929-12-3	129	7	62	5	9.25	5	17
M1-48	107	9	31	7	8.75	5	21
IR7790-18-1-2	91	9	28	9	6.25	5	23
IR5982-7-6-1	90	7	58	8	12.00	5	20

[a]Moderately unfavorable (mean yields > 1.5 t/ha). [b]Severely unfavorable (mean yields < 1.5 t/ha). [c]Difference in flowering date between environment 5 and 1.



8. Daily rainfall distribution and number of stress days at Santo Tomas, Batangas, Philippines, 1981 wet season.

accompanied by decreases in panicle length and grain size.

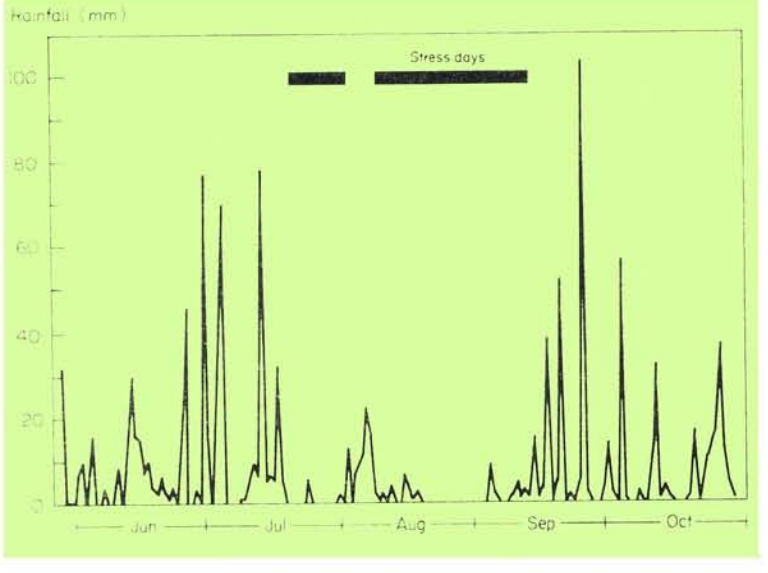
At the IRRI farm, no appreciable rain fell for 57 days, from 19 July to 16 September (Fig. 9). The heaviest rain, less than 1 inch, occurred in early August. There was no rain for the next 35 days. The protracted moisture stress affected both the vegetative and reproductive stages. The early-maturing lines that headed during the dry spell produced very light grains. Some other lines tolerated and survived the stress period and recovered when heavy rains began to fall in mid-September.

The prolonged stress period made possible the identification of promising lines that have drought resistance at both vegetative and reproductive stages as well as good recovery ability. Such lines are IR3646 lines, IR5873-20-1, IR6023-10-1-1, IR6115-1-1-1, IR10011-16-3, IR10110-23-1, and IR12721 lines. IR6115-1-1-1 and IR12721 lines recovered best.

Figure 10 shows IR6115-1-1-1 plants adversely affected by drought in early September; Figure 11 shows the same plants, 40 days later, fully recovered and producing new tillers and panicles.

IR3659-15-1-2, IR3880-29, IR5260-1, and TOX 502-13-NK14-N_1B showed drought resistance at both the vegetative and reproductive stages. But their recovery ability was very poor, probably because the plants had nearly completed their life cycle before sufficient rains came. Yields in these lines ranged from 0.1 to 0.4 t/ha.

Dryland rice yield trials *(Agronomy)*. The first



9. Daily rainfall distribution and number of stress days at the IRRI farm, 1981 wet season.



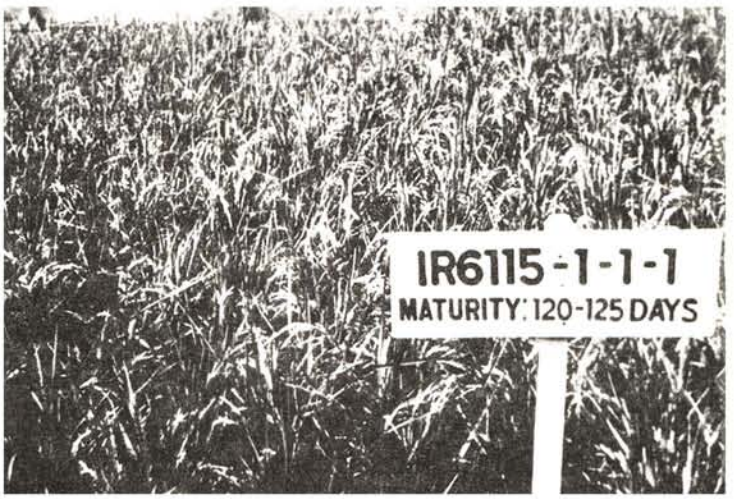
10. IR6115-1-1-1 plants suffering from severe drought stress at the IRR farm, 1981 wet season.

group in the 1981 dryland rice yield trials was the 26-entry International Upland Rice Yield Nursery (IURYN). The second group (Philippine) of 49 entries consisted of 29 selections from the 1978, 1979, and 1980 field drought screenings, 13 early-maturing promising nitrogen-responsive lines, and drought-tolerant checks Salumpikit and IR442-2-58, drought-susceptible checks IR20 and IRAT 9, and yield checks IR43, IR45, and C22.

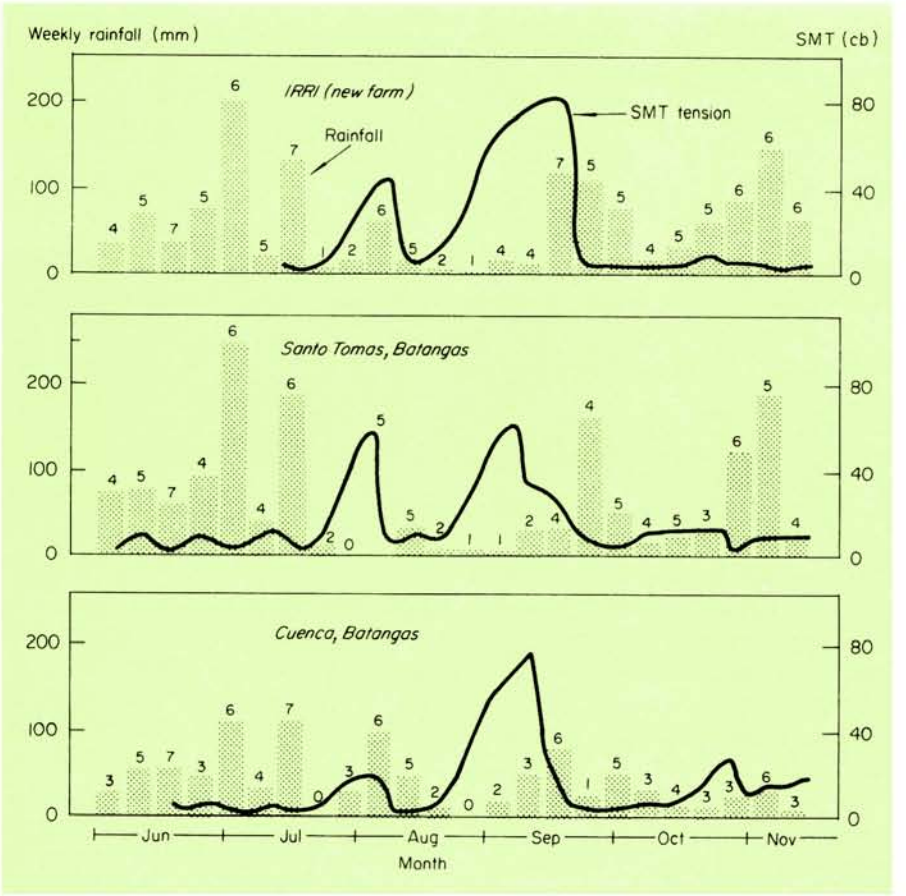
The tests were conducted at the IRRI farm, in two farmer's fields in Santo Tomas and Cuenca, Batangas, and at Bureau of Plant Industry experiment stations in Ilagan, Isabela, and La Granja, Negros Occidental. Two seedings each were made a month apart at IRRI and at the two Batangas sites. The first seedings at IRRI and Batangas and the only seedings in La Granja and Ilagan were done at the onset of the wet season.

The 1981 crop year was droughty at all five sites (Fig. 12, 13). Two periods of low or no rainfall and consequent soil moisture stresses occurred: the first in late July for all sites, the second and longest from mid-August to mid-September at IRRI, Santo Tomas, Cuenca, and La Granja, and in September at Ilagan.

Soil moisture stresses resulted in appreciably depressed yields at all sites for all entries. Only in the second seeding (30 June) at Santo Tomas, the



11. Full recovery of IR6115-1-1-1 40 days after severe drought stress at IRRI, 1981 wet season.



12. Weekly rainfall, number of rainy days per week, and soil moisture tension (SMT) in dryland rice yield trials at 3 sites. 1981 wet season.

first seeding (25 May) at Cuenca, and the only seeding (9 June) at La Granja (Table 4) did some entries yield more than 3 t/ha. The highest yield for the season was that of line IR9266-27-A, 3.9 t/ha, in the second (30 June) Santo Tomas seeding. But the line performed poorly at all other sites.

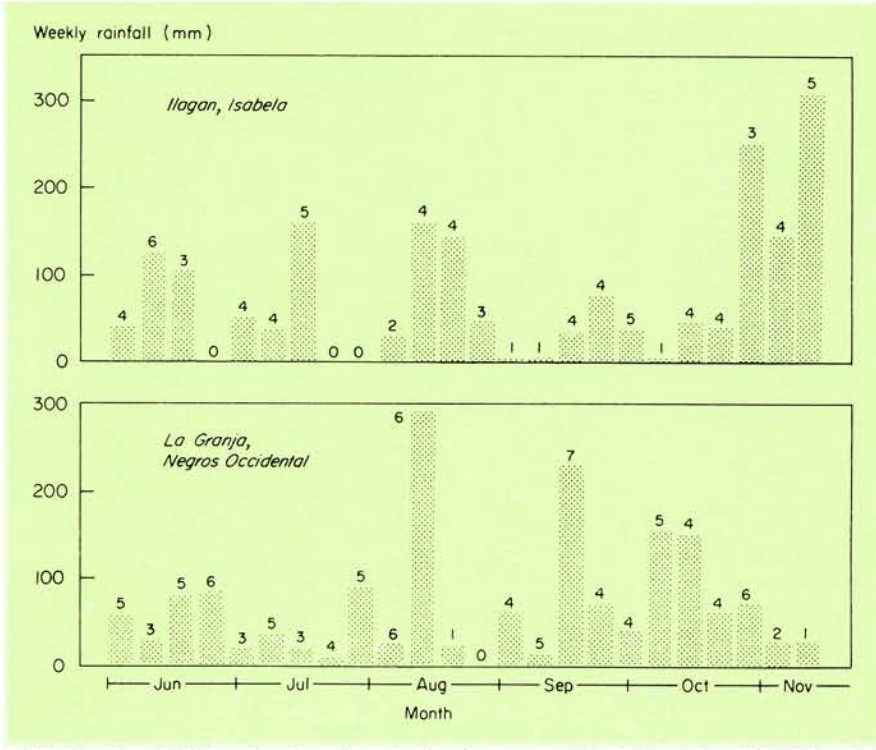
In the IURYN group, only IR9782-111-2-1-2 performed consistently better than the checks; the yield advantage was significant in three sites. The highest yielder (IR9782-111-2-1-2) was the earliest to head.

In the second group, 15 lines performed better than the best checks within site. Six were selections from drought screening tests, while 9 were early-maturing selections. The main factor for the better yields was growth duration. Except for three lines with growth durations similar to or longer than those of the checks, the early entries were the better yielders (Table 5). These early lines were past flowering stage when the second, and more severe, soil moisture stress set in.

Severe leaf blast and bacterial leaf streak infections added to yield reduction in Ilagan. These diseases also were observed at La Granja, Santo Tomas, and Cuenca, but lesions were only slight to moderate. Sheath blight infection was moderate in some entries at Cuenca.

This year's results were less unfavorable to early-maturing entries, the opposite of those of previous droughty years when dry spells starting in early August caught early varieties and lines at the reproductive stage. Then, longer maturing rices were still at the vegetative stage and able to recover as soon as soil moisture became available and to yield better than the early ones.

The drought-tolerant checks IR442-2-58 and



13. Weekly rainfall (mm) and number of rainy days per week in dryland rice yield trials at 2 Philippine Bureau of Plant Industry stations. 1981 wet season.

Table 4. Grain yield of selected rices in dryland rice yield trials at 5 Philippine sites. 1981 wet season.

Entry	Grain yield[a] (t/ha)								
	IRRI		Santo Tomas		Cuenca		Ilagan	La Granja	Mean
	10 Jun	9 Jul	26 May	30 Jun	25 May	13 Jul	4 Jun	9 Jun	
International (IURYN) group									
IR9782-111-2-1-2	1.0*	0.7	1.6*	2.8	3.0*	0.8	2.0	1.2	1.6
IR43 (check)	0.5	0.3	0.1	2.3	1.4	0.8	0.8	2.0	1.0
C22 (check)	0.2	0.5	0.2	1.6	1.1	0.6	0.8	2.1	0.9
Local (Philippine) group									
IR19728-9-3-2	0.2	1.4*	2.0*	1.8	3.1	1.1	2.4*	2.4	1.8
IR15429-268-1-2-1	0.5	1.3*	1.8*	1.3	3.0	1.0	2.0*	3.2	1.8
IR9101-37-1	0.4	1.0	2.7*	2.5	3.1	1.2	2.9*	0.8	1.8
IR19735-5-2-3-2-1	1.3*	1.2	1.6*	0.5	3.1	0.9	2.6*	2.5	1.7
IR9752-71-3-2	1.0	1.3*	1.4*	1.6	2.8	0.9	2.2*	2.3	1.7
IR8608-3-2-2-3	0.4	0.8	2.5*	2.3	2.9	1.0	2.1*	1.0	1.6
IR11288-B-B-288-1	0.5	1.0	2.6*	2.9	1.2	0.6	2.6*	1.2	1.6
IR19774-23-2-2	0.4	1.4*	1.6*	2.2	2.8	1.1	2.6*	0.8	1.6
IR9560-2-6-3-1	0.6	0.2	0.8	3.1	1.9	1.4	1.4	3.0	1.6
IR19743-25-2-2	0.6	1.0	1.8*	1.6	3.3	0.9	1.3	1.9	1.6
IR9995-76-2	0.7	1.5*	1.1	3.0	1.1	1.4	1.9*	1.4	1.5
IR9814-11-3	0.3	0.8	1.9*	2.7	3.0	1.2	1.8*	0.5	1.5
IR19743-46-2-3-3-2	0.7	1.0	1.0	1.4	3.0	1.0	1.8*	1.3	1.5
IR19746-28-2-2	0.7	1.1	1.6*	1.5	3.0	0.9	2.1*	1.3	1.5
IR9729-67-3	0.8	1.2	0.4	1.3	3.0	0.9	0.8	3.3	1.5
IR43 (check)	0.7	0.4	0.6	2.7	2.2	1.2	0.6	2.0	1.3
C22 (check)	0.4	0.8	0.2	1.7	1.6	0.9	0.6	1.9	1.0

[a] *Significantly higher than the higher yielding check at the 5% level by Duncan's multiple range test within experimental site.

Table 5. Grain yield and other agronomic characters of selected rices in dryland rice yield trials at 5 Philippine sites. 1981 wet season.

Entry	Grain yield (t/ha)	Flowering[a] (DS)	Plant ht (cm)	Panicles (no./m²)	Drought rating[b]	Important diseases[c]
International (IURYN) group						
IR9782-111-2-1-2	1.6	91 (82-106)	61	328	3.3	BLS, ShB
IR43 (check)	1.0	108 (101-116)	71	261	3.3	BLS, NBLS
C22 (check)	0.9	101 (92-109)	98	200	3.7	BLS
Local (Philippine) group						
IR19728-9-3-2	1.8	76 (67-84)	69	281	3.2	BI
IR15429-268-1-2-1	1.8	81 (71-96)	63	304	4.2	BI, BLS
IR9101-37-1	1.8	85 (73-100)	73	321	3.6	BLS
IR19735-5-2-3-2-1	1.7	79 (68-96)	64	345	4.0	BI
IR9752-71-3-2	1.7	81 (71-95)	60	302	4.2	BI, BLS
IR8608-3-2-2-3	1.6	89 (77-106)	70	278	4.0	BI
IR11288-B-B-288-1	1.6	117 (103-125)	73	306	3.8	–
IR19774-23-2-2-1-3	1.6	79 (67-95)	61	306	3.8	BI, BLS, ShB
IR9560-2-6-3-1	1.6	107 (98-116)	71	255	3.0	BLS
IR19743-25-2-2	1.6	80 (71-93)	69	327	3.8	BI, BLS
IR9995-76-2	1.6	105 (81-120)	79	265	2.8	BS
IR9814-11-3	1.5	91 (74-104)	77	260	3.8	BI
IR19743-46-2-3-3-2	1.5	78 (63-88)	66	290	4.5	BLS
IR19746-28-2-2	1.5	83 (72-97)	61	333	5.2	BI
IR9729-67-3	1.5	70 (60-82)	65	278	4.5	BI
IR43 (check)	1.3	104 (91-113)	70	249	4.0	BLS
C22 (check)	1.0	102 (90-111)	100	198	4.4	BLS

[a]Numbers in parentheses indicate range. DS = days after seeding. [b]Standard Evaluation System (SES) for Rice (1980) scale 0-9: 0 = no symptom of effects of soil moisture stress, and 9 = all plants apparently dead. [c]BI = leaf blast, BLS = bacterial leaf streak, NBLS = narrow brown leaf spot, ShB = sheath blight.

Salumpikit had drought rating averages of 3.8, similar to those of most of the entries in Table 4. Their yields were lower than those of the yield checks. Averages of the data on yield, plant characters, drought resistance, and insect resistance are summarized in Table 5.

Evaluation of rices for shallow rainfed drought-prone conditions *(Agronomy, Plant Breeding, and IRTP).* Trials at five sites — IRRI; Guimba and Gapan, Nueva Ecija; Tigbauan, Iloilo; and Liloan, Cebu evaluated promising breeding lines of IRRI and national programs for yield performance and reaction to drought stress.

The relationship between root-pulling force and yield performance under water-stress environments also was determined.

A group Balanced Block Design with 3 replications was used. Each replication was composed of three groups of materials: a Rainfed Wetland Culture Nursery (RWC) of 13 breeding lines from the dryland nurseries, 5 breeding lines from Thailand, and 2 check varieties under irrigated and rainfed water regimes; a Drought-Prone Areas Nursery (DPA) composed of 11 best performers from the 1980 DPA nursery and 10 GEU elite lines; and the First International Rainfed Lowland Rice Yield Nursery (IRLRYN).

Fertilizer was applied at 30-30-30 N, P_2O_5, and K_2O/ha basally incorporated as 30-0-0 topdressing at 30 days after transplanting (DT). Optimum weed and pest management practices were used. Textural and chemical analyses of test site soils are given in Table 6.

IRRI. The crop at IRRI transplanted on 29 July was the only crop that suffered a prolonged drought (8 Aug-16 Sep). The free water level (30-cm and 60-cm depths) remained below the ground surface for the entire duration of the crop. RWC check variety BPI-76 n.s. produced 0.6 t/ha, and Intan, 0.3 t/ha. Yields ranged from 0.1 t/ha (MR 7) to 2.1 t/ha (IR9852-22-3) over both the RWC and DPA trials.

Entries in the IRLRYN were transplanted at a separate site 26 June. Yields ranged from 0.2 t/ha (IR52) to 2.9 t/ha (IR13365-253-3-2). IR13365-253-3-2, IR13146-45-2-3, and IR14632-2-3 pro-

Table 6. Mechanical and chemical analyses of soils from different test sites in the Philippines, 1981 wet season.

Analysis	IRRI	Guimba	Gapan	Iloilo	Cebu
Mechanical					
Sand (%)	24.0	12.0	48.0	14.0	40.0
Silt (%)	42.0	46.0	35.0	48.0	32.0
Clay (%)	34.0	42.0	17.0	38.0	28.0
Soil texture	Clay loam	Silty clay	Loam	Silty clay loam	Clay loam
Chemical					
pH (1:1)	6.1	6.5	5.1	5.2	5.6
Organic matter (%)	1.13	1.25	0.442	0.859	0.72
Total N (%)	0.121	0.120	0.054	0.096	0.08
Potassium	0.83	0.20	0.02	0.80	0.24
Cation exchange capacity (meq/100 g)	29.5	26.9	8.7	23.0	14.6
Available zinc (ppm)	0.4	0.6	1.0	0.7	1.1

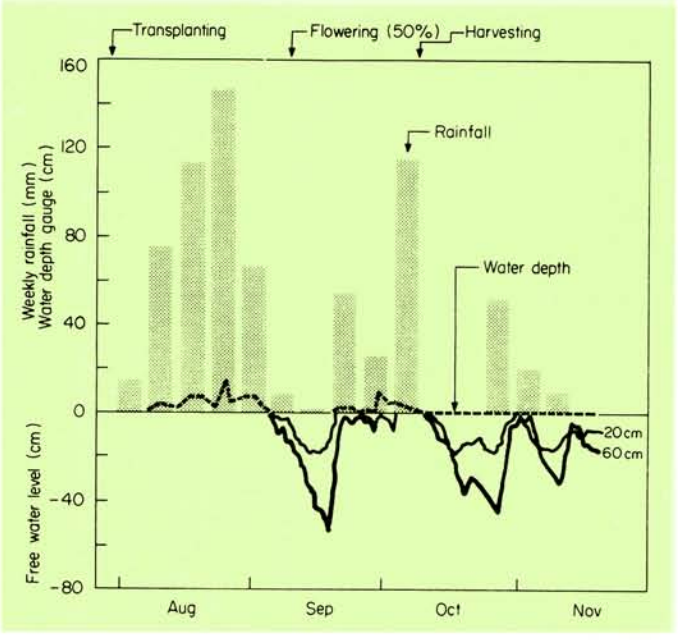
duced the highest yields. IR13146-45-2-3 and IR14632-2-3 performed well under both rainfed and irrigated conditions.

Guimba, Nueva Ecija. The crop at Guimba was transplanted on 29 July. Rainfall in August and the first week of September was sufficient to keep all plots well watered (Fig. 14). The crop had mild drought stress at maximum tillering, and the early-maturing groups, during panicle initiation. Most entries lodged at the hard-dough stage because of severe sheath rot and bacterial leaf blight infection. Mean yields for rainfed (5.2 t/ha) and irrigated (4.5 t/ha) plots were the highest among the five sites.

Entries with high yield potentials in both rainfed and irrigated plots were IR13146-13-3-3 (5.2 and 4.5 t/ha), IR19274-26-2-3-1 (4.9 t/ha and 4.3 t/ha), and IR14753-72-1 (4.9 and 4.3 t/ha).

Gapan, Nueva Ecija. The crop at Gapan was transplanted on 1 September. No pronounced stress occurred. However, severe lodging at the spikelet filling stage caused by the 24-November typhoon lowered mean yields. Bacterial leaf diseases were observed in some entries. The mean yield in the rainfed plots was 2.9 t/ha. The best yielders for both rainfed and irrigated plots were IR7149-35-2-3-2 (4.1 t/ha) and IR13146-13-3-3 (4.0 and 3.6 t/ha).

Tigbauan, Iloilo. The crop was transplanted 29 August. In the early- and medium-maturing groups, rainfall was evenly distributed from transplanting to flowering. Late-maturing entries experienced slight drought stress the first week of December.



14. Free water level in the paddy (piezometer at 20- and 60-cm depth), water depth gauge, and rainfall in the 1981 wet season, Guimba, Nueva Ecija, Philippines.

The free water level at 30- and 60-cm depths was rather low except during the typhoon on 26 September (Fig. 15). The water table receded 8 weeks after transplanting and remained low through ripening. The highest yields (4.5-4.6 t/ha) were those of KKN 7409-SKN-245-2 from Thailand, IR20, IR5629-64-3, IR5853-198-1-2, IR14753-72-1, and IR54.

Liloan, Cebu. The crop was transplanted 29 October. It was severely infested by rice whorl maggots and leaf-folders at the seedling stage. A rainfall of 248.6 mm was unevenly distributed from transplanting to flowering. Free water level in the field at 20- and 60-cm depths was rather low except during the first week of December (Fig. 16). The best yields (3.1-3.3 t/ha) were those of IR5629-64-3, IR13146-13-3-3, and IR18272-27-3-1-2-2.

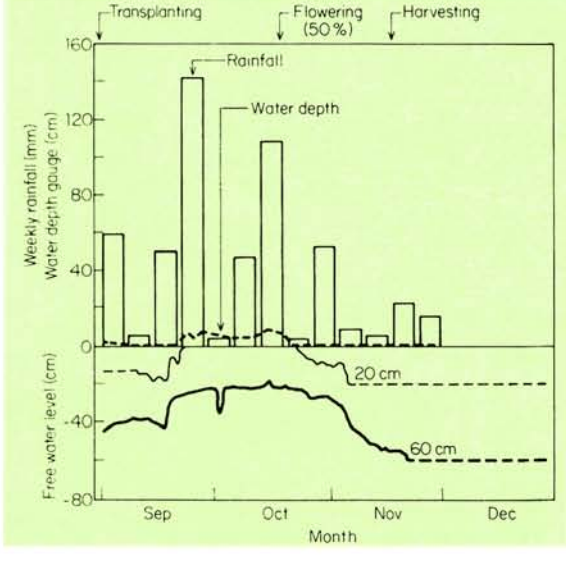
Combined performance. In the rainfed-wetland culture nursery, KKN 7205-39-3-SKN-1-1 (3.3 t/ha), Khao Dawk Mali 105 (2.6 t/ha), IR18848-35 (2.5 t/ha), KDML 65-60-45-45 (2.5 t/ha), and KKN 7409-SRN-245-2 (2.5 t/ha) had the highest mean yields across all sites (Table 7). In the drought-prone-areas nursery, IR14753-72-1 (3.7 t/ha), IR13146-13-3-3 (3.6 t/ha), IR5853-198-1-2 (3.4 t/ha), and IR5629-64-3 (3.4 t/ha) were the best overall performers (Table 7). In the IRLRYN, IR14753-49-2 (3.48 t/ha), IR14632-2-3 (3.4 t/ha), IR46 (3.1 t/ha), IR13146-45-2-3 (3.0 t/ha), and IR52 (3.0 t/ha) were the best performers (Table 7).

Root pulling was done from 20-30 days after transplanting (DT). Root-pulling force (kg) in the rainfed environments ranged from 12.39 to 18.99 kg in IR20 and IR54, respectively (Table 8). Table 8 shows the ranking of the top 10 entries with their corresponding root-pulling force under two water regimes.

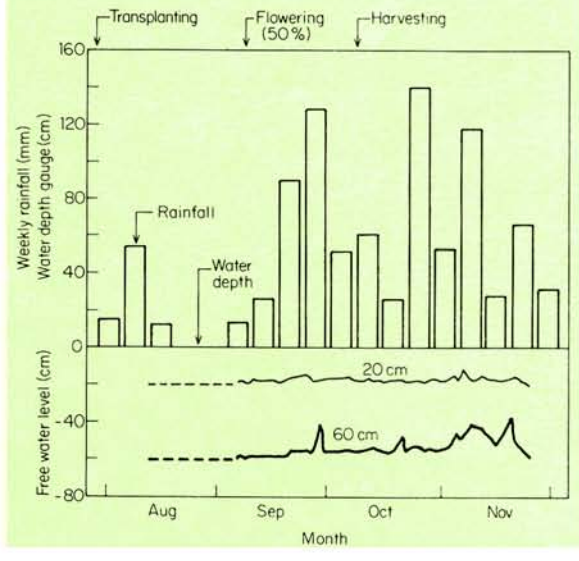
International collaborative evaluation of yield performance under two water regimes *(Plant Breeding).* Thirty-eight breeding lines from Thailand, Indonesia, and IRRI were evaluated for yield performance under two water regimes at two sites in Thailand — the Chumphae Rice Experiment Station and the Northeast Agricultural Center in Khon Khaen. Two traditional rainfed-wetland varieties, BPI-76 n.s. and Intan, were used as checks.

Chumphae Station. The yields in a rainfed field ranged from 1.9 to 3.8 t/ha and averaged 2.9 t/ha. The highest yielders, IR46 and IR13426-19-2, both produced 3.8 t/ha. Check variety BPI-76 n.s. yielded 3.1 t/ha, and Intan, 1.9 t/ha. Two breeding lines from Thailand, KKN7409-SRN-235-6 and KKN7409-SRN-245-1, each yielded 3.5 t/ha. Yields of 3 Indonesian lines ranged from 3.3 to 3.5 t/ha.

In irrigated plots, yields ranged from 2.8 to 4.8 t/ha and averaged 3.9 t/ha. Highest yielders were



15. Free water level in the paddy (piezometer at 20- and 60-cm depth), water depth gauge, and rainfall in the 1981 wet season, Tigbauan, Iloilo, Philippines.



16. Free water level in the paddy (piezometer at 20- and 60-cm depth), water depth gauge, and rainfall in the 1981 wet season, Liloan, Cebu, Philippines.

KKN 7409-SRN-235-6 (4.8 t/ha), KKN 7409-SRN-245-1 (4.6 t/ha), and IR9217-58-2-2 (4.5 t/ha). BPI-76 n.s. yielded 3.3 t/ha and Intan, 3.9 t/ha.

Northeast Agricultural Center and Khon Khaen Rice Experiment Station. The rainfed experimental plots were at the Northeast Agricultural Center (NEAC) and the irrigated plots at the Khon Khaen Rice Experiment Station (KKN).

The yields of rainfed field plots at NEAC ranged from 3.5 to 6.0 t/ha and averaged 4.7 t/ha. The highest yielders, IR9852-22-3, IR13146-41-3, and IR13365-253-2-2, produced between 5.6 and 6.0 t/ha. Indonesian variety B865C-MR-144-3-1-2 produced 5.4 t/ha; Thailand entries RD6, RD8, RD15; and KDML'65-G1U-45-45, from 5.1 to 5.4 t/ha. Check variety Intan yielded 4.1 t/ha and BPI-76 n.s., 3.6 t/ha.

In the irrigated plots at KKN station, the mean yield was only 3.5 t/ha. The highest yielder was IR46, 4.6 t/ha. IR5873-9-1, Indonesian variety B865C-MR-144-3-1-2, Thailand variety BKN7130-428-2, and check variety BPI-76 n.s. produced about 4.0 t/ha. Other entries yielded from 2.0 to 3.9 t/ha.

The highest yielders in the rainfed plots per-

Table 7. Top-yielding entries in rainfed trials, average of 5 Philippine locations, 1981 wet season.

Rank	Variety or line	Yield (t/ha)					$\bar{X}$
		IRRI	Guimba	Gapan	Iloilo	Cebu	
	Drought-prone areas nursery						
1	IR14753-72-1	1.9	4.9	4.1	4.5	2.9	3.7
2	IR13146-13-3-3	1.9	5.2	4.0	3.8	3.2	3.6
3	IR5853-198-1-2	1.4	4.9	3.6	4.5	2.5	3.4
3	IR5629-64-3	1.8	4.3	3.3	4.5	3.3	3.4
4	IR18272-27-3-1-2-2	1.7	3.9	3.9	3.8	3.1	3.3
5	IR19274-26-2-3-1	1.9	4.9	2.9	3.9	2.4	3.2
6	IR8192-200-3-3-1-1	1.8	3.9	3.5	4.1	2.2	3.1
6	IR22082-41-2	1.6	3.8	3.2	4.4	2.5	3.1
7	IR9852-22-3	2.1	4.1	3.6	3.0	2.2	3.0
7	IR9129-161-2	1.3	3.6	3.5	4.2	2.6	3.0
	IR36 (check)	1.9	3.6	3.5	3.8	2.9	3.1
	IR54 (check)	1.7	4.8	3.2	4.5	3.0	3.4
	Rainfed wetland culture nursery						
1	KKN7205-39-3-SKN-1-1		3.6	2.7	4.4	2.3	3.3
2	Khao Dawk Mali 105		2.6	1.8	4.1	1.7	2.6
3	IR18848-35		3.7	1.9	2.6	1.7	2.5
3	KDML65-60-45-45		2.7	2.5	3.5	1.4	2.5
3	KKN7409-SRN-245-2	0.1	3.2	2.8	4.6	1.9	2.5
4	IR18838-24	1.2	3.8	2.2	3.4	1.4	2.4
4	IR13754-5	0.7	3.8	1.5	4.3	1.9	2.4
5	IR10044-37-1	0.9	3.3	2.3	3.6	1.6	2.3
5	IR18845-23	0.4	3.6	1.6	3.7	2.1	2.3
6	IR10110-24-1	0.9	3.3	1.8	3.3	1.7	2.2
	BPI76 n.s. (check)	0.6	2.6	1.9	4.2	2.2	2.3
	Intan (check)		2.9	1.8	2.6	1.1	2.1
	International Rainfed Lowland Rice Yield Nursery[a] (IRLRYN)						
1	IR14753-49-2	1.4	4.4	4.1	4.4	3.1	3.48
2	IR14632-2-3	1.7	4.5	4.5	4.1	2.3	3.42
3	IR46	1.2	4.6	3.9	3.8	2.2	3.14
4	IR13146-45-2-3	2.1	4.3	3.0	3.5	2.2	3.02
5	IR52	0.2	4.4	3.7	4.3	2.4	3.00
6	IR13365-253-3-2	2.9	4.8	2.6	2.5	2.1	2.98
7	BR4	1.1	4.7	3.5	3.0	2.1	2.88
8	IR13358-85-1-3	1.6	4.4	3.7	2.3	2.2	2.84
9	BR51-282-8	0.7	4.3	3.1	3.7	2.2	2.80
10	IR10781-75-3-2	1.5	4.0	3.6	3.5	1.3	2.78

[a]Trial at IRRI was conducted at a separate rainfed site.

Table 8. Top 10 genotypes (av, 3 locations) and their root-pulling force (RPF) in rainfed and irrigated conditions. Philippines, 1981.

Rank	Variety or line	RPF (kg)	Rank	Variety or line	RPF (kg)
	Irrigated			*Rainfed*	
1	IR7149-75-2-3-2	18.02	1	IR5853-198-1-2	15.69
2	IR21015-121-2-2	17.97	2	IR9129-161-2	15.59
3	IR18848-35	17.55	3	IR21015-121-2-2	15.22
4	IR9852-22-3	17.41	4	IR9209-26-2	14.52
5	IR19670-206-3-3-3-3	17.32	5	IR19670-206-3-3-3-3	14.18
6	IR5853-198-1-2	17.15	6	KKN7909-SKN-245-2	14.13
7	IR13146-13-3-3	17.13	7	MR7	14.10
8	IR8192-200-3-3-1-1	16.86	8	IR14753-49-2	13.90
9	IR14753-72-1	16.67	9	IR18272-27-3-1-2-2	13.84
10	IR18272-27-3-1-2-2	16.64	10	IR10781-75-3-2	13.81
	IR54 (check)	18.99		IR52 (check)	15.05
	IR36 (check)	16.31		IR20 (check)	12.39

formed poorly in the irrigated field, 3.4-3.7 t/ha. Severe weed problems and some saline spots contributed to those lower yields.

ROOT STUDIES

Plant Breeding and Plant Physiology Departments

Correlation of root characteristics in F_2 populations *(Plant Breeding).* From the eight-parent diallel cross grown under aeroponic culture in 1980, three F_2 populations were selected and grown. The populations represent crosses between dryland/dryland, dryland/wetland, and wetland/wetland parents.

A positive association existed between root length and root-tip thickness (0.53**), dry-root weight (0.60**), and plant height (0.48**). Root-tip thickness correlated positively with plant height (0.54**) and dry-root weight (0.33**), but root thickness correlated negatively with tiller number (−0.24*) and root number (−0.14**).

Differences among variety-groups *(Plant Breeding).* The aeroponic culture is used to study varietal differences in various root characteristics and to assess differences in field and aeroponic cultures. The focus is on traditional dryland varieties and Indonesian bulu varieties, because the two variety-groups have similar aboveground plant morphology: tall plant stature; few, large, and thick culms; broad leaves; long and well-exserted panicles; large and bold grains; and a high frequency of awned panicles.

Some traditional hill (dryland) rices, such as Kalakari and Salumpikit, have the longest roots. But certain bulu varieties, such as Baok Putik and Hawara Bato, have roots as long as those of dryland varieties in the next ranking class. But other bulu rices have very short roots.

Bulu varieties in general do not have as thick roots (above 1 mm in diameter) as the best dryland varieties. Some bulus have very thin roots, and varieties such as Rodjolele and Baok also have short roots.

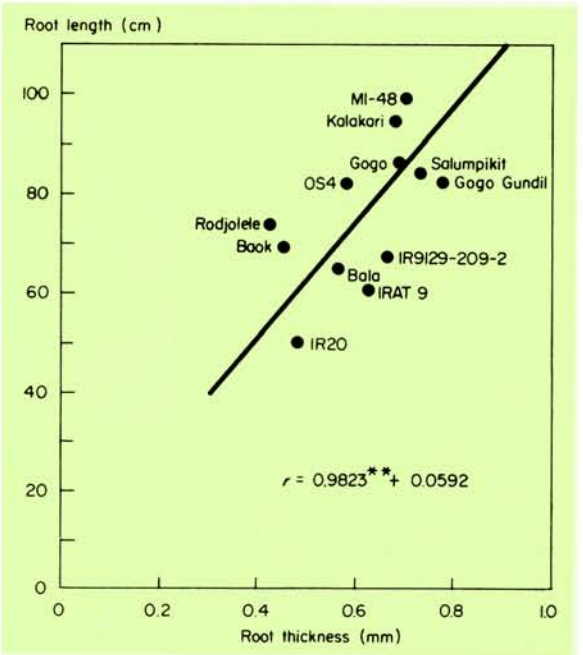
The semidwarfs, in general, have thin roots but root lengths vary from short (IR20) to intermediate (Bala).

The root numbers of dryland varieties vary from few (28) to dense (57). The bulu varieties were less variable, from 42 to 55. Roots of semidwarfs are moderately dense (47 in Bala) to dense (60 in IR9129-209).

Among 12 varieties tested (Fig. 17), root length and root thickness correlated positively ($r = 0.9823$**).

These data from aeroponic culture essentially parallel those observed in roots sampled from the field or from soil tubes and soil boxes. The deepest and thickest roots were found in the drought-resistant traditional dryland varieties. The bulus varied markedly in root length and thickness. The semidwarfs excelled in root number only.

Aluminum toxicity *(Plant Physiology). Varietal differences in tolerance of aluminum toxicity.* A total of 173 rices were screened for tolerance for



17. Relationship between root length and root thickness in dryland, bulu, and semidwarf varieties. IRRI, 1981.

aluminum toxicity using the relative root growth technique (Table 9).

Most of the tolerant selections were dryland varieties from South America and Africa. Bluebonnet 50, a U.S. wetland variety, also was tolerant. Some wetland varieties and selections were intermediate. Most were classified as susceptible. Apparently tolerance of aluminum toxicity and deep rooting habit are associated. The dryland varieties tolerant of aluminum toxicity are usually deep rooted.

Critical solution concentration. Aluminum at 30 ppm has been used in the standard solution culture technique to screen rice varieties for tolerance for aluminum toxicity. At 3 ppm Al, only susceptible varieties are slightly affected and then only at 0-2 weeks after germination. However, the aluminum concentration usually found in soil solutions of dryland acid soils is only 1-5 ppm.

Is tolerance for aluminum toxicity in rice more than sufficient for the aluminum concentrations usually found in acid dryland soils? To examine that question, seminal root growth was measured in a solution containing 10^{-4} M $CaCl_2$ and graded levels of aluminum. At 2 ppm Al, seminal root growth in both OS4, aluminum toxicity tolerant, and Cica 4, aluminum toxicity susceptible, was severely impaired (Fig. 18). Cica 4 showed a greater reduction in root length. At 3 ppm, root growth in both varieties was severely stunted.

The major difference between the standard solution culture and the seminal root experiment is in the composition of the test solution. Findings of the seminal root experiment suggest that the presence of nutrient salts in the solution has a profound influence on the critical concentration for measuring aluminum toxicity in rice.

To verify that point, root growth of 3 rice varieties was measured in 2 solutions, one that contained full strength of the standard culture solution and one 1/10th strength with graded levels of aluminum. In the full-strength solution, root growth of susceptible varieties IR45 and Cica 4 was impaired at 5-10 ppm Al; that of tolerant variety IAC 3 was impaired at 15 ppm Al (Table 10). At 1/10th-strength solution, root growth of the susceptible varieties was impaired at 2.5 ppm Al, that of the tolerant variety at 10 ppm Al.

It is clear that a high concentration of companion ions in the standard culture solution alleviates aluminum toxicity in rice.

Since acid dryland soils are likely to have low concentrations of bases and high concentrations of aluminum, about 2 ppm Al in the soil solution appears to be critical for susceptible varieties. These experiments also show that aluminum saturation of a soil, defined as the percentage of aluminum ion in the effective cation exchange capacity (sum of exchangeable calcium, magnesium, potassium, sodium, plus potassium chloride exchangeable aluminum, is a better criterion than exchangeable aluminum content for diagnosing soil aluminum toxicity.

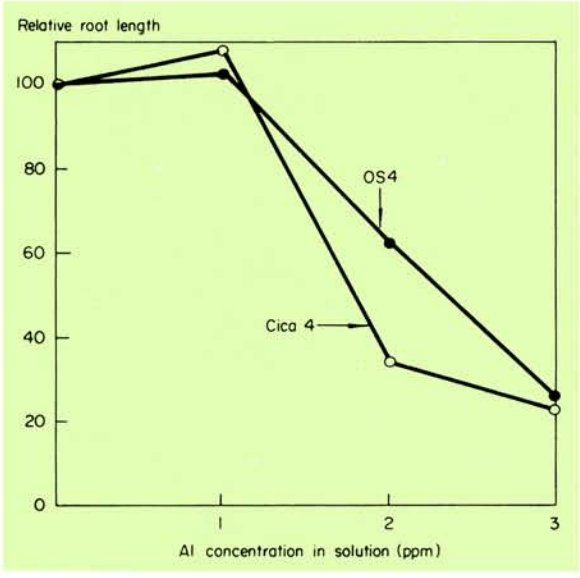
SOIL-PLANT-WATER RELATIONSHIPS

Agronomy and Soil Chemistry Departments

Drought tolerance under limited rooting depth *(Agronomy).* A greenhouse study on improved drought tolerance and the ability to recover from drought stress under limited rooting depth continued with 105 elite lines, including a few selected varieties and lines, evaluated in 2 seasons. All entries were seeded in dry soil in steel drums with an effective rooting depth of 45 cm. Soil in the

Table 9. Aluminum toxicity tolerance of 173 varieties, based on relative root growth, IRRI, 1981.

Tolerant	Intermediate	Susceptible
Agbede	Ardito	Ambarikor 1
Agulha	Batataes	Belem
Amarelao	Bingala	Binato
Bengue	Blue Rose	Binundok
Bico Branco	Bosque Sel. 693	B158 Bentoubala D.
Bico Preto	BPI 76	BD 2
Binirhen	Canairo Acc. no. 3307	Bombilla
Bluebonnet 50	Canairo Acc. no. 10753	Buntot Kabayo
Cateto	Catetao Dourado	C4-63G
Cateto Branco	C1 5368-1	Catetao 24
Cateto Dourado	C1 5354-1	Chang Chang
Chokoto 14	C1 8900-1	C1 1428
C1 2011	Conquista	C1 5358
C1 2012	Criollo	C1 8898-2
C1 2013	Dalila	Cica 4
C1 5354-2	Dawk Mali	Congo
Colombia 1	Elon-elon	Dawebyan (Acc. no. 3445)
Come-cru Preludo	Fortuna	Dawebyan (Acc. no. 3446)
Dinayang	Huk Do	Dinagat
Djaub	IR24	Djubuh
Djoweh	IR36	Ginwi G4
Dourado Agulha	IR48	IR5
Emata Yin	IR52	IR8
E425	IR442-2-58	IR20
Guaiba	IR944-102-2-3-2	IR22
IAC 1	IR1552-80-2-2-3	IR26
IAC 3	Khao Lo	IR28
IAC 9	Kinamay	IR29
IAC 10	Lampadan	IR30
IPEACO 162	Macan Binundok	IR32
IAC 1131	Magsanaya (Acc. no. 4019)	IR34
IAC 5100	Mantoya	IR38
Iguape Cateto	Maranhao 2	IR40
Kanan	Miltex 125	IR42
Miga	Minoro	IR43
Miltex	Misuho	IR44
Magdatu	Moroberekan	IR45
Matao Liso	M23 Mugad	IR46
Milfor 6-2	Mutselu	IR50
Monolaya	Muzzlo 45	IR1416-131-5
MI-48	Palawan	IR1561-228-3-3
Norin 24	Perola	IR1813-694-2
OS4	P3-1	IR2068-65-3
OS6	P3-105	IR2071-588-2-5-1
Pratao	P3-111	IR2070-24-1
Pratao Prococe	Perurutong NB	IR2076-67-3-5
Prolific	PI 190617-1	IR2851-42
Rexora	Secano	IR2852-8
Salak	Sikasso	Jappeni Tungkungo
Taal 2	Sinawit	Japones
TI 1	Sakotora S42	Lacross
Tres Meses	Sakotora S55	L102-8
UVS	Sanakevelle Paddy	Magsanaya (Acc. no. 725)
	Sornavari	Milagrosa
	Starbonnet	Mamoriaka
	Sueca	M. Bale
	Vencer	P3-93
	Wagwag	Sampaguita
	Yupul	Señorita
	20 A	Sinaba



18. Effect of aluminum on seminal root growth of 2 varieties. IRRI, 1981.

drums was watered regularly to 30 DS, then the soil was allowed to dry naturally.

When indicator plant Leb Mue Nahng (grown together with two other entries) appeared dead, the soil was sampled for moisture content and entries were scored for drought tolerance. Then, plants were rewatered. Recovery ability was scored 20 and 40 days after relief from stress.

Table 11 lists some entries that were outstanding in the dry season. The first eight entries in the list also performed fairly well in earlier tests. Distinct differences in recovery from drought were found 20 days after relief from stress. But after 40 days, plants had attained as many as or more than their original number of tillers. Leb Mue Nahng did not recover.

Reproductive drought resistance in IR52 *(Agronomy).* IR52 (IR5853-118-5) was released in 1980 in the Philippines as a rainfed lowland rice variety suited to drought-prone conditions. It consistently has outstanding drought resistance scores at the vegetative stage, exceeding those of the widely grown but only moderately resistant IR36.

IR52 and IR36 were compared for performance under several levels of drought stress during the 1981 dry season to determine whether IR52 exhibits superior drought resistance during the reproductive stage and, if it does, what factors might underlie its resistance.

A line source sprinkler system was used to apply water treatments. Each variety was planted on eight different dates to synchronize flowering periods.

IR52 had consistently higher root length densities at all depths than IR36 (Fig. 19). The root system of IR36 extended no deeper than 60 cm under any stress environment; the roots of IR52 extended as deep as 75 cm. The patterns of rooting with depth were similar for both varieties in three stress environments, perhaps because stress was not imposed until the reproductive stage, when root growth normally ceases.

The deeper and more prolific root system of IR52 presumably enabled the roots to extract more water during drought stress. This possibility was evaluated by measuring the weekly water balance from the beginning to the end of the stress period (21 days) to determine crop water use. IR52 had a higher water use than IR36, 6-11% depending on the stress environment, but the difference was not statistically significant (Table 12).

Infrared thermometry showed that IR52 maintained significantly cooler canopy temperatures

Table 10. Effect of salt concentration on aluminum toxicity. IRRI, 1981.

Variety	Salt concn	Root length[a] (cm) at Al concn of				
		0	2.5	5.0	10.0	15.0 ppm
IAC 3	1/10th strength	8.0 (100)	8.2 (103)	7.4 (93)	6.6 (83)	6.0 (75)
IR45		7.6 (100)	6.4 (84)	3.3 (43)	2.1 (28)	2.0 (26)
Cica 4		6.8 (100)	6.0 (88)	4.6 (68)	3.5 (51)	3.0 (44)
IAC 3	Full strength	12.6 (100)	13.0 (103)	12.2 (97)	11.8 (94)	10.6 (84)
IR45		10.2 (100)	9.6 (94)	9.2 (90)	8.7 (85)	8.4 (82)
Cica 4		9.5 (100)	9.0 (95)	9.0 (95)	8.4 (88)	7.6 (80)

[a]Figures in parentheses represent root length in percentage.

Table 11. Drought tolerance ratings at the vegetative stage of promising entries and their drought recovery scores 20 and 40 days after relief from stress. IRRI greenhouse, 1981 dry season.

Variety or line	Drought tolerance rating[a]	Recovery from drought[a]	
		20 days	40 days
IR9209-262-1-3-1	5	1	1
IR9209-262-3-6	7	1	1
IR9764-45-2-2	7	1	1
IR388-13-7	5	1	1
IR15318-2-2-2-2-2	7	3	1
Cauvery	7	5	1
IR9852-22-3	7	5	1
IR13426-19-2	7	5	1
IR5931-110-1	7	1	1
IR13146-41-3	5	1	1
IR13423-10-2-3	5	1	1
IR13423-17-1-2-1	7	1	1
IR19660-131-3-3-3-3	7	1	1
IR19729-5-1-1-3-2	7	1	1
IR19746-28-2-2-3	7	1	1
IR13358-85-1-3	7	5	1
IR15496-219-2-3-2	9	3	1
IR19743-25-2-2-3-1	5	3	1
Leb Mue Nahng (tolerant check)	9	9	9

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

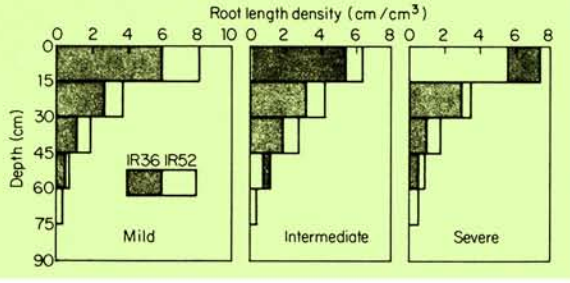
over the stress period than did IR36. IR52 also maintained higher leaf water potential under stress.

These differences indicate that IR52 has some advantage over IR36 in avoiding water stress at the reproductive stage and that a more effective root system is a primary component.

Unfortunately, IR52 did not translate its superior drought resistance components into significantly better plant performance under reproductive stress. The stress delayed flowering virtually by the same number of days in both varieties (Fig. 20). Delay in flowering tended to increase approximately 0.4 days for each day beyond the beginning of the stress period that no-stress flowering occurred.

Under mildly unfavorable conditions, IR52 had slightly (but not significantly) higher yields than IR36 (Fig. 21). The two varieties had identical yields under severe stress. The drought avoidance in IR52 appears to be most advantageous under relatively mild stress.

Leaf and panicle water potentials *(Agronomy).* Field measurement was used to determine differences in diurnal response of leaves and panicles to water stress at different stages of flowering.



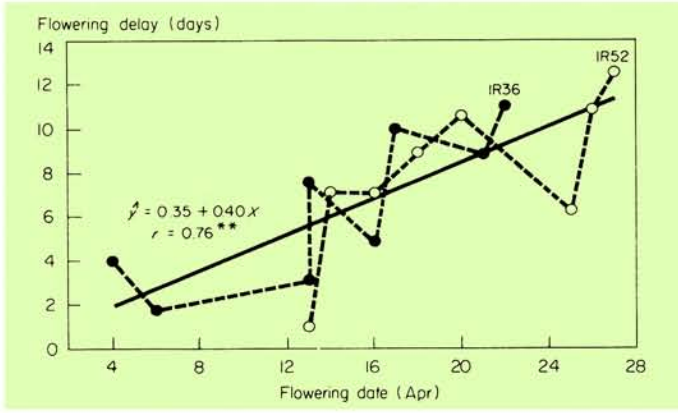
19. Root length density with depth of IR52 and IR36, averaged for 2 sampling dates (flowering and maturity). IRRI, 1981 dry season.

Sampling for water potential was done on 15 April from 0400-1900 hours on the control and stressed plots. Regardless of growth stage and water condition, panicles and leaves have similar trends in water potential. Differences in water potential are wider at early flowering and midflowering than at late flowering stage (Fig. 22) because exsertion of the panicle is a factor in panicle-water relation. Not-yet-fully-exserted panicles are less exposed at early flowering or at midflowering than at late flowering. At late flowering, panicles are usually fully exserted and exposed, with ψ values very close to those of the leaves.

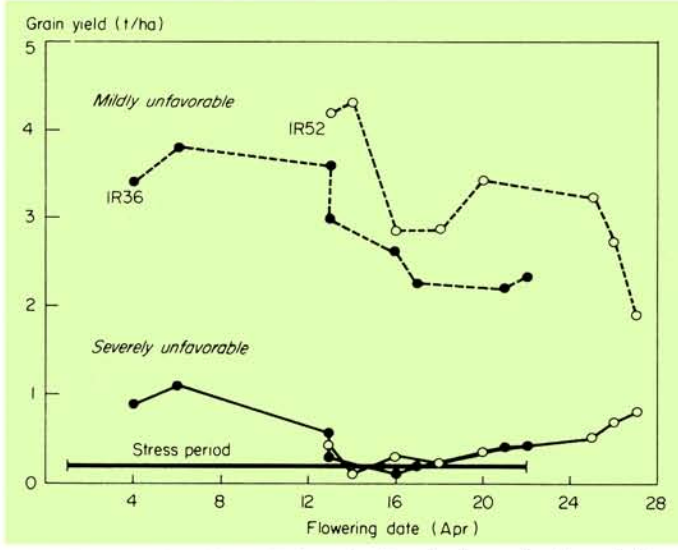
The same measurements showed that the water potential of leaves, in general, was more affected than that of panicles at any time during the diurnal measurement of both control and stress conditions. Leaves are more negative in water potential than panicles (Fig. 23). However, the regression lines suggest that the flagleaf ψ can be considered a good estimate of panicle water potential in the control and stressed plots, even when the panicles are not yet fully exserted.

Table 12. Total water use by crops (evapotranspiration) of 2 rice varieties grown under 5 stress environments imposed with a line source sprinkler system for 21 days at flowering. IRRI, 1981 dry season.

Variety	Evapotranspiration (mm) in stress environment				
	1 Mild	2	3 Intermediate	4	5 Severe
IR52	203	187	167	139	120
IR36	186	168	145	131	110
Difference	17^{ns}	19^{ns}	16^{ns}	8^{ns}	10^{ns}
Percentage	9	11	11	6	9



20. Delay in flowering under severe reproductive stress (environment 5 − environment 1) among 8 plantings of IR36 and IR52. IRRI, 1981 dry season.



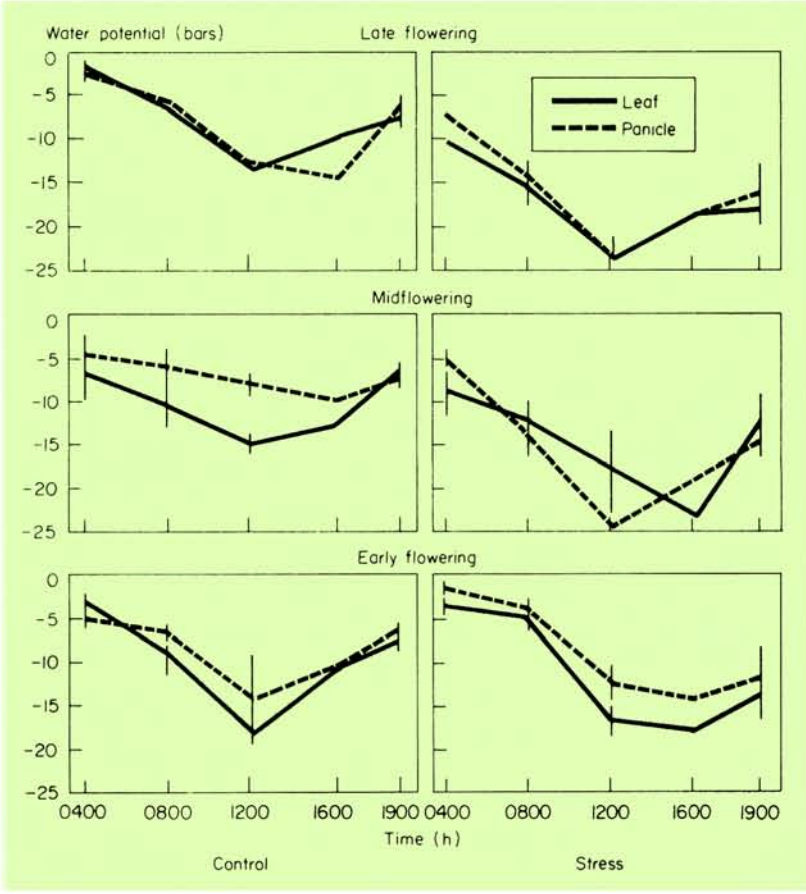
21. Grain yields of IR52 and IR36 under 2 levels of reproductive period drought stress: mildly unfavorable = environment 1; severely unfavorable = environment 5. IRRI, 1981 dry season.

Effects of osmotic stress on growth and nitrogen uptake *(Agronomy).* A study in phytotron growth cabinets described the growth of rice plants under osmotic stress and examined the effect of plant water stress on nitrogen uptake. IR36 seedlings, 21 days old, at high (40 ppm) and low (10 ppm) nitrogen levels, were exposed to decreased nutrient solution water potentials by the addition of polyethylene glycol 6000. The roots were separated from the solution by a semipermeable membrane. The nutrient solution, starting at −0.6 bar, was lowered stepwise to −1.0, −2.0, 4.0, and −6.0 at 2-day intervals.

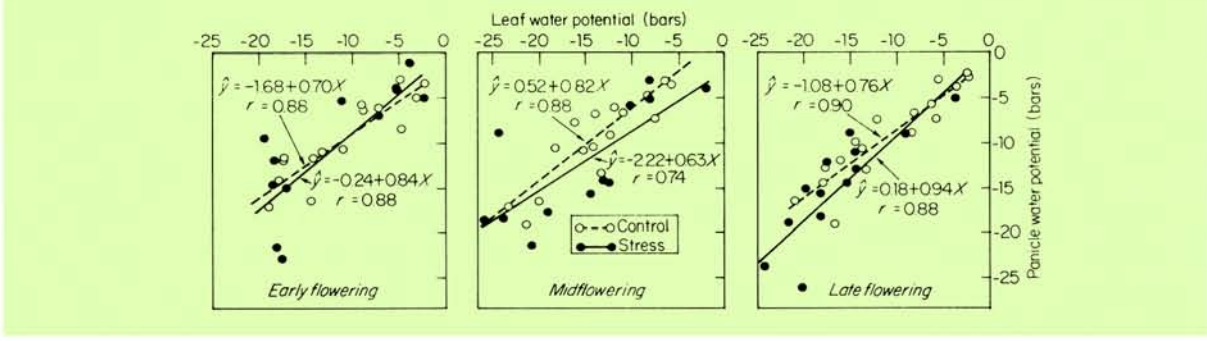
Plant height, leaf area, and shoot dry weight were reduced by exposure of the root systems to decreased osmotic potential of nutrient solution (Fig. 24). Osmotic stress enhanced root growth more in low nitrogen than in high nitrogen.

Dawn leaf water potential of stressed plants was 1.0 - 5.5 bars lower than nutrient solution water potential (Fig. 25). Low-nitrogen plants maintained higher water potentials than did high-nitrogen plants, possibly because they had more roots and smaller leaf areas.

The relationship between dawn leaf water potential and total nitrogen content of shoots harvested



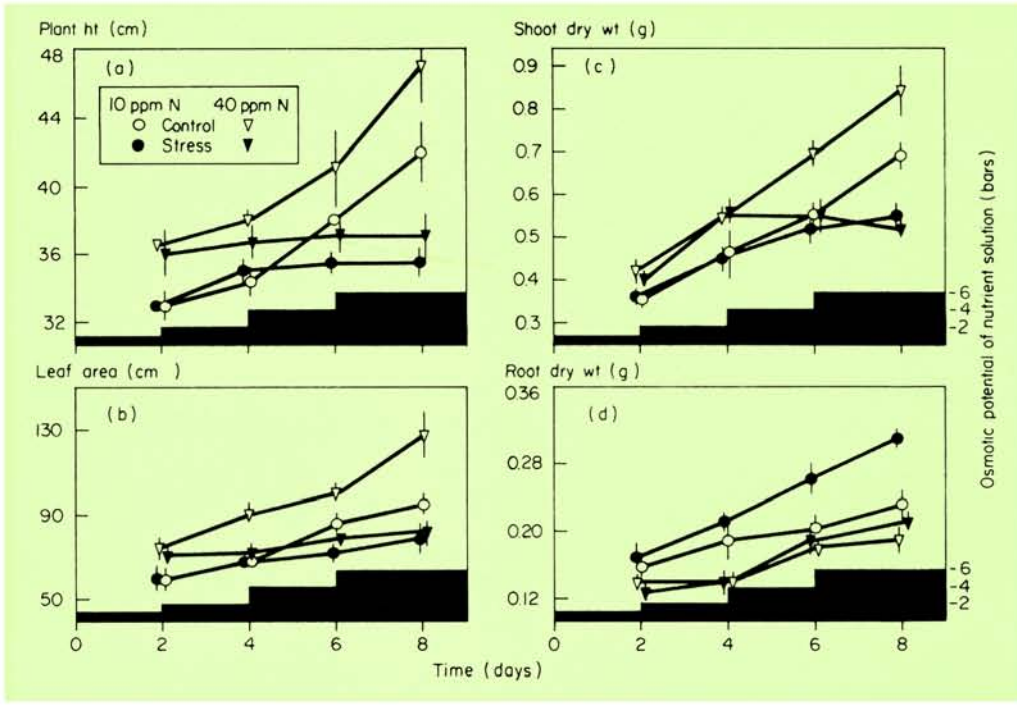
22. Diurnal pattern of rice flagleaf and panicle water potentials at different stages of flowering, IR36, 1981 dry season.



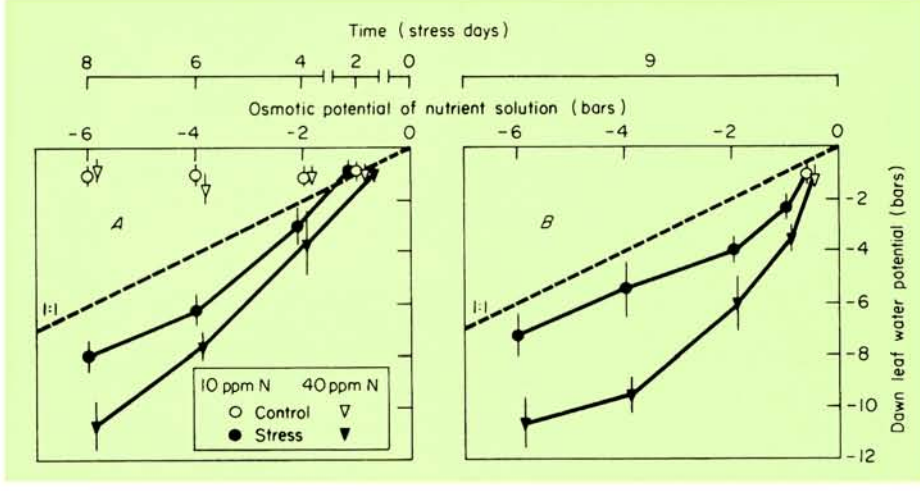
23. Relationship of flagleaf and panicle water potentials measured from 0400-1900 hours at different flowering stages, IR36, 1981 dry season.

on the last day of stress is shown in Figure 26. Plant water stress reduced total nitrogen uptake in both nitrogen treatments. Plants grown in 40 ppm N had greater total nitrogen uptakes because they had more dry matter and higher nitrogen concentrations than those grown in 10 ppm N. Decreased nitrogen uptake under osmotic stress could be due to reduced water uptake. Total nitrogen content increased linearly with cumulative transpiration, but plants in 40 ppm N contained more nitrogen than those in 10 ppm N (Fig. 27).

Therefore, reduced nitrogen uptake is not only a result of the unavailability of soil nitrogen because of low soil moisture content, but also is brought about by plant water stress per se. It is possible that reduced growth during water deficit is partly



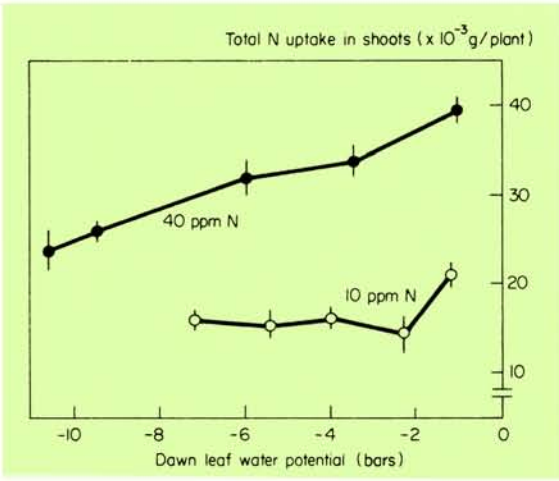
24. Effects of osmotic potential of nutrient solution on plant height, leaf area and shoots, and root dry weights of IR36 grown in 10 ppm (low) and 40 ppm (high) nitrogen. Plants in culture solution only are control and those in solutions with potential decreased by addition of PEG 6000 are stressed. Vertical bars indicate standard deviation of 3 replications. IRRI, 1981 dry season.



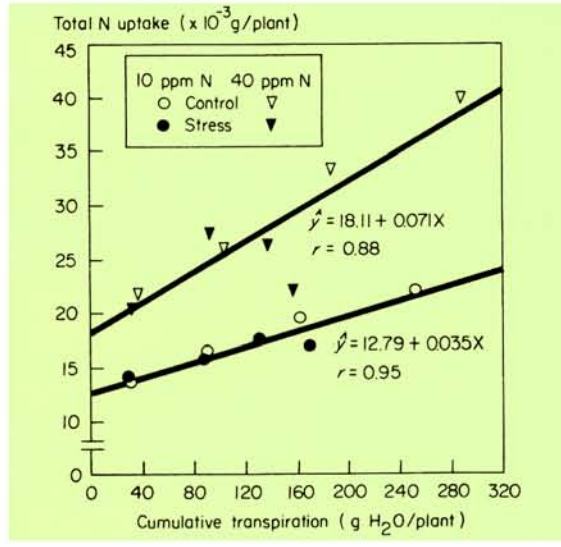
25. Relationship between dawn water potential of rice leaf and osmotic potential of nutrient solution during the first 8 days (A) and on the last day (B) of stress period. IRRI, 1981 dry season. Plants in culture solution only are control and those in solutions with decreased osmotic potentials are stressed. Diagonal dashed lines represent 1:1 values. Vertical bars indicate standard deviation of 3 replications.

caused by decreased nitrogen (nutrient) uptake.

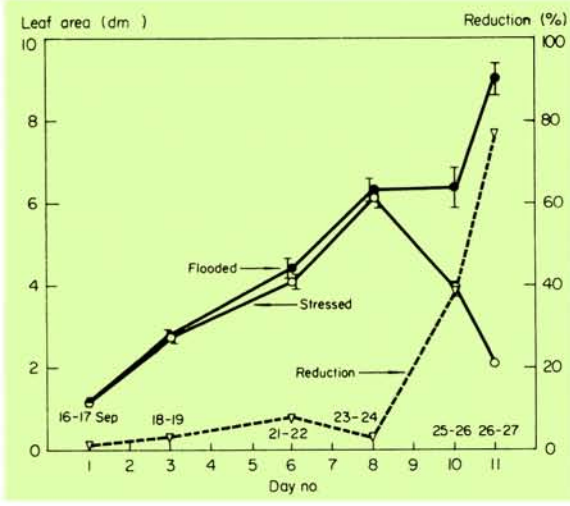
Effects of water stress on growth and nitrogen uptake of IR36 *(Agronomy and Soil Chemistry).* A series of greenhouse experiments documented the effects of decreasing moisture content on growth and nitrogen uptake of IR36. The experiment, in a randomized complete block design with five replications, involved two systems of water manage-



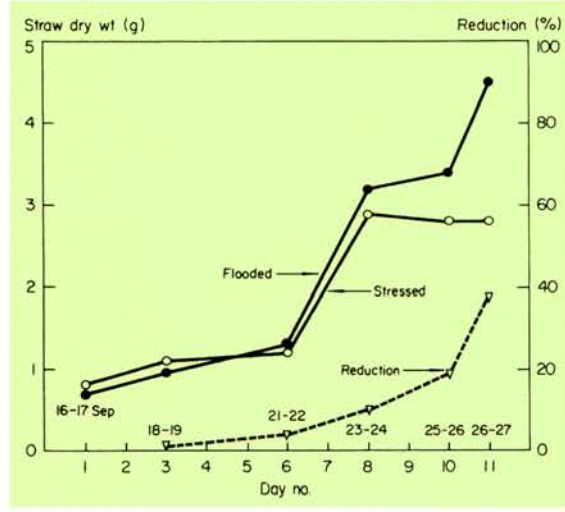
26. Relationship between dawn leaf water potential and total nitrogen uptake in rice shoots. Vertical bars indicate standard deviation of 3 replications. IRRI, 1981 dry season.



27. Relationship between total nitrogen uptake and cumulative transpiration of rice during an 8-day treatment period. IRRI, 1981 dry season.



28. Leaf area of flooded and stressed treatments with time. Drought screening greenhouse, 1981 wet season.

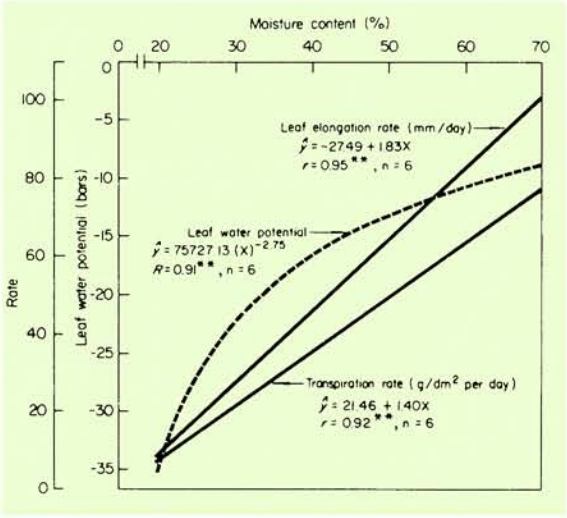


29. Dry weight accumulation of flooded and stressed treatments. Drought screening greenhouse, 1981 wet season.

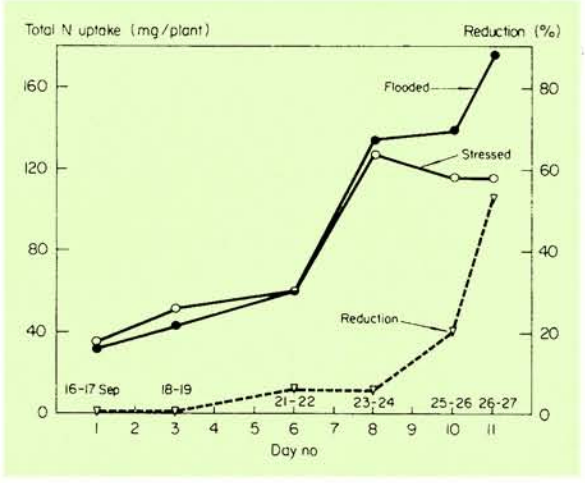
ment: flooded (2 cm standing water) and stress.

Five kilograms of soil was placed in a 32-× 24-× 10-cm deep container, thoroughly mixed, puddled, and maintained in flooded condition for 2 weeks before transplanting. Each tray received 100 ppm P as superphosphate (18% P_2O_5) and K as potassium chloride (60% K_2O) and 460 mg N as ammonium sulfate. Fertilizer was fully incorporated at transplanting. Two 21-day-old seedlings were transplanted in each tray, later thinned to 1 plant. Watering in stress treatments was stopped 11 days after transplanting.

Differences in leaf area between stressed and flooded plants were negligible from day 1 to day 8 (Fig. 28). On day 10, stressed plants had 38% less leaf area than flooded plants, and on day 11, 77% less. Leaf rolling and subsequent wilting caused the leaf area reduction. The trends in plant dry weight were similar (Fig. 29). The effects of stress were observable on day 6, but the reduction was not dramatic. Only on day 11 was straw weight in stressed plants reduced to 38% of that in flooded plants.



30. Effect of moisture content on transpiration rate (TR), leaf elongation rate (LER), and midday leaf water potential (LWP) of IR36. Drought screening greenhouse, 1981 wet season.



31. Total nitrogen uptake of flooded and stressed IR36 plants. Drought screening greenhouse, 1981 wet season.

A regression analysis of the effect of decreasing moisture content on midday leaf water potential (LWP), transpiration rate (TR), and leaf elongation rate (LER) is shown in Figure 30. The response of midday LWP to moisture stress is curvilinear, but that of TR and LER is linear. Midday LWP was not much affected when moisture content was high. LWP decreased sharply to -17 bars only at 40% MC, dropping to -35 bars at 20% MC. LER was sensitive to moisture stress, it decreased at 1.83 mm/day per unit decrease in moisture content. A further reduction in moisture content to 20% reduced LER to 9 mm/day. Similarly, transpiration rates decreased to 1.4 g/cm^2 per day per unit decrease in moisture content. As moisture became limiting, the TR was negligible.

Reduction of nitrogen uptake in stressed plants increased with moisture stress (Fig. 31). Six percent reduction was observed at once on the 3rd day of stress when moisture content was 49%. The biggest reduction (53%) of nitrogen uptake was further noted on the 11th day where moisture content was only 19%.

Genetic evaluation and utilization (GEU) program

Adverse soils tolerance

Soil Chemistry Department

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IMPROVED RICES SUITED TO SPECIFIC SOIL PROBLEMS **113**

In 1981, 17,614 rices were screened for tolerance for these soil stresses: salinity; alkalinity; acid sulfate, peat, and aerobic soil conditions; iron and boron toxicities; and deficiencies of phosphorus, zinc, and other elements. In the wet and dry seasons, 257 rices were evaluated in replicated experiments on adverse soils in farmers' fields at 21 sites in the Philippines (Table 1).

SALINITY

Mass screening. Of the 11,590 entries screened (8,466 from the salt tolerance hybridization program), 2,163 were tolerant. The outstanding entries were IR14632-22-3, IR15314-30-3, IR17494-32-1, IR19660-23-2, and IR19774-23-2, previously rated consistently tolerant; IR3858-6, IR8608-75-3, IR10198-83-4, IR13240-82-2, IR9672-140-2, IR19672-155-2, IR19054-227-3, and IR19186-91-2; new lines IR24646-252-1, IR25861-31-1, IR25922-46-3; and five pedigrees from the salt tolerance breeding program.

Concrete-bed tests. Eight selected rices were evaluated on an artificial saline soil with an electrical conductivity of the saturation extract (EC_e) of 8-10 dS/m in 6-m × 8-m concrete beds at IRRI. IR9884-54-3 and IR50 were the best, IR28 was by far the worst.

IRSATON. Five rices scored better than Pokkali (the tolerant check) in an artificial saline soil (initial EC_e of 9.5 dS/m) — IR4595-4-1, IR5657-33-2, IR6115-1-1, IR10168-54-4, and IR10206-29-2.

IR4595-4-1 was among the best in the international tests. IR4595-4-1 and IR5657-33-2 showed no salt injury at Dokri, Pakistan, where several rices died.

Table 1. Summary of screening for adverse soils tolerance. IRRI, 1981.

Soil stress	Varieties (no.)	
	Screened	Tolerant
Salinity	11,590	2,254
Alkalinity	2,785	416
Acid sulfate	309	23
Peat	187	4
Iron toxicity	609	116
Boron toxicity	171	16
Aluminum and manganese toxicities	45	12
Phosphorus deficiency	450	15
Zinc deficiency	1,338	65
Iron deficiency	163	9
Total	17,614	2,845

Yield trials. *IRRI.* Of 24 rices rated tolerant in the greenhouse, 9 yielded 2.5-3.1 t/ha in the dry season on an artificial saline soil with an initial EC_e of 9.7 dS/m. In the wet season, salt injury was less severe but lodging lowered best yields to about 2 t/ha.

Farmers' fields. In the dry and wet seasons, 27 rices were tested in 17 experiments at 8 locations in 4 Philippine provinces. The salt source was brackish creek water or saline ground water. The EC_e values ranged from 3-18 dS/m at planting to 1-17 dS/m at harvest. Five experiments were abandoned because of excess salt, deep flooding, or lack of water. Yields ranged from <1 t/ha to nearly 5 t/ha. Mean yields were 2.3-3.0 t/ha for rices for which data were available from at least 5 experiments.

Two rice crops. Most coastal saline lands in the Philippines are virtually uncultivated because of strong salinity in the dry season and deep flooding in the wet. In experiments in such fields at three locations, salt-tolerant, early-maturing rices IR50 and IR10198-66-2 were planted at the end of the rainy season and again early in the wet. The salt injury that occurs in March-April and flood damage that is common in July-August were alleviated and yields averaged 6 t/ha per year.

ALKALINITY

Mass screening. Of 2,785 rices screened, 416 showed tolerance. Outstanding were IR9736-16-1 and IR9764-45-2, which had been rated consistently tolerant; IR36; the IR lines 4595-4-1, 13592-9-3, and 15857-37-3; and 30 pedigree materials also looked promising.

Concrete-bed tests. On an artificial sodic soil (pH 8.6), IR36, IR42, IR46, IR50, IR9736-16-1, IR9884-54-3, and IR11418-15-2 did well. On a saline-sodic soil, IR36 performed best.

IRSATON. Among the rices found tolerant at IRRI were IR38, IR4432-28-5, IR4630-22-2, IR9736-16-1, and IR13149-3-2. IR4432-28-5 and IR4630-22-2 have done well in international tests in seven countries.

Yield trial. Ten rices were tested in a field located

in perhaps the only sodic soil area in the Philippines. Without gypsum, IR36, IR2307-247-2, IR4432-38-6, IR9764-45-2, and IR9884-54-3 (all rated tolerant in screening tests) yielded 2.0-2.6 t/ha. IR9752-1-2 yielded 0.5 t/ha.

ACID SULFATE SOILS

Mass screening. In 1981, 309 rices were screened in the field on an acid sulfate soil with pH 3.5 and 0.2% sulfate content. Among the 23 rated tolerant were IR34, IR36, IR48, IR52, IR13149-71-3, and IR15869-113-1.

Concrete-bed tests. IR36 and IR42 were the best of eight rices tested.

Yield trials. In the dry season, 15 tolerant rices were evaluated on an acid sulfate soil (pH 3.5) at 2 locations in Albay Province, Philippines. Average yields ranged from 3.1 to 5.3 t/ha. The top yielders were IR9764-45-2, IR9217-58-2, and IR4683-54-2. They also were among the highest yielders on an iron-toxic soil and had previously been rated tolerant of iron toxicity in mass screening tests.

In the wet season, average yields of another 15 varieties ranged from 0.9 to 3.5 t/ha. IR52, IR8236-464-3, IR9752-1-2, IR13149-43-2, and IR13446-20-3 yielded $<$ 3.0 t/ha. IR52 and IR13149-43-2 were rated tolerant in mass screening on the same soil.

Improved response of tolerant variety to soil amendments. In the wet season, responses of tolerant IR4683-54-2 and sensitive IR26 to 0 and 5 t lime/ha and 0, 25, and 50 kg manganese dioxide/ha were studied factorially on an acid sulfate soil (pH 3.5; exchangeable sulfate 0.13%) in a field adjacent to the other experimental sites.

Tolerant IR4683-54-2 responded better than IR26 to lime and manganese dioxide (Table 2).

Table 2. Response of 2 rices to lime and manganese dioxide on an acid sulfate soil, Burabod, Albay, Philippines, 1981 wet season.

Variety or line	Lime (5 t/ha)	Manganese dioxide (50 kg/ha)	Yield (t/ha)
IR26	No	No	0.0
IR4683-54-2	No	No	0.7
IR26	Yes	No	1.8
IR4683-54-2	Yes	No	3.5
IR26	No	Yes	0.0
IR4683-54-2	No	Yes	1.7
IR26	Yes	Yes	1.6
IR4683-54-2	Yes	Yes	3.8

IRON TOXICITY

Mass screening. Of 609 rices screened in the greenhouse, 116 were tolerant. IR36, IR46, IR4227-109-1, IR13168-143-1, IR25588-32-2, B2149b-Pn-26-1, and BW78-7 were outstanding.

Yield trials. In the dry season, 15 rices were evaluated in a field in Albay, Philippines, where iron toxicity had been observed earlier. Top yielders were IR4683-54-2 (5.4 t/ha), IR9764-45-2 (4.8 t/ha), IR29385-1-1 (3.8 t/ha), IR4432-28-5 (3.6 t/ha), and IR9217-67-3 (3.6 t/ha).

PEAT SOILS

Mass screening. In the dry and wet seasons 187 rices were screened on a peat soil (pH 5.8, organic carbon 18.6%, available zinc 0.1 mg/kg). Only IR9729-67-3 and IR13427-60-1 were tolerant; 30 others were moderately tolerant.

Concrete-bed tests. IR32 and IR34 did well in the dry season; IR34 and IR9764-45-2 in the wet.

Yield trial. In the wet season, 23 IR cultivars were evaluated on a peat soil over a basal application of 50 kg N, 25 kg P, and 50 kg K/ha in the absence of applied zinc. Yields ranged from 1.3 t/ha for IR28 to 3.4 t/ha for IR42.

Varietal response to zinc. Zinc deficiency is an important limiting factor on peat soils. In the dry and wet seasons, 11 rices were grown on 2 peat soils with and without added zinc over a basal N, P, K dressing.

Average yields for the two locations and two seasons ranged from 1.5 t/ha for IR19743-25-5 to 3.5 t/ha for IR9764-45-2. Response to zinc ranged from 0.1 to 0.8 t/ha. The three top yielders without zinc, IR9645-2-2, IR8192-31-2, and IR8192-156-2, showed a nonsignificant negative response.

AEROBIC SOILS

The main chemical growth-limiting factors on aerobic soils at field capacity are aluminum and manganese toxicities on acid soils and iron defi-

ciency on slightly acid, neutral, and alkaline soils.

Concrete-bed tests. Of eight rices, IR43, IR8072-1-31, and IR11248-242-3 did best on the very strongly acid soil (pH 3.8); IR2061-522-6 and IR11248-242-3 on the strongly acid soil (pH 4.6); IR8072-1-31 on the slightly acid soil (pH 6.5), and IR36, IR8072-1-31, and IR11248-242-3 on the alkaline soil (pH 7.7). IR11248-242-3 was the best overall performer.

Yield trials. In the wet and dry seasons, 45 rices were evaluated on an Ultisol (pH 4.9) in a farmer's field in Laguna, Philippines. In the dry season, yields of IR43 (2.4 t/ha) and IR36 (2.0 t/ha) were best. The yield of IR5716-18-1 was poorest (0.4 t/ha). In the wet season, IR6115-1-1 was the best yielder (2.8 t/ha), IR43 next (2.2 t/ha), and IR8 last (1.2 t/ha).

BORON TOXICITY

Screening. Of 171 rices screened, IR5, IR42, IR43, IR46, IR52, and IR54 were tolerant.

Yield trials. *IRRI.* In the dry season, 25 IRRI varieties were evaluated on a boron-toxic field (available boron 6.7 mg/kg). IR42, IR46, and IR48 yielded more than 6 t/ha; IR34 3.4 t/ha; and IR8 3.7 t/ha. In a similar test of promising elite lines, IR8192-200, IR9129-209-2, IR9763-11-2, and IR9846-215-3 yielded 4.9-5.0 t/ha.

There was no clear-cut correlation between yield and intensity of the usual boron toxicity symptoms (marginal leaf scorch and elliptical necrotic spots).

PHOSPHORUS DEFICIENCY

Mass screening. Rices were rated according to relative tiller number with and without adequate phosphorus in the culture solution.

$$\text{(Relative tiller number} = \frac{\text{tiller no. without P}}{\text{tiller no. with P}} \times 100\text{)}.$$

The 450 rices tested differed widely in response to inadequate phosphorus and sufficient phosphorus. Entries divided into three groups:

1. Rices that tillered well at low phosphorus and did not respond appreciably to increased phosphorus. They had high relative tiller numbers and were efficient phosphorus users. IR10199-128-2, IR13427-40-2, IR20977-45-1, and IR21526-37-2 were in this group.
2. Rices that had low tiller numbers at low phosphorus levels but responded dramatically to increased phosphorus. They are efficient users of phosphorus at high levels of the element. IR19729-5-1, IR19743-25-2, and IR21912-131-3 were in this group.
3. Rices that tillered poorly at both low and adequate phosphorus levels. Such rices are not likely to have a high yield potential. Arias, Along Phow, CSR-1, Suhamdi, and Tatsuni Mochi were in this group.

Yield trials. In the wet and dry seasons, 32 IR cultivars and lines were tested on a phosphorus-deficient Ultisol (pH 4.7, Olsen P 3 mg/kg) without phosphorus fertilizer. IR48 and IR9764-45-2 each had a combined wet- and dry-season yield exceeding 9 t/ha. IR36, IR5440-11-2, and IR7790-18-1 each had a 2-season yield of less than 5 t/ha.

ZINC DEFICIENCY

Mass screening. In a farmer's field in Laguna Province, Philippines, 1,338 rices were screened on a Tropaquent soil (pH 7.0, organic carbon 5.0%, available zinc 0.05 mg/kg). IR24, IR29, IR30, IR32, IR34, IR36, IR38, IR40, IR43, and IR48 and 41 IR lines were rated tolerant.

Yield trials. In the wet season, 20 rices were tested without zinc on a field adjoining the mass screening test. IR22 and IR36 were the top yielders (3 t/ha). The poorest yielder was IR2071-685-3 (0.8 t/ha). With zinc, IR54 yielded 3.9 t/ha and IR28, 2.1 t/ha. Responses to a 4% zinc oxide dip ranged from 0 to 2.3 t/ha, with a mean of 1.2 t/ha. Tolerance for zinc deficiency conferred a comparative

Table 3. Performance of rice varieties and lines tolerant of problem soils. IRRI, 1981.

Soil problem	Variety or line	Yield (t/ha)
Salinity	IR50, IR5657-33	3.6
Alkalinity	IR36, IR4595-4	3.6
Strong acidity	IR42, IR4683-54	4.2
Peat	IR42, IR8192-31	3.1
Aluminum toxicity	IR43, IR6115-1	3.8
Phosphorus deficiency	IR52, IR8192-200	4.4
Zinc deficiency	IR36, IR8192-31	2.9
Iron deficiency	IR36, IR52	2.8

Table 4. Yield advantage due to soil stress tolerance in modern rices tested in farmers' fields in the Philippines (1977-1981).

Stress	Total no.			Mean yield[a] (t/ha)		
	Tests	Sites	Rices	Min	Max	Advantage
Salinity	23	14	63	1.5	3.6	2.1
Alkalinity	3	2	47	0.9	3.6	2.7
Iron toxicity	12	4	55	2.2	4.8	2.6
Peat	13	5	39	1.4	3.1	1.7
Aluminum/manganese toxicity	3	1	32	2.0	3.8	1.8
Phosphorus deficiency	13	2	110	1.9	4.4	2.5
Zinc deficiency	25	10	91	0.8	2.9	2.1
Iron deficiency	8	3	65	0.9	2.8	1.9

[a]Mean of tests for each stress.

yield advantage of about 2 t/ha.

In the dry season, 34 rices were tested on a strongly zinc-deficient Tropaquept (pH 7.9, organic carbon 3.9%, Olsen P 30 mg/kg, available zinc 0.1 mg/kg) in South Cotabato Province. Without applied zinc, 17 died. IR46, IR48, and IR8192-31-2 and IR8192-166-2 survived. When zinc was applied, all but 2 rices recovered dramatically, with responses from 0.5 to 5.0 t/ha.

In a parallel test in South Cotabato on a Halaquept (pH 8.2, organic carbon 2.0%, Olsen P 29 mg/kg, available zinc 0.3 mg/kg) IR34, IR50, IR13146-243-2, IR4683-54-2, IR8192-166-2 yielded 2.5-3.0 t/ha without zinc. The rest produced no grain. As on the Tropaquept soil, response to zinc was dramatic, from 0 to 5.9 t/ha, with a mean of 2.2 t/ha.

Table 5. Yields of tolerant varieties with and without amendments in 3 soil problems.

Soil problem	Variety	Treatment	Grain yield (t/ha)
Iron toxicity	IR43	No lime	6.2
		With lime	6.2
	IR26	No lime	3.9
		With lime	4.8
Phosphorus deficiency	IR54	No phosphorus	4.7
		With phosphorus	5.1
	IR36	No phosphorus	2.4
		With phosphorus	4.1
Zinc deficiency	IR54	No zinc	4.4
		With zinc	5.2
	IR26	No zinc	3.1
		With zinc	4.2

OTHER DEFICIENCIES

Greenhouse tests revealed striking differences in reactions to deficiencies of nitrogen, potassium, and sulfur of IR rices.

Nitrogen. All eight rices tested showed deficiency symptoms on a nitrogen-deficient soil (pH 6.5, total N 0.114%). IR28 and IR3880-29 had the best yields.

Potassium. On a potassium-deficient soil (pH 5.9, exchangeable K 0.3 mmol/kg, total K 76 mg/kg) IR36, IR50, and IR8192-200-3 were the highest yielders, IR34 was one of the lowest.

Sulfur. IR8, IR46, and IR48 showed the least signs of sulfur deficiency on a soil with an available sulfur content of 2 mg/kg.

IMPROVED RICES SUITED TO SPECIFIC SOIL PROBLEMS

Modern disease- and insect-resistant rices suited to specific soil problems have been identified. The yields of some of these rices grown in farmers' fields without soil amendments are given in Table 3.

Tolerance of IR cultivars for a given soil stress confers a comparative yield advantage of about 2 t/ha (Table 4).

Varietal tolerance for soil stresses can substitute for or supplement soil amendments. IR43 without lime yielded more than IR26 with lime, and IR54 without fertilizer yielded more than IR26 and IR36 with fertilizer (Table 5).

Genetic evaluation and utilization (GEU) program

Deepwater and flood tolerance

Plant Breeding and Plant Physiology Departments and Thailand-IRRI Cooperative Deepwater Rice Project

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DRY MATTER PRODUCTION OF SUBMERGENCE-TOLERANT AND SUSCEPTIBLE RICE SEEDLINGS

Plant Physiology Department

Submergence tolerance. Seedlings of 12 rice varieties with varying submergence tolerance were grown in trays. At 10 days after soaking, the trays were submerged in 30-cm-deep water for 6 days. Then, plants were allowed to recover for 1 week.

Survival 1 week after 6 days' submergence ranged from 26 to 84%. Kurkaruppan, FR 13A, Thavalu (15325), and Thavalu (15314) were submergence tolerant; other varieties were moderately tolerant or susceptible (Table 1).

Leaf area and seedling height. There was little correlation between submergence tolerance and seedling height and leaf area before treatment.

Dry weight. Average total dry weight decreased during submergence (Table 1), but FR 13A and Kurkaruppan recovered rapidly with a high increase in dry weight.

Carbohydrate content. Carbohydrate in the seeds varied, but not in relation to submergence tolerance.

While before submergence there were no apparent differences in carbohydrate content between tolerant and susceptible varieties after 6 days' submergence, susceptible varieties as a group had a larger decrease in carbohydrate content than tolerant varieties, indicating that during complete submergence either respiration was relatively low or photosynthesis was relatively high, or both, for tolerant varieties.

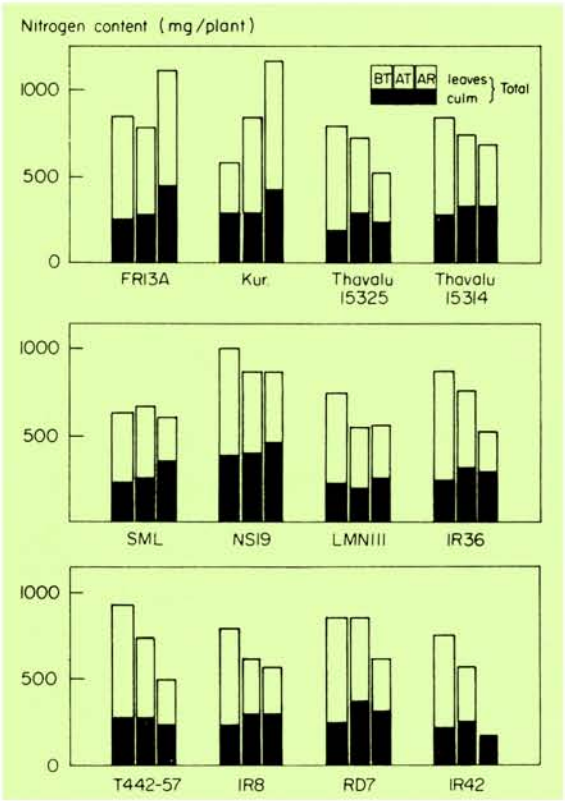
After submergence, tolerant varieties recovered total plant height and total carbohydrate content faster than did susceptible varieties. FR 13A and Kurkaruppan, the two most tolerant entries, also had the highest carbohydrate content. IR42, the most susceptible, had the lowest carbohydrate content. Tolerant Thavalu 15325 and Thavalu 15314 had relatively low carbohydrate content after submergence and after recovery.

Submergence tolerance and residual carbohydrate content correlated only *after* submergence.

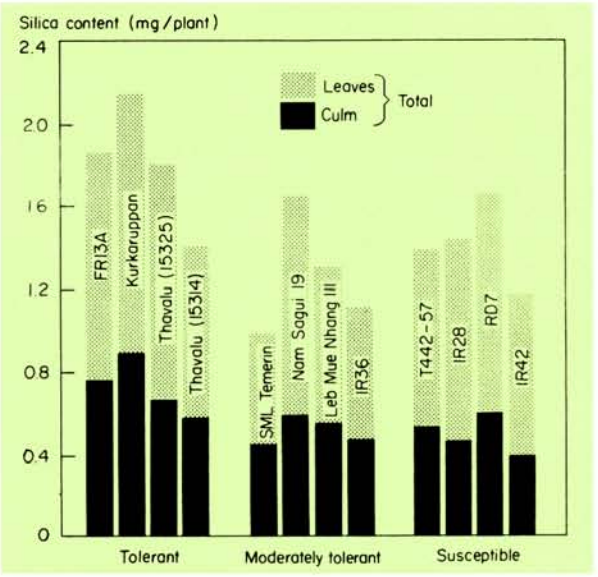
Nitrogen content. Most of the nitrogen in the seedlings was found in the leaves. No differences in nitrogen content and submergence tolerance were observed (Fig. 1). After treatment, most nitrogen in the leaves was lost. After 1-week recovery, nitrogen levels had increased in FR 13A and Kurkaruppan.

Table 1. Survival, plant height, and total dry weight before treatment (BT); increase in plant height and total dry weight after 6 days' submergence (AT); and total dry weight 7 days after recovery (AR). IRRI, August 1980.

Variety	Survival (%)	Plant ht (cm) BT	Increase in ht (%) AT	Total dry wt (mg/plant)		
				BT	AT	AR
Tolerant						
FR13A	84	19	17	16	16	26
Kurkaruppan	83	18	30	18	18	27
Thavalu (15325)	84	17	20	15	14	13
Thavalu (15314)	83	23	18	15	16	15
Av	83.5	19.3	21.3	16.0	16.0	20.3
Moderately tolerant						
SML Temerin	76	17	80	12	14	13
Nam Sagui 19	64	23	23	19	19	20
Leb Mue Nahng 111	68	15	56	15	14	13
IR36	70	16	45	15	15	11
Av	69.5	17.8	51.0	15.3	15.5	14.3
Susceptible						
T442-57	43	17	20	17	16	11
IR8	59	17	17	14	12	13
RD7	61	17	27	17	17	14
IR42	26	17	18	14	12	5
Av	47.3	17.0	20.5	15.5	14.3	10.8



1. Nitrogen content of culm and leaves of 10-day-old seedlings before submergence (BT), after submergence (AT) for 6 days, and after recovery from submergence (AR). IRRI, 1981.



2. Silica content of 10-day-old rice seedlings of different varieties tested for submergence tolerance. IRRI, 1981.

Silica content. Tolerant varieties were generally upright and rigid, especially in the culm section, even before submergence, and their silica level was generally higher than that of susceptible varieties, especially in the culm (Fig. 2). Kurkaruppan had the highest silica content.

Photosynthesis and respiration. *Untreated seedlings*. Photosynthesis at 60 and 20 klux, and respiration were measured on the second leaf blade of 10-day-old seedlings with an infrared gas analyzer. Varieties did not differ significantly in photosynthetic rate at 60 and 20 klux and in survival (Table 2). A significant decrease in photosynthesis was due to decreases in light intensity from 19 to 44%. But the changes did not show a relationship to submergence tolerance.

Most tolerant varieties had lower respiratory rates than did susceptible varieties but the correlation between respiratory rate and submergence tolerance was not significant. Photosynthesis-respiration (P-R) ratios at 60 and 20 klux did not correlate with submergence tolerance.

Submerged seedlings. Varietal differences in rate of photosynthesis of 10-day-old seedlings during 4 hours of complete submergence at 29° C did not correlate with photosynthesis and submergence tolerance or with survival (Table 3).

During submergence, seedlings with high photosynthetic rates (tolerant varieties) also had high respiratory rates, so that their P-R ratios were relatively low. This suggests that photosynthetic products were used immediately by the plant for repair or growth.

Oxygen release and uptake. The capacity of varieties grown in culture solution in the greenhouse to transport oxygen from shoots to the root system was determined on 10-day-old seedlings after submergence at different water levels for 6 days and after recovery for 5 days. There was no consistent association between submergence tolerance and oxygen release rate (Table 4).

Oxygen transport from shoots to roots decreased with increased submergence. When seedlings were completely submerged at 30-cm depth, the roots of susceptible varieties absorbed oxygen from the water; those of tolerant varieties continued to release oxygen. That suggests that tolerant varieties have a greater oxygen reserve in the plant or that

Table 2. Photosynthesis and respiration of 10-day-old seedlings of varieties tolerant of and susceptible to complete submergence. IRRI, October 1980.[a]

Variety	Photosynthesis[b]		Decrease (%)	Respiration[b] (mg CO_2/dm^2 per hour)	Photosynthesis/respiration		Specific leaf wt (mg/cm^2)
	60 klux	20 klux			60 klux	20 klux	
Tolerant							
FR13A	24.4	16.2	34	3.4 ab	7	5	1.96
Kurkaruppan	23.2	14.6	37	2.5 bc	9	6	2.03
Thavalu (15325)	26.3	18.8	28	2.1 c	12	9	2.05
Thavalu (15314)	21.6	15.4	29	2.6 bc	8	5	2.10
Av	23.88	16.25	32	2.65	9.0	6.5	2.04
Moderately tolerant							
SML Temerin	25.9	14.6	44	4.8 a	5	3	2.07
Nam Sagui 19	18.6	14.3	23	4.0 a	5	4	2.01
Leb Mue Nahng 111	20.8	16.0	23	2.7 bc	8	6	2.00
IR36	26.5	19.8	26	3.7	7	5	2.05
Av	22.95	16.18	29	3.8	6.2	4.5	2.03
Susceptible							
T442-57	25.8	20.8	19	2.9 bc	9	7	2.09
IR8	25.9	18.0	31	2.8 bc	9	7	2.17
RD7	27.1	20.8	23	3.1 b	9	7	2.17
IR42	24.0	16.3	32	3.2 ab	7	5	2.10
Av	25.70	18.98	26	3.0	8.5	6.5	2.13

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]At 300 ppm CO_2.

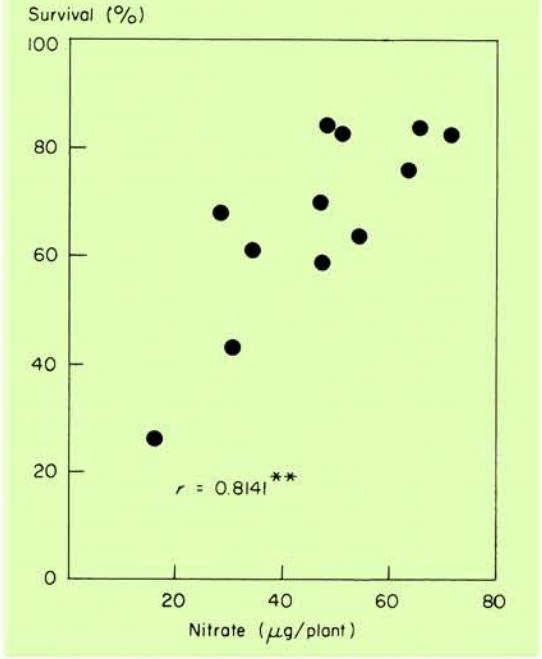
Table 3. Photosynthesis and respiration of 10-day-old rice seedlings during submergence. IRRI, October 1980.

Variety	Gross photosynthesis (μg O_2/h per plant)		Respiration (μg O_2/h per plant)	Photosynthesis-respiration	
	30 klux	15 klux		30 klux	15 klux
Tolerant					
FR13A	21	21	23	0.93	0.92
Kurkaruppan	18	17	19	0.97	0.92
Thavalu (15325)	23	23	26	0.88	0.87
Thavalu (15314)	22	21	22	1.00	0.96
Av	21.0	20.5	22.5	0.94	0.92
Moderately tolerant					
SML Temerin	18	14	12	1.46	1.16
Nam Sagui 19	22	19	22	1.02	0.88
Leb Mue Nahng 111	20	19	18	1.12	1.09
IR36	16	15	16	1.00	0.96
Av	19.0	16.8	17.0	1.15	1.02
Susceptible					
T442-57	21	19	17	1.24	1.13
IR8	25	25	22	1.14	1.13
RD7	17	17	16	1.05	1.03
IR42	13	9	11	1.17	0.79
Av	19.0	17.5	16.5	1.15	1.02

Table 4. Oxygen release rate in the roots of a 10-day-old seedling submerged at different water depths.[a] IRRI, 1981.

Variety	O_2 release rate (μml O_2/plant per minute)		
	0 cm	10 cm	30 cm
Tolerant			
FR13A	296	94 bcd	11 bcd
Kurkaruppan	281	138 abcd	49 ab
Thavalu (15325)	293	132 abcd	26 abc
Thavalu (15314)	430	193 a	79 a
Av	325	139	41
Moderately tolerant			
SML Temerin	152	64 d	-10 bcd
Nam Sagui 19	287	93 bcd	-48 de
Leb Mue Nahng 111	304	75 cd	-114 e
IR36	343	105 bcd	-34 cde
Av	272	84	-52
Susceptible			
T442-57	318	154 abc	-31 bcd
IR8	293	53 d	-56 de
RD7	414	165 ab	-52 de
IR42	251	71 cd	-53 de
Av	319	11	-48

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



3. Relationship of nitrate content of the culm before water treatment to submergence tolerance. IRRI, 1981.

photosynthesis continues at a higher rate among submergence-tolerant varieties, with the plants releasing oxygen through the roots as a by-product. It also shows the importance of the leaves and oxygen transport in maintaining aerobic respiration in the roots.

Nitrate and nitrate reductase activity. The nitrate content of 10-day-old seedlings of the 12 varieties was analyzed by the phenol-disulfonic acid method. Nitrate was found in all parts of the plants; culms had higher average values in tolerant varieties than in susceptible ones. On the basis of dry weight, tolerant varieties as a group had more nitrates per plant than susceptible varieties. Nitrate content in the culm before treatment correlated highly ($r = 0.8141^{**}$) with submergence tolerance (Fig. 3).

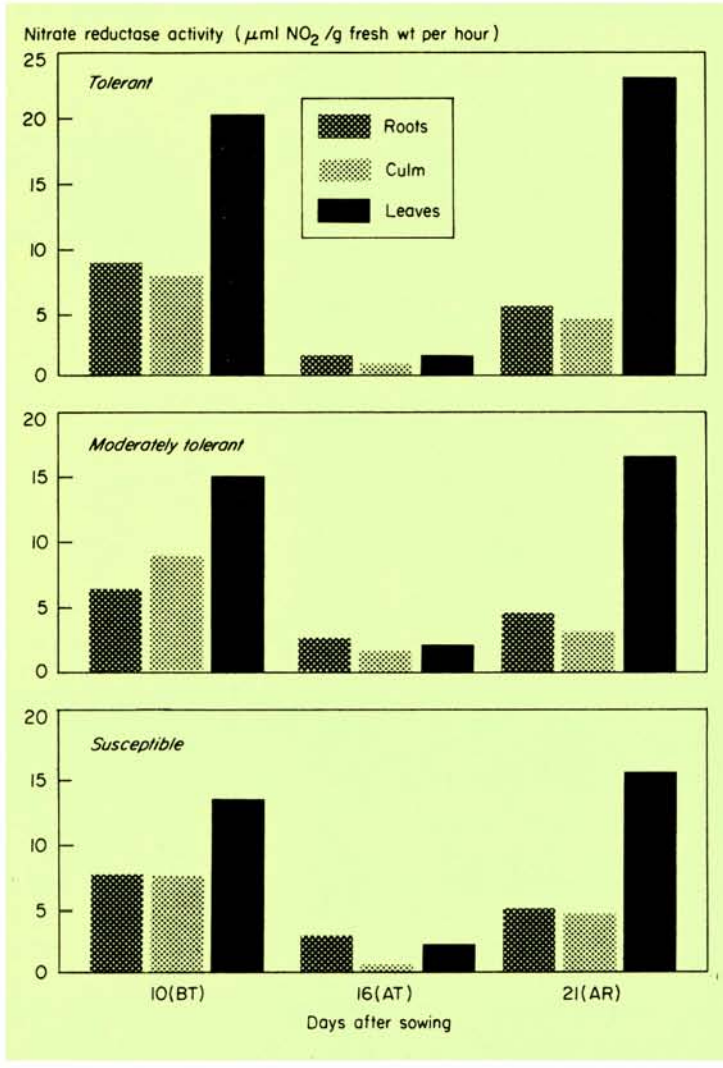
Before submergence, nitrate reductase activity (NRA) was highest in the leaves and, in general, higher in both roots and leaves in tolerant varieties than in the susceptible varieties (Fig. 4). NRA markedly decreased during submergence and increased during recovery.

The higher NRA and higher nitrate content in the culms of tolerant varieties may relate to more rapid recovery from submergence but not necessarily to higher tolerance for submergence.

The marked reduction in NRA during submergence indicated a change in metabolic activity. Protein metabolism was most affected, especially in the leaves. High NRA in the roots after submergence correlated with low submergence tolerance ($r = -0.6917^{**}$). After submergence, plants with low root NRA reduced nitrate slowly and the immediate demand for carbohydrate in the roots decreased.

Tolerant varieties contained more potassium than susceptible varieties. The culm and leaves had higher potassium content than the roots. Potassium content in the culm was related to submergence tolerance ($r = 0.5767^{*}$). The higher level of potassium in tolerant varieties may indicate that photosynthates are translocated rapidly and that the energy released for oxidative phosphorylation is higher among tolerant varieties.

Physiological characters and tolerance. Tolerance for complete submergence at the seedling stage could not be explained by any single physiological character. Some varieties survived by elon-



4. Nitrate reductase activity of roots, culm, and leaves of different varieties with varying degress of submergence tolerance before water treatment (BT), after treatment (AT), and after 1-week recovery from submergence (AR). IRRI, 1981.

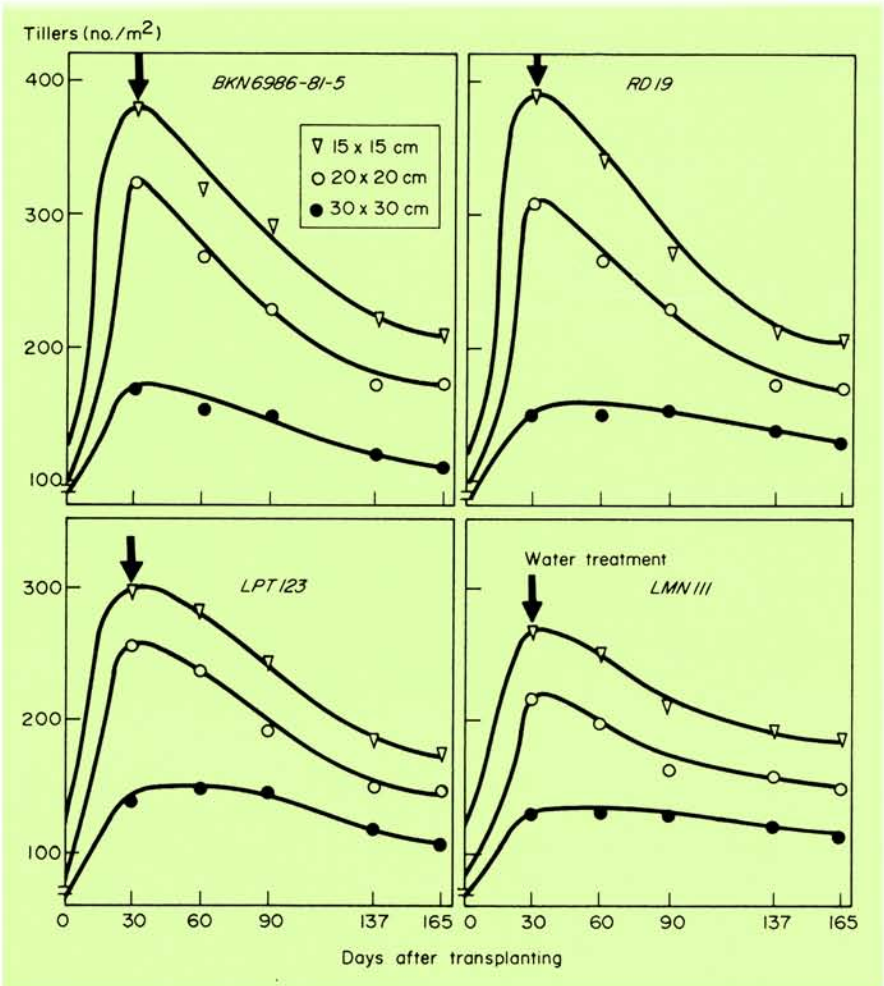
gating their leaves above the water. Others maintained a high level of carbohydrate during submergence. Still others had green and active leaves, stiff culm, and high nitrate reductase activity after submergence.

RELATIONSHIP OF PLANTING METHOD TO TILLERING AND YIELD

Thailand-IRRI Cooperative Deepwater Rice Project, and Plant Physiology Department

Several experiments were conducted at the Huntra Rice Experiment Station in the wet season, with BKN 6986-81-5, LMN 111, LPT 123, and RD 19 in main plots and agronomic practices in subplots.

Spacing. Response of cultivars to spacing was evaluated at water depths up to 110 cm. Close spacing significantly increased tiller number at every growth stage (Fig. 5). When deepwater treatment was introduced 30 days after transplanting, tiller production ceased and tiller number per unit area went down as tillers died. Tiller reduction was highest in plots transplanted at close spacing, but at harvest, tiller number per unit area was still superior.



5. Effect of spacing on tiller number of 4 rice varieties grown at 70-cm water depth. Huntra Rice Experiment Station, Thailand, 1980 wet season.

Yield. Close spacing significantly increased yields at all water depths (Table 5). Yield responses to close spacing were associated with responses of number of panicles per unit area.

Seeding rate. The effect of seeding rate on tillering and yield of rice was studied in naturally flooded deepwater plots. A maximum water depth of 180 cm was recorded just before flowering.

In crops broadcast on a dry soil at a high seed rate, tiller numbers peaked 10-30 days after seedling emergence (Fig. 6). Subsequent reduction in tiller number was attributed to the effect of drought stress and nutrient deficiency. Plots with high seed rates experienced remarkably greater reduction than plots with low seed rates, regardless of variety, possibly because of increased competition for nutrients and moisture.

Seeding method. The effect of seeding method on tiller production was also evaluated.

Row seeding gave the best crop stand at 10 days after seedling emergence (Fig. 7), but the difference was not significant. Seeding method did not significantly affect tiller number at the vegetative growth stage. However, at the reproductive stage, tiller numbers were lower in the 35-cm-spaced, row-seeded plots than in the 25-cm-spaced, row-seeded and broadcast plots. At 400 seeds/m^2, 35-cm spacing between rows was too wide.

Table 5. Effect of spacing on yield of 4 varieties grown under 3 water levels. Huntra Rice Experiment Station, Thailand, 1980 wet season.

Variety	Yield[a] (t/ha)			Mean
	15 x 15 cm	20 x 20 cm	30 x 30 cm	
	30-cm water depth			
BKN6986-81-5	2.9	2.85	1.81	2.51 b
LMN111	2.56	2.76	2.26	2.53 b
LPT123	3.08	3.07	2.35	2.83 b
RD19	3.67	3.56	3.23	3.49 a
Mean	3.05 a	3.06 a	2.41 b	
	70-cm water depth			
BKN6986-81-5	1.85	1.74	1.08	1.56 a
LMN111	1.70	1.79	1.48	1.66 a
LPT123	1.96	1.72	1.23	1.64 a
RD19	2.36	2.21	1.58	2.05 a
Mean	1.97 a	1.87 a	1.34 b	
	110-cm water depth			
BKN6986-81-5	1.50	1.13	0.79	1.14 a
LMN111	2.03	1.85	1.68	1.85 a
LPT123	1.70	1.52	0.78	1.33 a
RD19	1.96	1.85	1.21	1.67 a
Mean	1.80 a	1.59 a	1.12 b	

[a]Separation of means of variety/spacing at the same water depth, by Duncan's multiple range test at 1% level.

Tiller numbers decreased 30 days after emergence presumably because of drought stress and insufficient nutrients. Leaf yellowing occurred earlier in LMN 111 than in other varieties. Yellowing was highest in the 35-cm-spaced, row-seeded plots.

A marked reduction in tiller numbers at maximum water depth in BKN 6986-81-5 indicates an inability to cope with sudden water rise. Regardless of variety, tiller reduction after sudden water surge was much greater, and the resulting tiller numbers at flowering were much lower in 35-cm-spaced row plots than in other treatments. More seeds per row, and resulting greater competition for nutrients, produced weaker and shorter tillers.

RELATIONSHIP OF CULM AND LEAF SHEATH TO SUBMERGENCE TOLERANCE

Plant Physiology Department

Many environmental as well as plant factors determine the submergence tolerance of rice varieties. Overlapping leaf sheaths and round culms might contribute to submergence tolerance. The leaf sheath and culm diameters of 137 breeding lines screened for submergence tolerance were measured.

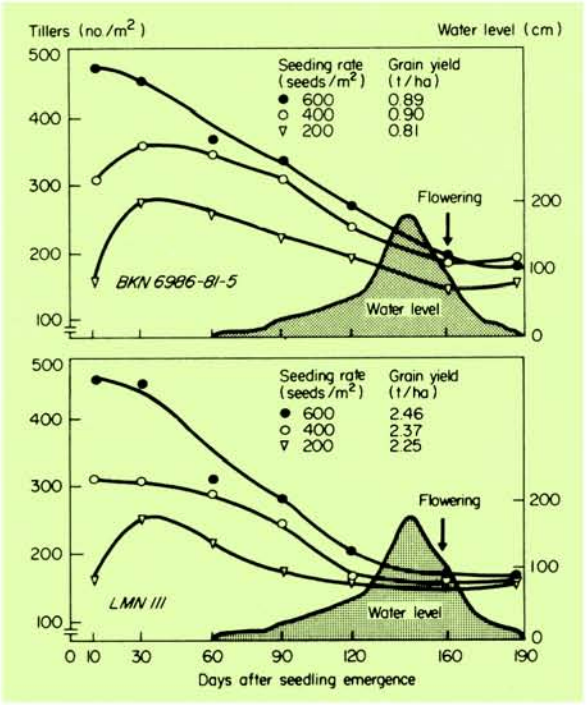
Culm (cross section) roundness was the best criterion for selecting submergence tolerance (Table 6). A relatively high percentage of entries with tolerance for submergence had round culms. However, many round-culm entries were not tolerant and the low percentage (33%) of recovery of tolerant lines makes using this character for selection imprecise and unattractive.

Selecting for both round culm and overlapping leaf sheaths did not improve selection criteria. Determining the survival of seedlings submerged in water for a period of time continues to be the most convenient method of assessing submergence tolerance.

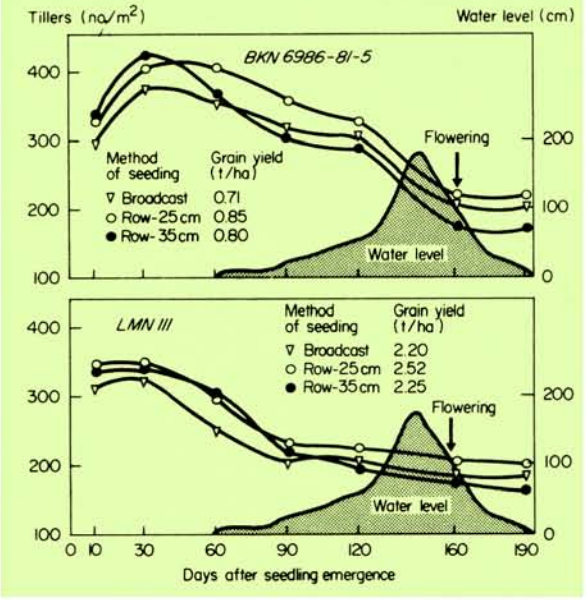
FLOATING RICES IN FARMERS' FIELDS

Thailand-IRRI Cooperative Deepwater Rice Project and Plant Breeding Department

The four farmers' fields test sites at Phuu Khaw Thong, Ayuthaya Technological College, Km 67, Asian highway, and Wang Noi are flooded by the Chao Phya river but are located at varying distances from the river, with different obstacles such



6. Effect of seeding rate on tiller number of BKN6986-81-5 and LMN 111 grown under natural deepwater condition. Huntra Rice Experiment Station, Thailand, 1980 wet season.



7. Effect of seeding methods on tiller number of BKN6986-81-5 and LMN 111 grown under natural deepwater condition. Huntra Rice Experiment Station, Thailand, 1980 wet season.

Table 6. Classification of 137 lines by roundness of culm and overlapping of leaf sheaths, and submergence tolerance. IRRI, 1981.

Plant character	Submergence classification (no. lines)		Submergence tolerant entries (%)[a]
	Tolerant	Susceptible	
Overlapping leaf sheath	18	51	26
Nonoverlapping leaf sheath	19	49	28
Round culm	21	43	33
Flat culm	16	57	22

[a]Submergence tolerant entries (%) = $\frac{\text{number of tolerant entries in class}}{\text{total number of entries in class}}$

as road beds between each site and the source of floodwater (Fig. 8).

A total of 730 plots were dry seeded in June 1981, but the total number of cultivars evaluated was less than that because of considerable overlap between sites.

Lines that showed good performance had grain characteristics acceptable for Thailand, and flowered late enough to avoid damage by rats are listed in Table 7.

DEEPWATER RICE IN THAILAND

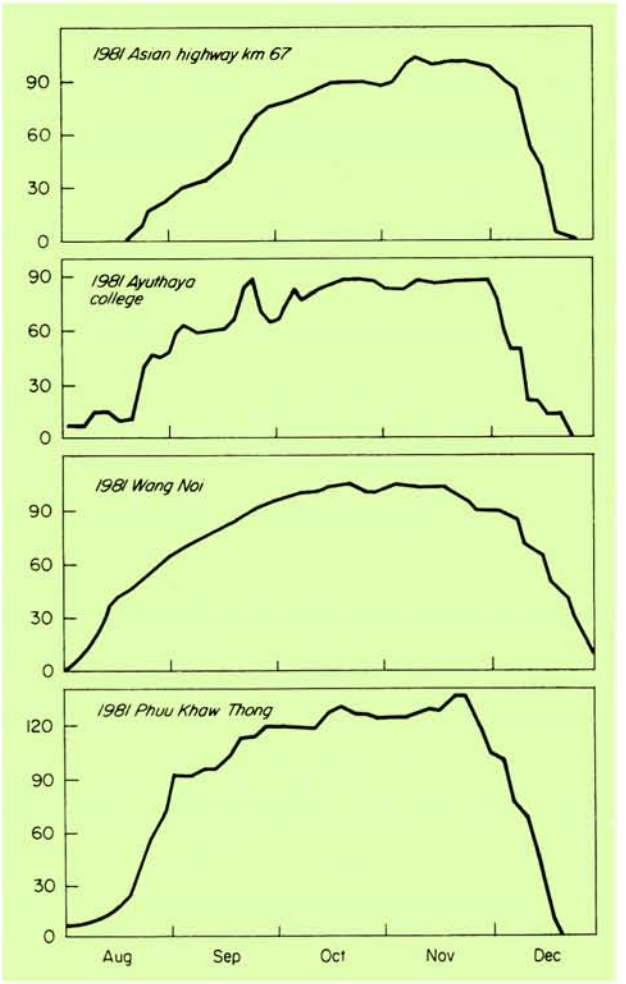
Thailand-IRRI Cooperative Deepwater Rice Project

Projects on weed control, methods of crop establishment, response to fertilizer of traditional and improved varieties, effect of time of sowing on growth patterns, and growing of dryland crops in the dry season on stored water have been initiated in collaboration with the Thailand Department of Agriculture.

Pest incidence. The major pests in the wet season were rats, stem borers, and ragged stunt virus. Minor pests were gall midge before flooding and a leaf-eating gryllid. No other organisms were observed in outbreak proportions.

Rats attacked deepwater rice at all growth stages but yield losses estimated at 20% were not measured. Stem-cutting by rats affected the accuracy of field counts and resulted in underestimates of damage by stem borers.

Damage by stem borers was low during the preflood period, but increased steadily to reach



high levels before harvest. At Huntra, 10% of the stems were damaged by early November and 42% had been attacked by harvest. The mean levels of damaged stems in 63 fields were: September 6%, October 11%, November-December (heading) 27%, and at harvest 39%. Near the regional yield trials, 18% of the stems in 2 early varieties were damaged by the heading stage; for LMN 111 and PG56 these levels were 29% at heading and 40% at harvest. The yellow borer is the predominant species.

Clear symptoms of ragged stunt virus were observed in virtually every field, despite apparently low brown planthopper populations. In some fields, more than 20% of the stems showed definite symptoms, which persisted to harvest. It is estimated that yields in those fields were reduced by 1.0-1.5 t/ha.

Agronomic management practices. Among the 25 farmers interviewed, some applied fertilizer in acid sulfate soil around Prajinburi, usually after flooding. A few fields were hand weeded and most were sprayed with herbicides, but control was not effective. Yields ranged from 1.1 to 3.8 t/ha. Khao Puang gave the highest yields, exceeding 3.5 t/ha in 3 fields.

8. Hydrographs of 4 sites for pedigree lines in farmer's fields around Ayuthaya, Thailand, 1981.

Table 7. Lines of floating rice with excellent survival and other attributes in the 1981 wet season.

Designation	Cross	Plant length[a]	Harvest date	Grain length	Grain appearance[b]
SPR7224-0-0	HTA1645/IR648-2-8	165	1-5	1	1
SPR7282-2-0-23-1	HTA1645/IR648-2-8	190	12-21	3	1
SPR7282-2-0-8-3	HTA1645/IR648-2-8	174	1-5	1	2
SPR7282-2-0-15-1	HTA1645/IR648-2-8	214	1-5	1	3
SPR7282-2-0-8-1	HTA1645/IR648-2-8	233	1-5	1	4
SPR7282-2-0-24-1	HTA1645/IR648-2-8	230	12-22	3	2
SPR7290-13-12-1-1	KNN 11/IR661-1-140	201	1-1	2	3

[a] In deep water. [b] Clearness of grains.

Genetic evaluation and utilization (GEU) program

Adverse 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. Breeding for cold tolerance received additional emphasis after unusually low temperatures occurred during the growing season in several countries in 1980. Cold-tolerant varieties or lines from national programs were the donor parents for 361 simple or multiple crosses. Plant type and growth duration were the principal criteria in the selection of 7,638 plants from the F_2 populations of 115 crosses at IRRI, and 216 breeding lines were selected from 510 F_4 to F_6 populations.

Through the collaborative project with the Philippine Bureau of Plant Industry, 852 lines were selected from among 2,028 lines of 88 F_3-F_9 crosses at Banaue, Ifugao, Philippines. Agronomic characteristics were evaluated for 608 varieties or lines in the Observational Nursery (ON) and Observational Yield Trial (OYT). The 10 promising lines with cold tolerance and high yield potential in the Banaue OYT are shown in Table 1.

Cropping pattern in Banaue. Farmers in Banaue traditionally plant a single crop of rice per year, using the tall, traditional varieties with long growth duration. The crop is sown in late December to late January and harvested from the end of June to the end of July (Fig. 1). The total growing period is about 6 months.

Experiments in Banaue during the last 2 years have indicated the possibility of planting 2 crops per year, using early-maturing varieties (120 days). The first crop should be sown in December. Minimum temperatures during December, January, and February range from 12° to 14° C. Rice plants can pass the early vegetative stage without damage, despite the low minimum temperature and the low light intensity.

To increase second crop productivity, cold damage at reproductive and ripening stages should be avoided by preparing the seedbed in April to May. Harvest of the second crop should be completed before September, when temperature and light intensity start to decline.

Korea-IRRI Collaborative Project. *Observational Yield Trial.* Varieties or lines were selected from the Rice Cold Tolerance Screening Nursery in Chuncheon, Korea, on the basis of leaf color, fertility, and phenotypic acceptability when treated with cold water (17° C) from tillering stage to maturity. Entries were planted in six rows under farmers' field conditions. The 50 center hills were harvested to determine the yielding ability of each entry.

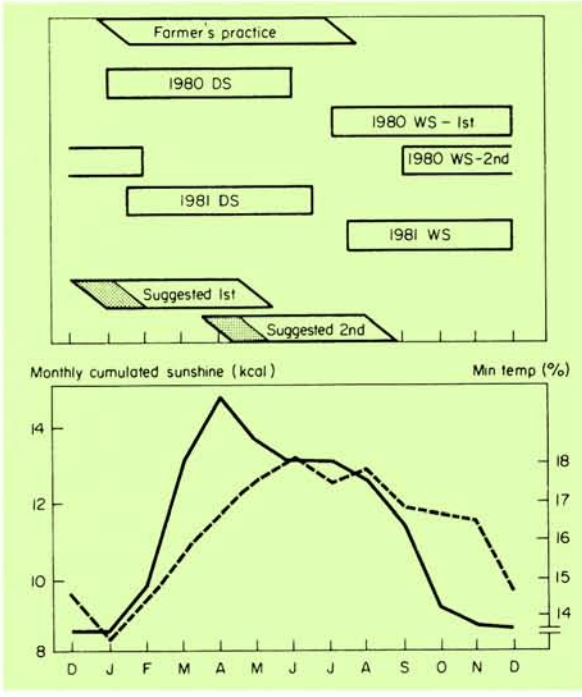
Although 1981 was considered a favorable growing season, only 8 entries gave yields greater than 6 t/ha:

IR7167-33-2-3-3-2-3-1	6.40 t/ha
IR9202-33-4-2-1	6.41
IR15924-265-3	6.69
IR20897-B-45	6.28
SR5204-39-2-1	6.23
SR5204-39-5-3	6.06
SR5204-91-4-1	6.92
Sterjaree 45	6.08

Table 1. Cold-tolerant lines from the Banaue (Ifugao, Philippines) Observational Yield Trial (1981 dry season).

Line	Yield (kg/ha)	Days to flowering	Ht (cm)	Sterility (%)	Discoloration[a] (score)
IR2061-522-6-9	7429	113	81	18.1	3
IR9758-K2	7248	105	70	32.2	3
IR9129-136-2-2-1-2	6873	102	53	15.1	3
IR13155-60-3-1-3	6660	105	101	17.9	1
IR13155-60-3-1-2-1	6438	107	99	29.2	3
IR5716-18-1	6317	109	74	27.4	1
IR8606-298-3-1-1-2	6303	99	55	19.1	1
IR20910-B-67	6180	101	88	6.8	5
IR8455-K2	6154	104	62	18.3	3
IR20897-B-16-1	5923	105	111	13.8	3
Onoy (local check)	5522	100	125	14.0	1

[a]Scoring based on the 1980 Standard Evaluation System for Rice.



1. Suggested rice cropping pattern, monthly cumulated sunshine, and minimum daily temperature in Banaue, Philippines, DS = dry season, WS = wet season.

Several lines of SR5204, IR9202, and IR7167 have consistently high yields in the OYT. SR5204-39-5-3 was also one of the high yielders in the 1980 OYT (6.20 t/ha). SR5204-91-4-1, with the highest yield, is early maturing (104 days from seeding to heading) and may be planted in colder areas without much delay in maturity.

IR7167-33-2-3-3-1-3-1 is a cross between China 1039 and Kn-1b-361. Kn-1b-361 is also the male parent of IR9202. Both IR7167 and IR9202 are of intermediate plant height. IR15924-265-3, the highest yielder among the IR lines in the OYT, is a cross between K17-9-1-1/Kn-1b-214-1-43 and IR3941-25-1. Plant breeders recognize the importance of the Kn-lines in crosses for low-temperature areas.

Grain yield correlates with days to heading ($r = -0.31^{**}$), fertility ($r = 0.41^{**}$), and phenotypic acceptability ($r = -0.31^{**}$). The negative correlation between days to heading and grain yield indicates that shorter duration varieties can escape cold damage during the reproductive and ripening stages.

Although phenotypic acceptability correlates with yield ($r = -0.31^{**}$), yield is a more reliable basis for selection because it is a quantitative parameter and may be taken objectively.

Average grain yield was slightly higher in the OYT in 1980 (7.89 t/ha) than in 1981 (6.92 t/ha). Analysis of the yield components showed that 1981 entries had lower average panicle numbers per hill (9.1 panicles) than the 1980 entries (13.7 panicles/hill). There was no marked difference in average spikelet fertility between 1980 and 1981 entries.

Good panicle exsertion is desired in areas where rice is harvested panicle by panicle, but is relatively unimportant in areas where threshing is done with machines. Almost all entries had well-exserted panicles, as expected, since good panicle exsertion was a basis for selecting entries in earlier screenings.

Number of days to heading varied from 101 days in ARC7098 and IR77224 to 145 days in Khonorullo. Most high yielders flowered earlier than Josaengtongil, the earliest (109 days) of the Korean recommended varieties. IR20897-B-45, SR5204-39-2-1, SR5204-91-4-1, and Sterjaree 45 were among the top yielders that flowered in 102-104 days.

Harvest index correlated positively with grain yield ($r = 0.65^{**}$) and negatively with culm length ($r = -0.39^{**}$). The harvest index might underestimate yielding ability of tall entries. All high-yielding entries had a harvest index greater than 0.5, except IR15924-265-3, with 0.42. IR15924-265-3 has a culm length of 124 cm, which may be suitable in high-elevation areas of the Philippines and Indonesia, where less fertilizer is applied than in Korea. The harvest index is important when comparing varieties having almost equal culm lengths.

Pedigree nursery. The pedigree nursery for cold tolerance in Korea started in 1978. In 1981, 57 crosses, 1,639 lines, and 64 F_4 bulk populations were planted in Chuncheon and Jinbu, Korea. Jinbu has a higher altitude and usually lower temperatures than Chuncheon. In Chuncheon, 941 plants were selected; in Jinbu, 399. The pedigree nursery in Korea has been helpful in making preliminary selections, greatly reducing the amount of breeding materials to be planted in the national programs. Many national programs for rice cold tolerance cannot handle large populations.

Rapid generation advance (RGA) for cold-tolerant rice. In 1981, 134 crosses for low-tempera-

ture areas were planted in the RGA facilities at IRRI. A total of 178 generations involving more than 240,000 plants were advanced. In Chuncheon, 199 selections were included in the 1981 Rice Cold Tolerance Screening Nursery. Five lines showed some promise but need further evaluation (Table 2). The best lines from RGA were earlier and in general taller than the check variety Suweon 235. Panicles were much larger. Three of the five lines had high fertility, even in the inlet (17° C). Ten RGA lines from the cold tolerance screening nursery have been included in the 1982 IRCTN.

From the RGA materials, 21 crosses were planted and 630 selections were made. These materials will be evaluated in the pedigree nursery and cold tolerance screening nursery in Chuncheon.

Similar plantings and selections of RGA materials are being done in China, India, Nepal, Indonesia, Bangladesh, Burma, Pakistan, Vietnam, Turkey, Liberia, and Japan. Seeds of selected materials will be sent to IRRI for seed increase and further evaluation in the cold tolerance screening nursery.

Rice Cold Tolerance Screening Nursery. A total of 1,417 entries, including a susceptible and resistant check interspersed every 20 entries, were subjected to cold water gradients of 17° to 27° C from tillering to maturity. The best entries, mostly from Korea, were selected in Korea. This emphasizes the importance of selection at specific locations. Grouping entries from areas of similar low temperature patterns would also be useful.

In Korea and similar places where a high degree of cold tolerance at seedling, tillering, and reproductive stages is needed, a growth duration of less than 120 days, culm length of less than 70 cm, and high fertility are desirable. The entries most suitable for such areas were:

Cheoulwon 28	SR3001-48-5-3
Cheoulwon 29	SR4071-24-4-2
Hokuriku 109	SR5204-39-5-3
Reimei	Suweon 295-9
Shimokita	Suweon 295-11
S295-E2	Suweon 303

In high-altitude areas in the tropics, where the temperatures are not as severe as those in Korea, longer growth durations ($> 120 \leq 135$ days from seeding to flowering) and taller plants (culm length $> 70 \leq 115$ cm) are acceptable. The panicles must be well exserted and the plants must be cold tolerant at seedling and tillering stages. The entries that satisfy these criteria are:

Osora	YR1560-53-3-1-4
HPU129	Suweon 306
YR1567-26-3-2-1	6542B3-16-3-B
YR1567-26-3-2-2	SR4095-27-1-9-2-2

Screening for tolerance for low air temperature during reproductive stage. The 1981 IRCTN plus additional selected entries were seeded before, during, and after the normal seeding date in Chuncheon to increase the possibility of an entry's being subjected to low air temperatures during the reproductive stage.

Of the entries that flowered late when the average minimum air temperature was lower than 15° C, the most cold resistant in terms of spikelet fertility were:

Taichung 65	Ggaebyeo	K84
Taipei 309	Taipei 309	Suweon 305
Pawn Buh	Chianung 2	
SR3055-18-4-4-4	Olbyeo	
SR4131-19-3-1	Kalimpong 1	

Table 2. Performance of promising Rapid Generation Advance lines in the 1981 Cold Tolerance Screening Nursery.

Line	Leaf discoloration[a]	Days to heading	Fertility (%)	Spikelets (no./panicle)	Panicles (no./hill)	Phenotypic acceptability	Panicle exsertion	Culm length (cm)
IR20654-R-R-R-4-2	1	105	53	146	11.0	5	1	91
IR20654-R-R-R-4-3	1	105	56	142	12.7	5	1	83
IR22623-R-R-4-2	6	118	88	148	11.3	4	3	89
IR24312-R-R-19-3	3	118	89	146	12.3	5	3	68
IR24350-R-R-3-2	7	119	89	185	13.3	4	7	62
Suweon 235	1	136	85	114	23.3	1	1	69

[a]Scoring based on the 1980 Standard Evaluation System for Rice.

HIGH TEMPERATURE

Plant Physiology Department

Field testing heat-tolerant selections. Heat-tolerant selections identified by phytotron screening are being tested under field conditions in Saudi Arabia, Iraq, and California, USA. Many IET lines from India performed well in the field at Al-Hassa, Saudi Arabia (Table 3). IET4658 and IET6238 had 65% higher grain yields than the local check Hassa No. 1. The higher yields of the IET lines are attributed to higher degrees of heat tolerance indicated by higher fertility. Hovayzeh, a heat-tolerant variety from Iran, had low fertility at Al-Hassa. However, the same variety had high fertility at Imperial Valley, California. Apparently, some factors other than heat tolerance affected performance at Al-Hassa.

Fertility vs grain yield. The relationship between fertility and grain yield is not always simple. Grain yield is mainly determined by fertility and total spikelet number per unit land area. The total number of spikelets per unit land area is in turn determined by number of panicles per unit land area and number of spikelets per panicle and is controlled by vegetative and reproductive growth. In other words, the number of spikelets — determined before flowering — sets the ceiling for achievable yield. Fertility determines how much of that potential will be achieved if extremely adverse conditions (weather, diseases, or pests) do not affect ripening.

Table 4. Grain yield and fertility of selected varieties and lines, Imperial Valley, California, USA, 1979.

Line	Fertility (%)	Grain yield (g/m^2)	Grain yield corrected for 95% fertility[a] (g/m^2)
IR3941-97-1	95	247	247
IR9208-22-2-2	93	351	359
N22	91	343	358
IR4427-51-6-3	91	252	263
IET 4658	79	405	487
IET 5085	73	415	540
IET 5236	65	405	592
C4-63G	57	255	425
Lebonnet	33	65	187
Starbonnet	19	51	255

[a]Grain yield x 0.01 = grain yield.

Grain yield does not necessarily correlate with percentage fertility (Table 4). For example, fertility of IET 5085 is much lower than that of N22, but grain yield is higher. To estimate achievable yield, measured grain yields were corrected to grain yields at 95% fertility. It is clear that increased heat tolerance will raise grain yields of IET 4058, 5236, and 5085 to 5-6 t/ha.

But grain yields of Lebonnet and Starbonnet will remain low, even if tolerance for high temperature-induced sterility is improved. Apparently, the vegetative and reproductive growth of these varieties are extremely poor at Imperial Valley.

C4-63G, a Philippine variety, appears to be well

Table 3. Grain yield and fertility of selected varieties and lines in Al-Hassa, Saudi Arabia, 1980.[a]

Variety or line	Fertility (%)	Grain yield (t/ha)	Remarks
IET 4094	73	3.5	From India; selected in the Phytotron
IET 4658	80	4.3	From India; selected in the Phytotron
IET 4700	61	3.6	From India; selected in the Phytotron
IET 5688	74	2.8	From India; selected in the Phytotron
IET 5734	50	2.2	From India; selected in the Phytotron
IET 6238	70	4.3	From India; selected in the Phytotron
N.T.U. no. 306	35	2.3	From Taiwan
Hovayzeh	33	0.7	From Southern Iran
C4-63G	17	0.8	Susceptible check
Hassa no. 1	50	2.6	Local check

[a]Data obtained by C. I. Lin, in collaboration with IRRI.

adapted until flowering to both Imperial Valley and Al-Hassa environments. C4-63G could produce a reasonably high yield if it gained heat tolerance at flowering.

To increase grain yields in the heat-prone area, both fertility and size of growth before flowering must be improved. This principle can be applied to other types of stress, such as low temperature and drought, where spikelet sterility is a major cause of yield reduction.

Genetic evaluation and utilization (GEU) program

Innovative breeding methods

Plant Physiology and Plant Breeding Departments

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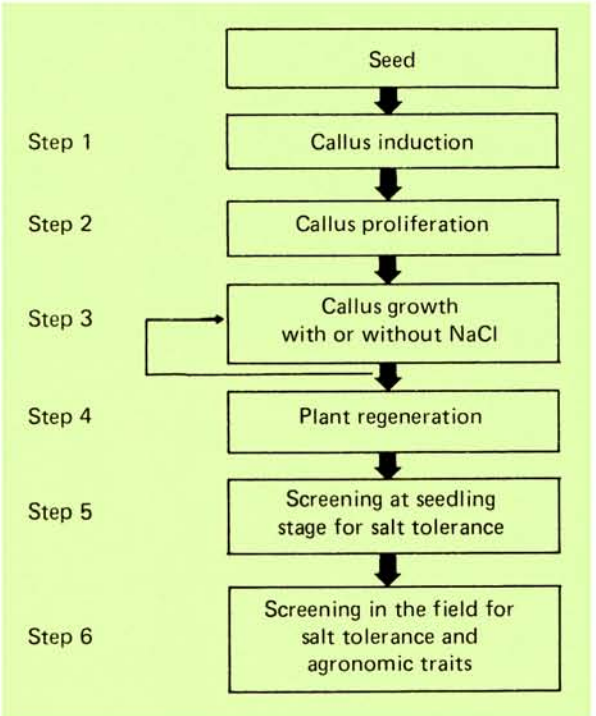
RAPID GENERATION ADVANCE **143**

Plant Physiology Department

Induction and selection of salt-tolerant mutants. *Seed-derived callus culture system.* Any part of a plant — embryos, root or stem sections, germinating seedlings, and leaves — can be induced to form callus. Seeds are an excellent material to start with because the rigorous surface sterilization that can be applied results in minimal contamination of the resultant callus culture.

A simple and efficient seed-derived callus culture system with six steps has been established (Fig. 1).

1. Callus is induced from surface-sterilized brown rice on the modified Murashige-Skoog (MS) medium.
2. The callus is subcultured for proliferation using the same modified MS medium.
3. Proliferated callus is divided into small pieces (about 50 mg each). Pieces are transferred to the modified MS media (with or without sodium chloride for induction and selection of salt-tolerant mutants). Step 3 is repeated 3-6 times. If sodium chloride-enriched medium is used during subculturing, salt-tolerant callus lines may develop.
4. The callus is transferred to test tubes with regeneration medium. Roots of regenerated plants are dipped in 0.1% nicotine-amide aqueous solution for 1 hour to stimulate rooting and the plantlets are transplanted in plastic pots containing soil and fertilizer. The pots are placed in a plastic chamber with a relative humidity of almost 100%. Fluorescent lamps light the chamber. A week later, the pots are transferred to a glasshouse room maintained at day/night temperatures 29°/21° C.
5. Seeds from regenerated plants are grown to the three-leaf stage and screened for salt tolerance by solution culture in an artificially lighted growth cabinet. This technique allows 540 seedlings/cabinet to be screened each 3-5 weeks, depending on the degree of salt tolerance. The salt-tolerant mutant plants found are transferred to a normal culture solution, then to potted soil.
6. Seeds from mutant plants are grown in the field and screened for salt tolerance and agronomic traits.



1. Seed-derived callus culture system. IRRI, 1981.

The three media used in the seed-derived callus culture system are modifications of the MS medium (Table 1). Medium I and Medium II contain 2 mg 2,4-Dichlorophenoxy acetic acid (2,4-D)/liter to induce callus. Many varieties can develop callus without yeast extract, but some varieties — particularly IR lines — require yeast extract to develop a healthy callus. Medium II may or may not contain sodium chloride. α-naphthalene acetic acid (NAA) and kinetin replace 2,4-D in medium III. Sucrose is increased to 70 g/liter.

Factors affecting callus growth. These factors affecting callus growth have been examined: variety, incubation time, light, composition of culture media, and immature seeds.

Variety had a profound influence on induction and proliferation of callus. The efficiencies of callus induction averaged about 45%; they ranged from 5% for Giza 170 to 85% for Reiho (Table 2). Giza 170, Giza 173, the Mahsuris, and some IR lines had efficiencies of less than 30%. Extending the incubation time from 3 to 7 weeks increased callus induction efficiency to 48% for Giza 170 and 97% for Giza 173.

Table 1. Composition of media used for callus induction, screening of salt (NaCl)-tolerant callus, and plant regeneration. IRRI, 1981.

Medium I (callus induction, steps 1 & 2)	Concn	Medium II (selection, step 3)	Concn	Medium III (regeneration, step 4)	Concn
MS medium[a]		MS medium		MS medium	
2,4-D[b]	2 mg/liter	2,4-D	2 mg/liter	NAA[c]	2×10^{-6} M
				Kinetin	5×10^{-5} M
Sucrose	30 g/liter	Sucrose	30 g/liter	Sucrose	70 g/liter
		NaCl	5-30 g/liter		
With or without yeast extract	3 g/liter	With or without yeast extract	3 g/liter	Yeast extract	3 g/liter
				Casein hydrolysate	3 g/liter
Agar	8 g/liter	Agar	8 g/liter	Agar	8 g/liter
pH	5.8	pH	5.8	pH	5.8

[a]Murashige-Skoog medium. [b]2,4-Dichlorophenoxy acetic acid. [c]α-Naphthalene acetic acid.

Table 2. Varietal differences in efficiency of callus induction from mature rice seeds.[a] IRRI, 1981.

Variety	Seeds inoculated (no.)	Callus induction efficiency (%)
Fujisaka 5	168	71
Koshihikari	132	67
Norin 20	159	76
Reiho	119	85
Taichung 65	158	73
Giza 170	164	5
Giza 173	235	29
Mahsuri (Acc. no. 44452)	225	12
Mahsuri (Acc. no. 10929)	239	11
CICA 4	198	44
OS4	240	43
ADT28	140	41
Kalarata	137	64
Nona Bokra	159	64
SR 26B	96	54
Pokkali	214	48
IR8	147	54
IR26	152	43
IR28	98	68
IR30	132	32
IR36	42	57
IR42	131	53
IR50	138	40
IR52	177	31
IR54	152	46
IR4432-20-2	173	20
IR4432-38-6-5-2	121	12
IR4595-4-1	82	62
IR4630-22-2	69	30
IR4763-73-1	86	58
IR9852-19-2	142	23
IR9884-54-3	101	42
IR9884-54-3-1	115	46
IR9975-5-1	132	13

[a]Callus induced on Medium I without yeast extract in the dark at 26°-27°C for 3 weeks.

Callus is normally induced in the dark, but lighting greatly improved induction for the Mahsuris. The addition of yeast extract to the medium increased the callus induction efficiency to 80-100% for all varieties. The use of immature seeds, 10, 20, and 30 days after anthesis, did not improve callus induction efficiency.

Factors affecting plant regeneration. Variety, length of culturing period, and immature seeds were examined for their effects on plant regeneration.

Again, variety had a pronounced effect on plant regeneration (Table 3). Efficiency of plant regeneration is reasonably high for japonica and traditional indica varieties, but is very low for IR lines. The use of immature seeds improved plant regeneration efficiency of IR lines somewhat, but this improvement was counterbalanced by increased

Table 3. Plant regeneration from rice callus originated from seeds at different developmental stages. IRRI, 1981.

Variety	Developmental stage of seed[a] (days after anthesis)	Calluses inoculated (no.)	Regeneration (%)
Fujisaka 5	10	39	61.5
	20	11	27.3
	30	22	59.1
	mature[b]	82	17.0
Koshihikari	10	–	–
	20	–	–
	30	34	0.0
	mature[b]	61	0.0

Continued on next page

Table 3 continued

Variety	Developmental stage of seed[a] (days after anthesis)	Calluses inoculated (no.)	Regeneration (%)
Norin 20	10	40	37.5
	20	24	29.2
	30	34	70.6
	mature[b]	64	13.0
Reiho	10	39	56.4
	20	48	39.6
	30	20	80.0
	mature[b]	67	31.0
Taichung 65	10	87	52.9
	20	37	48.6
	30	34	61.8
	mature[b]	131	62.0
ADT 28	10	44	47.7
	20	34	38.2
	30	29	31.0
	mature[b]	38	16.0
Kalarata	10	17	51.2
	20	31	12.9
	30	16	18.8
	mature[b]	70	17.0
SR 26B	10	35	14.3
	20	10	50.0
	30	34	5.9
	mature[b]	18	17.0
IR8	10	25	4.0
	20	39	7.7
	30	23	0.0
	mature[b]	12	0.0
IR26	10	26	11.5
	20	23	8.7
	30	47	0.0
	mature[b]	3	0.0
IR28	10	7	0.0
	20	12	16.7
	30	9	0.0
	mature[b]	4	0.0
IR30	10	15	6.7
	20	9	0.0
	30	7	0.0
	mature[b]	7	0.0
IR36	10	3	0.0
	20	15	6.7
	30	14	0.0
	mature[b]	6	0.0
IR42	10	8	0.0
	20	10	0.0
	30	35	0.0
	mature[b]	9	11.0

[a]Developing seeds harvested 9-11 days after anthesis (10 days), 19-21 days after anthesis (20 days), and 29-31 days after anthesis (30 days).
[b]No information on date of harvest.

contamination during callus induction. Other means of increasing the regeneration efficiency of IR lines are being considered. The efficiency of plant regeneration decreased with increase in number of passages of subculture; it also varied with variety. This decrease, however, does not seriously bar plant regeneration up to the fifth or sixth passage.

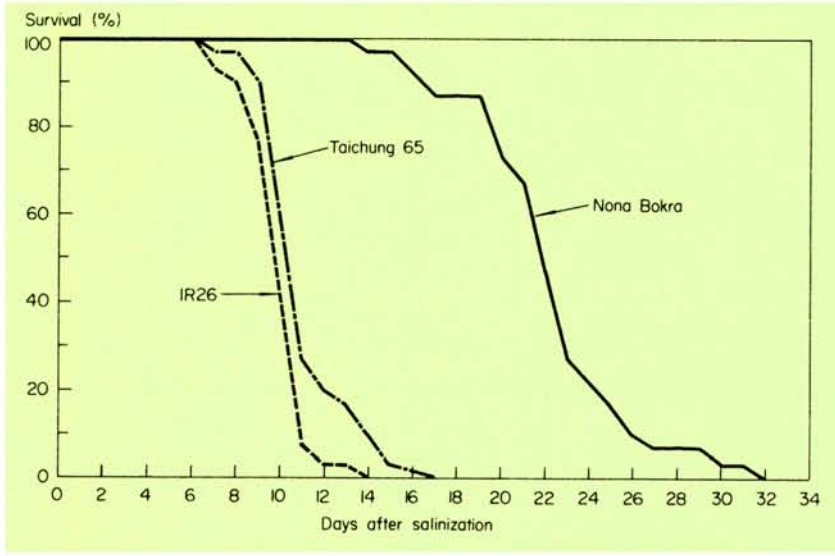
Sodium chloride concentrations in the medium (step 3) varied from 5 to 30 g/liter. Growth of callus was retarded at 10-15 g/liter and greatly impaired at 20 g/liter. At 30 g/liter, no callus growth was observed. Therefore, 15 g/liter was chosen as the concentration for selecting salt-tolerant callus lines.

When callus is transferred to the selection medium, it usually turns dark brown, an indication of necrosis. However, when step 3 is repeated more than three times, a vigorously growing callus comes out of the necrotic callus. The salt-tolerant callus lines continue to grow better in subsequent subculture.

The simple and efficient screening technique uses a solution culture technique. A deep enamel tray (33 × 26 × 11 cm) holds 7 liters of culture solution. A styrofoam sheet cover-lid with 60 holes spaced 2 cm apart accommodates 60 seedlings. One-week-old (3-leaf-stage) seedlings are transplanted into the standard culture solution plus 0.75% NaCl. Electric conductivity of the solution is about 16 mmho/cm. A Koito KG growth cabinet accommodating 9 trays is maintained at 29° /21° C (day/night), about 70% relative humidity, 12 hours photoperiod, and 20 klx light intensity.

After salinization, the tips of lower leaves begin to dry. With time, leaf drying moves upward and the entire plant turns brown. A dead plant is one whose leaf blades and leaf sheaths have lost green color. For convenience, the length of time within which 50% of the seedlings have died is termed D_{50}. The D_{50} is a quantitative measure of salt tolerance for a given variety. There is a marked varietal difference in salt tolerance (Fig. 2). D_{50} is estimated at 10 days for IR26 and Taichung 65, and at 22 days for Nonabokra.

More than 8,000 plants were regenerated within a year. Seeds from different panicles of the same plant were well mixed and 30 seeds were used for salt-tolerance screening. Mutation occurs in two



2. Survival of 3 rice varieties following salinization with 0.75% sodium chloride. IRRI, 1981.

directions: increased-sensitivity and increased tolerance. Several salt-tolerant mutant plants from Taichung 65 have been identified. Those plants are growing in potted soil for seed multiplication and for further examination of salt tolerance heritability.

Somaclonal variation in visible plant traits. Tissue culture per se, without sodium chloride stress in step 3, appears to induce a wide range of genetic variability. Many abnormal plant traits have been observed for both R1 and R2 plants (Table 4). But abnormal traits do not always occur in all plants regenerated from one callus line or among different shoots of the same plant. That suggests that plants from one callus line are heterogenic and some regenerates are chimeric. The pooled frequency for chlorophyll mutation in 6 varieties was estimated at 9.3%, about the same as in irradiation mutation but lower than the frequency induced by chemical mutagens.

The mutation in visible plant traits suggests that mutation would also occur in physiological and biochemical traits, making somatic tissue culture a new avenue of research for the generation of a wide range of genetic variability.

Anther culture. In 1981, evaluation of the application of anther culture to varietal improvement continued. Varieties respond differently to androgenesis (the capacity of pollen grains to produce plants). For example, japonica varieties responded

Table 4. Somaclonal variation in visible plant traits. IRRI, 1981.

R_1 plants	R_2 plants	
	Seedling stage	Heading stage
• Stripes (white or yellow) on leaf blades and leaf sheaths • Open spikelets • Tetraploid (identified by large grain size, awn, dark-green and stiff leaves, low fertility) • Large grain with normal fertility • Awn • Dwarfism with dark-green and twisted leaves	• Chlorophyll mutations Albino, Lethal Yellow, Chlorina, and White and Yellow Strips • Lethal mutation • Dwarfism • Rolled leaf	• Reduced plant height • Early maturity • Sterility

Table 5. Callus production of Taipei 309 anthers on semisolid and liquid media. IRRI, 1981.

Plating medium	Anthers				Calluses produced	
	Plated (no.)	Producing callus		With multiple callus		
		No.	%	No.	%	No.	%
J-19 Liquid	507	–	–	–	–	1644	324.3
J-19 Semisolid	515	127	24.7	120	23.3	–	–
E-24 Liquid	177	–	–	–	–	1201	678.5
E-24 Semisolid	384	87	22.7	87	22.7	–	–

much better than indica varieties in anther culture.

Efforts were concentrated on trying to improve the medium and other culture factors. One study examined the effects of agar on the triggering of androgenesis. Without agar in the two media already developed (J-19 and E-24), efficiencies of 600% (number of calluses per anther plated) were possible. With agar, efficiencies were only up to 25% (Table 5).

Most of these results were obtained in Taipei 309, a japonica, and Mingolo, an indica, varieties considered model systems in IRRI studies because of their callus and plant regeneration efficiency. So far, through anther culture plants have been regenerated and seed produced from 12 japonicas, 9 indicas (Table 6), and 5 F_1 hybrids (Table 7).

In F_1 hybrids, attention has been on transferring the regeneration capacity of varieties that are high callus and high plant regenerators to varieties that have more desirable agronomic characteristics.

Table 6. Varieties that have regenerated plants and produced seeds through anther culture. IRRI, 1981.

Japonica	Indica
Baegogna	BG 90-2
Giza	Hunan 72
Jado	IR30
Kwan Fu 401	IR40
Minehikari	Leb Mue Nahng III
Nong Baek	Mingolo
Paikan tao	Mingo AC-2
Taichung 65	Moosa tarum
Tainan 5	Taichung Sen Yu 195
Taipei 177	
Taipei 309	
Taipei 309 AC-2	

HYBRID RICE

Plant Breeding Department

Heterosis studies. *Yield potential of irrigated hybrid rice*. Hybrid rice continued to show yield advantages in 1981 trials. Of 62 hybrids evaluated in replicated dry-season yield trials, 42 showed significant heterosis (12.6-58.4%); 23 of those showed significant heterobeltiosis (11.2-48.5%). Nine of the 23 hybrids also showed significant standard heterosis (13.6-34.4%). Yields and some agronomic characteristics are given in Table 8. One experimental hybrid yielded 10.4 t/ha, against IR54's 7.8 t/ha. In the 1981 wet season, of 9 experimental hybrids, Zhen Shan 97A/IR13420-6-3-3-1, yielded 6.2 t/ha, against IR36's 4.9 t/ha, and IR42's 5.0 t/ha.

Three experimental F_1 hybrids were evaluated during the 1981 wet season at the Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, under irrigated conditions. V20A/IR54 and Zhen Shan 97A/IR54 yielded about 1 t/ha more than the check varieties IR36 (4.1 t/ha) and IR54 (4.0 t/ha). They did not perform as well under irrigation at the IRRI farm because of severe sheath blight disease incidence and brown planthopper attack. Susceptibility to those biological stresses was inherited from the female parent

Table 7. F_1's sexual crosses that have regenerated plants and produced seeds through anther culture. IRRI, 1981.

Hybrid	Hybrid
Mingolo/D66	Taipei 309/IR30
Silewah/Taichung 65	Taipei 309/IR36
Taipei 309/IR20	

Table 8. Yield and some agronomic characteristics of promising F_1 rice hybrids. IRRI, 1981 dry season.

Hybrid	Yield (t/ha)	Vigor 30 DT[a]	Plant ht (cm)	Days to 50% flowering	Lodging (%)
Set 1					
IR11248-242-3-2/IR2823-103-5-1	8.9	2	104	93	17
IR11248/IR13525-97-1-1-3	8.8	2	99	94	25
IR36, check	7.4	4	90	87	25
IR54, check	7.2	2	108	95	100
Set 2					
IET 3257/IR2797-105-2-2-3	10.4	2	123	100	0
IET 3257/IR54	10.3	1	113	87	30
IR36, check	7.7	2	89	85	0
IR54, check	7.8	2	110	92	30
Set 3					
IR11248-242-3-2/IR2823-399-5-6	9.2	4	106	94	100
IR11248/IR13188-9	9.0	2	98	87	0
IR11248/IR9224-23-2-2	9.0	3	95	84	0
IR36, check	7.9	4	89	87	90
IR54, check	7.4	3	110	94	100
Set 4					
IR11248-242-3-2/IR15324-117-3-2	9.3	2	109	94	100
IR34/IR2797-125-3-2-2-2	9.1	2	112	87	90
IR36, check	8.0	3	89	86	60
IR54, check	7.5	2	107	93	100

[a] 1 = extra vigorous; 3 = vigorous; 5 = plants intermediate or normal. DT = days after transplanting.

introduced from China. F_1 hybrids for tropical conditions, in which disease and insect incidence is higher, must be derived from parents possessing the necessary disease and insect resistance.

Suitability of F_1 hybrids for rainfed lowland conditions. Work in China and IRRI has indicated that some F_1 hybrids have good early seedling and vegetative vigor, better developed and stronger root systems (Fig. 3), slightly superior height, and increased photoperiod sensitivity. These traits should help the hybrids suppress weeds, adjust to water regime, and overcome soil and nutritional disorders in rainfed wetland conditions. Some experimental hybrids evaluated under rainfed wetland conditions at Malasiqui, Pangasinan, Philippines (in collaboration with the Rice Production and Training Research Department), yielded better than check varieties IR36 and IR52 (Table 9). The yield superiority of the F_1 hybrids could be further enhanced by the choice of parents adapted to rainfed wetland conditions.

Male sterility and fertility restoration in rice. The 12 cytoplasmic male-sterile (cms) lines available at IRRI were maintained and evaluated. Cytosteriles Yar-Ai-Zhao A, Gang-Yi-Ya-Ai Zhao A, Birco, MS 517A, MS 519A, and BT MS were not yet stable for pollen sterility and are being purified further through successive backcrossing with their maintainer lines.

Patterns of pollen abortion in some cytosterile lines. Chinese scientists classify aborted pollen of



3. Root systems of an F_1 hybrid (center) compared with those of its parents (on both sides) in rainfed lowland conditions. IRRI, 1981.

Table 9. Heterobeltiosis and standard heterosis for yield in some F_1 rice hybrids evaluated under rainfed lowland conditions, Pangasinan, 1981 wet season.

Hybrid	Yield (t/ha)	Heterobeltiosis (%)	Standard heterosis[a]
V 41A/IR54[b]	5.0	+13	+20*
V 20A/IR54[b]	4.9	+10	+17
97A/IR54[b]	4.6	+ 3	+10

[a] Estimated over IR36 and IR52 (mean yield 4.2 t/ha). [b] Better parent.

cytosterile lines by number of nuclei — uninucleate, binucleate, and trinucleate. But when large numbers of samples are handled, this classification system is impractical. At IRRI, a simplified system classifies sterile and fertile pollen on the basis of shape and staining pattern (Fig. 4).

The pollen classes are: unstained withered sterile (UWS), unstained spherical sterile (USS), stained round sterile (SRS), and stained round fertile (SRF). Five cms lines — V40A, Zhen Shan 97A (97A), V41A, Wu 10A, and Pankhari 203A (P 203A) — were grouped into three types on the basis of predominant class of pollen grains (Fig. 5).

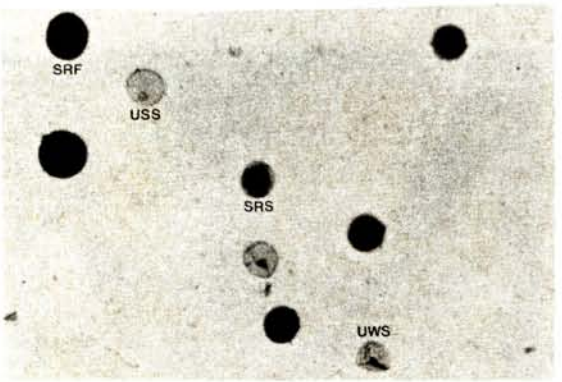
Type 1: Almost all pollen grains appear as UWS and USS — V41A, V20A, 97A.

Type 2: The majority, 51%, of the pollen grains appear as USS, 36% as SRS, and 14% as UWS —P 203A.

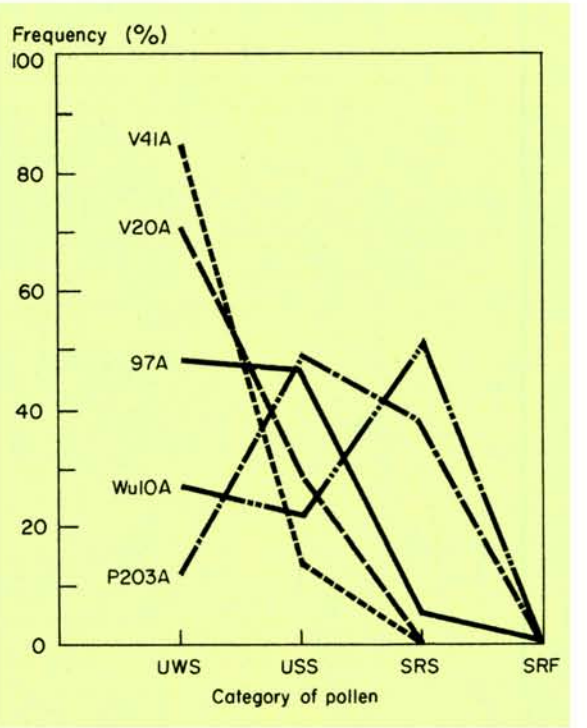
Type 3: The majority, 52%, of pollen grains are SRS; 20-25% are UWS and USS — Wu 10A.

The five cytosterile lines are derived from three sources of cytoplasm (Table 10). Cms lines derived from a particular cytoplasm seem to abort at a specific stage of pollen development. Chinese scientists have observed that the pattern of pollen abortion in cms lines depends upon the genetic diversity between the cytoplasmic donor parent and the nuclear donor parent. If the two parents are distantly related, pollen abortion takes place early (uninucleate stage). If they are closely related, pollen abortion is delayed (binucleate or trinucleate stage). In the IRRI studies, Type 1 cms lines also have more distantly related cytoplasmic nuclear donor parents than Type 2 and Type 3 cms lines. Hence, pollen abortion takes place earlier in Type 1 cms lines than in Types 2 and 3.

Effect of temperature on pollen sterility of cytosterile lines. Five cytosterile lines — V20A, Zhen Shan 97A, V41A, Wu 10A, and Pankhari 203A —were grown in the IRRI phytotron in 3 temperature regimes — 26° day/18° C night (temperature 1), 29° day/21° C night (temperature 2), and 35° day/26° C night (temperature 3) — with natural light and 90% humidity. These regimes represent the average temperatures in most rice-growing



4. Features of different categories of pollen: UWS (unstained withered sterile), USS (unstained spherical sterile), SRS (stained round sterile), and SRF (stained round fertile). IRRI, 1981.



5. Frequency of different categories of pollen in 5 cytoplasmic-genetic male-sterile lines of rice. IRRI, 1981.

Table 10. Pollen abortion in 5 cytoplasmic-male sterile (cms) lines in relation to source of cytoplasm.

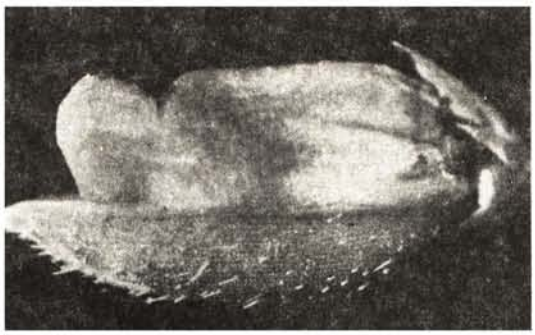
Cms line	Origin	Pattern of pollen abortion	Source of cytoplasm	Maintainer line
Zhen Shan 97A	China	Type 1	*Oryza sativa* f. *spontanea* (WA)	Zhen Shan 97
V20A	China	Type 1	"	V20
V41A	China	Type 1	"	V41
Pankhari 203A	IRRI	Type 2	TN1	Pankhari 203
Wu 10A	China, Japan	Type 3	Chinsurah Boro 11 (BT)	Wu 10

countries. All the cms lines showed stable, complete pollen sterility in all three temperature regimes. In fact, under adverse temperatures abortion took place earlier than it did at optimum temperature.

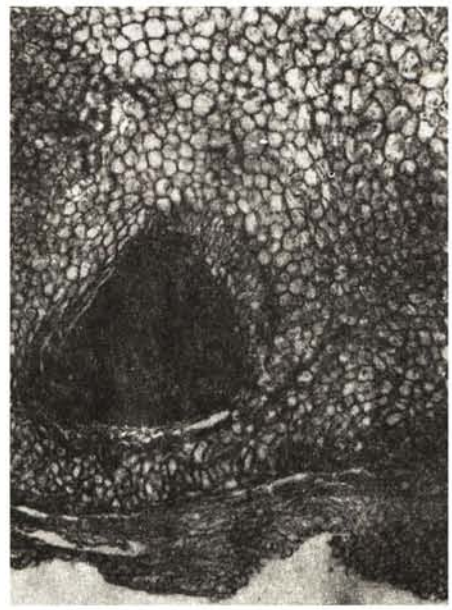
Pseudo grain set on cytosterile Wu 10A. Pseudo grain was set on cytosterile Wu 10A introduced from China. This line was developed from the BT cytosterile line introduced from Japan. The pseudo grains were filled with liquid instead of solid endosperm. Filling in some spikelets was excessive, to the extent that the husk would crack. However, when the pseudo grain was opened, only liquid substance oozed out and when dried, only papery kernel remained (Fig. 6).

Several thousand such pseudo grains were kept for germination after drying and breaking of dormancy, but none germinated. Young ovaries from spikelets 7-15 days after blooming were cultured using simple coconut milk medium. Several remained green for more than 5 months, but did not develop further. Microtome section showed only a few layers of ovary wall, but no endosperm tissue. At the embryo position, a mass of tissue grew without differentiation. In some cases, young primordia of coleorhiza could be seen (Fig. 7). In no case did primordia of coleoptile develop. With this incomplete embryonic axis, no germination can occur. Further studies are needed on this material to explore the possible occurrence of apomixis in rice.

Development of cytosterile lines adapted to



6. Features of a pseudo grain of cytosterile Wu 10A; open husk shows papery kernel. IRRI, 1981.



7. Young primordia of differentiated coleorhiza of pseudo grain of Wu 10A. IRRI, 1981.

tropical conditions. The cms lines with *Oryza sativa* f. *spontanea* (WA) cytoplasm introduced from China, although stable for pollen sterility, are not adapted to tropical rice-growing conditions because of susceptibility to several diseases and insects. Improved rice varieties and elite breeding lines developed at IRRI and in other Asian countries outside China have been screened for ability to maintain the sterility of these cms lines. About 400 lines have been screened so far and 78 have been found to be effective maintainers.

Backcrossing with 50 of the improved maintainer lines is in progress with the materials in first to fourth backcross generations. Agronomic and other traits of the lines used in third and fourth backcrosses are given in Table 11. With one to two additional backcrosses, some cms lines adapted to tropical rice-growing conditions should be available. These cms lines can then be used as female parents to develop F_1 hybrids for tropical rice-growing countries.

Identification of restorer lines adapted to tropical conditions. Out of about 400 elite rice varieties and breeding lines screened for restoration ability of WA cytosterility system, 88 lines have been found to be effective restorers. Many of these lines possess multiple resistance to diseases and insects (Table 12) and can be used in developing F_1 rice hybrids. Chinese scientists have started using some of these lines to develop new F_1 rice hybrids possessing multiple disease and insect resistance.

Hybrid seed production. Hybrid rice seed production by the cytoplasmic male sterility system involves three stages:

1. multiplication of male-sterile (*A*) and maintainer (*B*) lines,
2. multiplication of restorer (*R*) line, and
3. production of hybrid seed ($A \times R$).

Techniques of hybrid-seed production standardized in China involve:

- adjustment of seeding dates of parents to attain synchronization of flowering;
- a male-female ratio of 1:6;
- planting across the wind direction;
- clipping of flag leaves of male-sterile and restorer lines to expose their panicles for increased cross-pollination;
- application of gibberellin (20 ppm) on the male-sterile and restorer lines at the initial heading stage to improve their panicle exsertion;
- supplementary pollination, using the rope-pulling method 3-5 times on a calm day during anthesis; and
- isolation distance of 40-100 m or isolation time of 21 days.

Using these techniques, 19-32% natural outcrossing on 3 cytosterile lines resulted in a hybrid seed yield of 1.3-1.7 t/ha during the dry season at IRRI (Table 13). This compares with the seed set obtained on cms lines in China.

Attempts to produce hybrid seed during the wet season were unsuccessful because of severe damage to cytosterile lines by brown planthoppers and ragged stunt virus disease (Fig. 8). This further confirmed the need for male sterile and restorer parents to possess resistance to diseases and insects before being used to develop F_1 rice hybrids for the tropics.

Selecting and breeding cms lines with well-developed and exserted stigma and restorer lines with large anthers, abundant pollen and longer filaments should further increase seed set on male-sterile lines. Such variability in floral traits exists

Table 11. Characteristics of elite rice varieties and breeding lines identified as maintainers of WA cytosterility system, used for developing new cytoplasmic-male sterile lines.

Line or variety	Ht (cm)	Maturity (days)	Tillering	Disease or insect score[a] (1-9 scale)							Backcrosses already made (no.)
				BL[b]	BB[c]	ShB[d]	BPH[e]			GLH[f]	
							1	2	3		
IR747B2-6-3	79	96	17	3	3	5	3	9	3	9	4
IR10154-23-3-3	77	97	17	2	5	6	3	9	3	9	4
IET 3257	115	130	18	8	5	5	7	9	9	7	4
IR10176-24-6-2	69	100	20	1	1	5	3	9	3	9	3
IR10179-2-3-1	80	97	17	7	5	6	5	9	5	9	3

[a]Scoring based on the 1980 Standard Evaluation System for Rice. [b]Blast. [c]Bacterial blight. [d]Sheath blight. [e]Brown planthopper. [f]Green leafhopper.

Table 12. Characteristics of some elite rice varieties and breeding lines identified as restorers of WA cytosterility system.

Variety or line	Maturity (days)	Ht (cm)	Tillering	Disease or insect score[a] (1-9 scale)						
				BL[b]	BB[c]	ShB[d]	BPH[e]			GLH[f]
							1	2	3	
IR50	107	100	14	–	–	5	1	1	3	3
IR9801-1-14-2-2-3	110	105	19	4	1	5	3	3	3	5
IR9828-41-2-1	107	86	15	5	3	5	1	3	9	5
IR9967-110-3-3-2	102	105	12	4	1	5	3	3	3	3
IR13427-60-1-3-2-2	106	96	15	2	1	5	3	3	6	3
IR13524-21-2-3-3-2-2	110	84	14	7	3	5	1	3	3	5
IR21015-180-3-3	110	96	15	5	1	5	3	3	7	3
IR36	113	97	15	5	–	–	1	1	3	7
IR52	115	99	13	8	7	6	1	3	3	3
IR54	118	103	13	6	5	6	1	3	9	3
IR2797-125-3-2-2	120	95	30	8	1	5	3	3	7	5
IR11297-49-1-3	114	97	14	8	1	6	3	3	3	5
IR15847-215-2-1	120	110	13	4	1	5	3	3	3	5
IR17521-2-7-2-2-2-2	120	103	15	7	1	5	3	3	3	3
IR18342-4-3	119	115	13	3	1	5	1	3	7	1
IR18599-68-1	112	108	13	5	1	5	3	3	5	3
IR19577-80-3-1	116	96	15	8	1	5	1	5	3	7
IR21015-174-3-3	115	105	14	–	1	5	3	5	7	3
IR21526-4-3-3	119	115	17	8	1	6	3	3	3	5
IR32	130	88	12	7	5	4	1	3	7	5
IR42	130	105	15	5	–	5	1	1	5	9
IR46	121	102	14	8	7	6	1	3	3	9
IR48	128	80	11	8	5	5	1	3	7	3
IR9217-43-2-2-1	130	135	13	–	1	6	1	3	9	5
IR9802-50-1-2-2	121	109	14	7	1	5	1	3	3	3
IR10781-143-2-3	128	113	13	4	1	5	1	3	5	5
IR13410-71-3-2	123	111	13	–	1	6	1	3	5	5
IR13525-2-3-3-2-1	121	114	11	2	1	6	1	3	3	3
IR13538-6-2-2-3-2	121	110	14	1	3	6	1	1	3	5
IR14497-15-2	122	112	13	4	1	5	1	3	7	9
IR15324-36-2-2-3	126	106	12	6	1	6	3	5	3	1
IR15795-72-3-2-3-3	125	101	16	7	1	5	1	1	3	5
IR18349-22-1-2	121	127	15	5	1	5	1	1	1	5
IR19052-227-3	121	100	15	8	1	6	1	1	1	3
IR19083-22-2-2	121	100	12	5	1	5	1	3	9	3
IR19660-187-2-2-3-2	122	114	11	6	1	6	1	3	1	3
IR19661-63-1-2-3	132	100	15	6	1	6	3	3	3	3
IR19661-131-1-2	122	106	13	5	3	6	1	1	1	3

[a]Scoring based on the 1980 Standard Evaluation System for Rice. [b]Blast. [c]Bacterial blight. [d]Sheath blight. [e]Brown planthopper. [f]Green leafhopper.

among rice varieties. A genetic stock (designated as 6209-3) possessing very large (5 mm) and well-exserted (100%) stigma has been introduced from Sichuan Academy of Agricultural Sciences, Chengdu, China. This stock was developed from the cross Guan Keng A (a cytosterile indica line)/*Oryza rufipogon*//*O. longistaminata*. Work has been initiated to transfer its large stigma trait into the genetic background of selected maintainer lines, then into cms lines.

Table 13. Extent of natural outcrossing in some cytoplasmic male-sterile (cms) lines of rice in hybrid seed production plot. IRRI, 1981 dry season.

Cms line	Seed set[a] (%)	Seed yield (t/ha)
Zhen Shan 97A	19	1.3
V20A	23	1.7
V41A	32	1.6
Mean	25	1.5

[a]Pollen parent, IR54.



8. Insect and disease damage of a Chinese cytosterile line in a seed production plot. IRRI, 1981 wet season.

Effect of temperature on characters influencing seed set on male-sterile lines. Seed set on male-sterile lines depends on agronomic and floral characters of the *A*, *B*, or *R* lines, or all three. Some of these characters are plant height, tiller number, length of flag leaf, panicle exsertion, spikelets per panicle, duration of flowering, pollen fertility of *B* or *R* line, time and duration of anthesis, extent of stigma exsertion, and anther size. The effect of 3 temperature regimes — 26° / 18° C, 29° / 21° C, and 35° / 27° C — on the expression of these characters in 5 *A* lines, 5 corresponding *B* lines, and 1 *R* (IR54) line was studied. Both low (26° / 18° C) and high (35° / 27° C) temperatures affected these characters adversely, indicating that seed production would be feasible only under optimum temperature regimes. Although male sterility in *A* lines was stable, *B* and *R* lines became partially sterile in the adverse temperatures.

High temperature induced early anthesis, and low temperature delayed the process (Table 14). The trend was the same for termination of anthesis and peak hour of anthesis. Florets continued to open for 1-2.75 hours in optimum temperature, a little longer in low temperature, but a shorter time in high temperature.

The florets of *A* and *B* lines opened for different durations. All *A* lines except Wu 10A remained open for more than 200 minutes, 2-3 times more than did the corresponding *B* lines. This means that *A* lines are capable of receiving pollen longer than *B* lines.

The extended duration of anthesis in *A* lines per se may not result in increased cross-pollination, since the *B* or *R* lines do not provide pollen that long. Because stigma of the *A* lines remains receptive for 3-5 days, the *A* lines possessing exserted stigma can set more seed by being pollinated later. This makes it important to verify the receptivity of the exserted stigma under different agroclimatic situations.

These results indicate that hybrid breeding of rice offers opportunities for increasing varietal productivity, not only in irrigated but also in rainfed wetland conditions. The genetic tools cytoplasmic male sterility and fertility restorer lines, essential for the development of hybrid rice varieties, are available and can be further improved.

Table 14. Time-range, peak hour (in parentheses), and opening duration of individual spikelets of various *A, B,* and *R* lines in 3 temperature regimes, 28 June 1981 (clear sun 530 g cal/cm^2 per day).

Line	Time-range and peak hour			Opening duration (minute)		
	Temp 1	Temp 2	Temp 3	Temp 1	Temp 2	Temp 3
V20A	10.40-13.30 (11.40)	10.15-13.00 (11.00)	10.05-11.15 (10.30)	275	260	205
97A	11.20-13.30 (11.50)	10.50-13.00 (11.05)	10.40-11.30 (11.05)	315	280	245
V41A	11.05-13.30 (11.25)	10.32-13.00 (11.00)	10.30-11.25 (10.50)	260	268	235
P 203A	10.45-13.30 (11.45)	10.20-13.00 (11.00)	10.00-11.10 (10.45)	165	180	90
Wu 10A	11.10-13.00 (11.40)	10.40-12.32 (11.30)	10.43-11.40 (10.50)	115	105	97
V20B	10.40-13.35 (11.40)	10.30-12.30 (11.00)	10.15-11.25 (11.00)	120	80	59
97B	11.15-13.30 (11.45)	10.55-12.30 (11.30)	10.50-11.30 (11.10)	111	100	33
V41B	11.10-13.30 (11.40)	10.55-12.33 (11.10)	10.30-11.30 (11.00)	100	55	53
P 203B	10.50-13.25 (11.50)	10.35-12.35 (11.40)	10.05-11.10 (10.55)	90	85	30
Wu 10B	11.10-12.40 (11.40)	10.50-12.30 (11.30)	10.45-11.40 (10.56)	90	80	25
IR54	10.40-13.30 (11.00)	10.52-12.00 (11.00)	10.40-11.30 (10.53)	105	65	30

Techniques of hybrid seed production known to yield 1-1.5 t seed/ha can be modified to further increase the yield. The major factors for national programs are efficient seed production, certification, and distribution programs. Research has begun in India, Indonesia, Philippines, and USA to explore the prospects for this innovative breeding approach.

Table 15. Survival of outcrossing hybrid populations grown in salt water (av, 2 generations in Rapid Generation Advance).

Salt concn	SR 26 B	Pokkali	Composite
0%	100	100	96
0.2%	100	100	81
0.4%	56	92	20
0.6%	7	23	0

RAPID GENERATION ADVANCE

Plant Physiology and Plant Breeding Departments

Of 281 hybrid populations grown, 112 were received as new F_2 populations. Some of these were grown more than once. Thus a total of 337 populations of these crosses were grown in rapid generation advance (RGA), and 41 populations were grown in the field.

A randomly outcrossing population of IR38502, CP 106 from 28 F_1s involving the genetic male-sterile IR36 (MS), and several salt-tolerant parents was established. This population was handled in standard RGA procedure and subjected to 4 treatments: one irrigated with fresh water and 3 irrigated with 0.2%, 0.4%, and 0.6% salt water. Selection procedure is designed to remove salt-susceptible plants before each random crossing cycle, gradually upgrading the population for salinity tolerance. Table 15 illustrates the effect of salt concentration on survival of salt-resistant checks and the population.

Genetic evaluation and utilization (GEU) program

International Rice Testing Program

International Rice Testing Program

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INTERNATIONAL NURSERIES

The nursery program expanded in 1981, with 1,530 nursery sets assembled and dispatched to 52 countries in the International Rice Testing Program (IRTP) network. Most of the nurseries were observational sets intended for evaluation in target environments. Others were screening sets for testing against specific soil, insect, and disease problems.

To better support the needs of national rice improvement programs, 9 nurseries were added: Leaf Scald, Sheath Rot, Brown Spot, Cercospora, Bacterial Blight, Leaf Folder, Acid Sulfate, Acid Upland, and Peat Soil Screening sets. In addition, the deepwater observational nursery was categorized into sets for flood tolerance, medium deepwater, and floating rice.

A total of 1,945 entries from 35 countries and IRRI were included in the various nurseries and screening sets.

Results from more than 500 test locations from trials conducted in 1980 were analyzed and published. For yield nurseries, analyses were made over all locations and by region to show the range of adaptability of the entries. Summaries of data for such climatic factors as rainfall, atmospheric temperature, and solar radiation during the crop season were included in the report.

Entries from the 1980 IRTP trials that showed good yield performance across many sites, high scores for phenotypic acceptability in various target environments, and the best resistance to or tolerance for various stresses are listed in Table 1.

LINKAGES WITH NATIONAL PROGRAMS

Participation of IRRI scientists in national and regional IRTP-sponsored monitoring tours and workshops continued to strengthen effective linkages among the national programs and the GEU program at IRRI. On monitoring tours, scientists from national programs and IRRI can review local and IRTP trials. Tour participants share research experiences, discuss possible research strategies, and decide on how collaborative programs such as the IRTP and similar activities can be most beneficial to participating countries.

IRRI scientists and scientists from other rice-growing countries in Asia participated in the monitoring tour held in the People's Republic of China. The tour focused on diseases and breeding for disease resistance.

Another tour looked into the problem soils in India. Participants observed local, national, and IRTP trials on problem soils and discussed ways to intensify collaborative research in this area. In another problem area, a group visited Bihar, West Bengal, Bangladesh, and Thailand to look at deepwater rice problems.

A regional monitoring program in West Africa covered research and testing activities in Senegal, Liberia, Ivory Coast, and Nigeria. Participants saw the need for early-maturing varieties that are resistant to drought and to blast, leaf scald, and sheath blight diseases in that region, where rice is grown predominantly in dryland conditions.

The first travelling workshop was held in Brazil to review the current status and thrust of dryland rice improvement programs of national and international organizations in Latin America, Africa, and Asia. It stressed the importance of establishing a network of scientists working on dryland rice.

Scientists from 22 countries participated in a regional workshop for Latin America held in Colombia.

PUBLICATIONS

IRTP continued to publish results of the various nurseries, reports of monitoring tours, and workshop proceedings and recommendations. These publications were printed and dispatched to cooperators in 1981.

General report

- Global Rice Improvement Network: Five Years of IRTP

Nursery reports

1980 Final Reports

Yield

Irrigated

- IRYN-VE (Very Early)
- IRYN-E (Early)
- IRYN-M (Medium)
- IRYN-L (Late)

Rainfed

- IURYN

Table 1. Promising entries in the 1980 IRTP nurseries that showed good performance across many locations.

Nursery	Promising entries
	Yield – Irrigated
IRYN-VE (Very Early)	• IR9729-67-3, IR19746-28-2-2, BG367-7, IR19743-25-2-2
IRYN-E (Early)	• IR9828-91-2-3, IR36, IR50, IR13429-196-1, Chianung sen yu 13
IRYN-M (Medium)	• BR51-282-8, IR54, IR13540-56-3-2-1, IR15318-2-2-2-2, BG400-1, BR168-2B-23, IR42
IRYN-L (Late)	• RP1064-14-2-2, MTU7029, RP975-109-2, CR1006, Mahsuri
	Yield – Rainfed
IURYN (upland)	• IR5931-110-1, BG35-2, B733c-167-3-2, CR156-5021-207, IR5853-118-5 (IR52), IR6115-1-1-1, IR9560-2-6-3-1, IR995-96-2
	Observational – Irrigated
IRON	• AD9246, IR4744-295-2-3, IR52, IR8608-82-1-3-1-3, IR9209-217-1-2-2, IR9224-140-3-2-2-3, IR9698-16-3-3-2, IR9782-111-2-1-2, IR9784-142-1-3-3, IR9852-22-3
IRARON (arid regions)	• B459b-Pn-32-3-5, C633 (IET3268), IR9761-1-2, MRC603-383, PAU14-2-2-B-9-2-1-1-1, PK178, Pusa 2-21, Rasht 507, SKL17-67-11 (IET6507), IR50, GZ864-2-1-1, CR410-1-3-4, CR547-1-2-3, CR547-1-2-5, CR581-6-1-1, GZ809-4-1-2, GZ916-3-1-1-2, Sakhai
	Observational – Rainfed
IURON (upland)	• BG35-2, CR156-5021-207, IR3880-29, KMP34, ARC10372, C924-9
IRLRON (lowland)	• Mahsuri, IR13146-45-2, BR10, BR51-282-8, Pelita I-1, IR4819-77-3-2, IR4829-89-2, IR10781-75-3-2, IR10781-75-3-2-2, IR13146-41-3, IR13564-95-1
IRDWON (deepwater)	• BKN6986-147-2 (RD19), SPR7233-1-24-2-2-2-3, SPR7292-151-2-1-B-B, Chamara, FRRS43/3, Khama
	Stress screening
Temperature IRCTN (cold)	• Fuzi 102, Olbyeo, China 1039, Deog-Jeog-Jodo, Hwanghaedo, Eiko (Acc 9417), IR8455-K2, IR9099-K1, K78-13, IR9129-K1, IR9202-5-2-2-2, K39-96-1-1-1-2
Problem soils IRSATON (salinity and alkalinity)	• *Salinity:* Vegetative: C23-3-1, Getu Mutant 2735, IR36, IR2307-247-2-2-3, IR4595-4-1-15, IR4630-22-2-5-1-3, IR4630-22-2-17, Rok 8, Rok 9, Pokkali Maturity: IR36, IR4432-28-5, IR4595-4-1-15, IR4630-22-2-5-1-3, IR4630-22-2-17, IR9852-19-2, Rok 8, Rok 9, TNAU17069, Pokkali *Alkalinity:* CSR1, Getu, IR2058-78-3-2-3 (IR46), IR4432-28-5, IR4462-22A-2-10, IR8236-B-B-359-2-2, IR11418-19-2-3, Pokkali

Continued on next page

Table 1 continued

Nursery	Promising entries
Diseases	
IRBN (blast)	• IR1416-128-5-8, IR1905-81-3-1, IR4227-18-3-2, IR4547-4-1-2, IR4547-6-2-5, IR5533-PP850-1, IR5533-PP854-1, IR13149-19-1, Tetep, Carreon, Ta-poo-cho-z, Tres Marias, C46-15, 5287
IRTN (tungro)	• AC4236, ARC10342, ARC10495, ARC11353, ARC11554, Utri Merah, Utri Rajapan, BR51-66-3, IR9209-249-1-2-3-2, RD6-516-29-1-4-1-1
Insects	
IRBPHN (brown planthopper)	• IR13427-45-2-3-3, IR17496-2-25-1
IRSBN (stem borer)	• IR9828-23-1, IR13639-34, IR13635-38, IR19735-30-3-3

Observational
Irrigated
- IRON
- IRARON (Arid Region)

Rainfed
- IURON (Upland)
- IRLRON (Rainfed Lowland)
- IRDWON (Deep Water)

Stress Screening
Temperature
- IRCTN (Cold Tolerance)

Soil
- IRSATON (Salinity/Alkalinity)

Diseases
- IRBN (Blast)
- IRTN (Tungro)

Insects
- IRBPHN (Brown Planthopper)
- IRSBN (Stem Borer)

Fieldbook
- 1981 Master Fieldbook

Report for IRTP nurseries in Africa (1979-1980)

Rice improvement monitoring tour reports
- Breeding and Diseases Monitoring Tour (China)
- Problem Soils Monitoring Tour (India)
- Deep Water Monitoring Tour (Bangladesh, India, Thailand)
- Regional (West Africa) Monitoring Tour (Senegal, Liberia)
- Upland Rice Monitoring Tour (Mato Grosso, Brazil)

Blast and upland rice traveling workshop report (Brazil)

Reference publication
- Standard Evaluation System for Rice (2nd Edition)

Genetic evaluation and utilization program (GEU)

Integrated GEU program

Plant Breeding and Plant Physiology Departments, Thailand-IRRI Cooperative Deepwater Project, and Information Services Department

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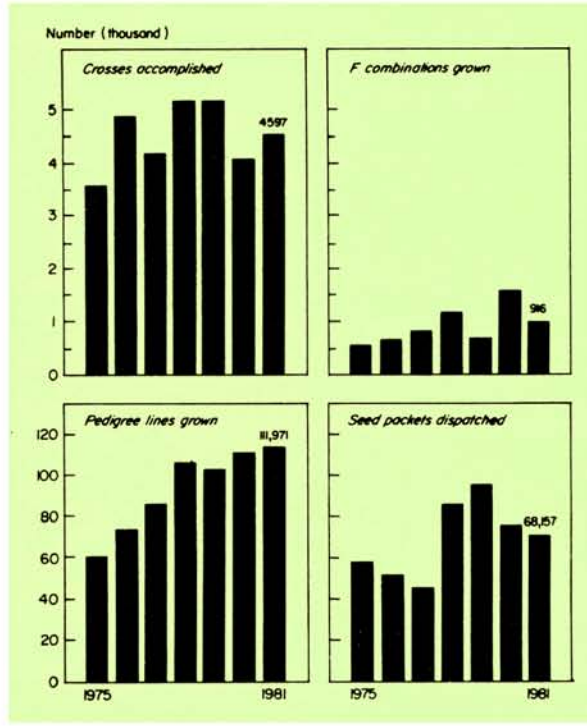
INTERNATIONAL RICE GENETIC SURVEY **157**

EXCHANGE OF GERMPLASM

Plant Breeding Department

In 1981, IRRI sent abroad a total of 68,157 seed packets of breeding lines (Fig. 1) — 6,233 packets of improved IRRI breeding lines and varieties dispatched in response to requests from scientists in other countries and 61,924 packets of the best IR breeding lines and varieties provided to national programs by the International Rice Testing Program (IRTP). Many seed samples of IRRI breeding lines also were exchanged through collaborative research projects.

The germplasm bank provided 9,337 seed samples of cultivated rices to researchers in other countries. An additional 539 seed samples of wild species of *Oryza*, 58 of genetic testers and mutants, and 62 of *O. glaberrima* were sent.



1. Volume of the IRRI Genetic Evaluation and Utilization program, 1975-81.

IRRI LINES NAMED IN NATIONAL PROGRAMS

Plant Breeding Department

National rice improvement programs released 14 IRRI varieties or breeding lines during 1981 (Table 1), bringing the total of named national varieties from IRRI materials to 99. Eleven varieties were named directly by IRRI before 1975.

- IR841, released in Argentina, has long slender grains. This variety was named earlier in Brazil.
- Saavedra 5, released in Bolivia, is a very high yielding variety. It was recommended earlier in Cuba.
- Suakoko 12, named in Liberia, is blast resistant and iron-toxicity tolerant.
- Shwe-Thwe-Lay, released in Burma, is high yielding with sturdy stems.
- Yar 5, recommended in Burma, has very high yield potential and drought tolerance. It was recommended earlier in Vietnam and several countries in Africa.
- IR1545, released in Ecuador, has excellent yield potential and superior grain quality.
- IR1561, named in Mauritania, is early maturing and has excellent yield potential. It also was recommended in Vietnam, Egypt, and China.
- IR50, released in Indonesia, is early maturing and multiple disease and insect resistant, identical to its Philippine counterpart.
- IR52, recommended in Indonesia, is drought tolerant, identical to its Philippine counterpart.
- IR54, named in Indonesia, is high yielding, multiple disease and insect resistant, identical to its Philippine counterpart.
- IR42, recommended in Nigeria, is high yielding and has multiple tolerance for various soil stresses, identical to its Philippine counterpart. It also is recommended and widely grown in Indonesia and Malaysia.
- IR46, released in Cameroon, is identical to its Philippine counterpart.
- IR30, recommended in Nigeria, is early maturing and has multiple disease and insect resistance, identical to its Philippine counterpart.
- IR36, approved as an all-India release by the Central Variety Release Committee, New Delhi, is early maturing and high yielding, and has multiple resistance to diseases and insects

Table 1. IRRI lines named in other countries during 1981.

Variety name	Selection no.	Parents	Country where named
IR841	IR841-63-5-18	IR262-43-8-11/Khao Dawk Mali 136	Argentina
Saavedra 5	IR1529-430-3	IR305-3-17/IR24	Bolivia
Suakoku 12	IR1416-131-5	IR400-28-4/Tetep	Liberia
Shwe-Thwe-Lay	IR751-592	IR8*2/Peta*5//Belle Patna	Burma
Yar 5	IR1529-680-3-2	IR305-3-17/IR24	Burma
IR1545	IR1545-339-2-2	IR24/DZ 192	Ecuador
IR1561	IR1561-228-3-3	IR579-48-1/IR747B2-6-3	Mauritania
IR50	IR9224-117-2-3-3-2	IR2153-14-1/IR28//IR36	Indonesia
IR52	IR5853-118-5	Nam Sagui 19/IR2071-88// IR2061-3-6	Indonesia
IR54	IR5853-162-1-2-3	Nam Sagui 19/IR2071-88// IR2061-3-6	Indonesia
IR42	IR2071-586-5-6-3	IR1561-228-1/IR1737// CR94-13	Nigeria
IR46	IR2058-78-1-2-3	IR1416-131-5/IR1364-37// IR1366-120/IR1539-111	Cameroon
IR30	IR2153-159-1-4	IR26//IR20*4/*O. nivara*	Nigeria
IR36	IR2071-625-1-252	IR1561-228-1/IR1737// CR94-13	India

and tolerance for many problem soil conditions, identical to its Philippine counterpart. It was recommended earlier by the states of Orissa and West Bengal, and is the most widely grown variety of rice in the world.

BREEDING OPERATIONS

Plant Breeding and Plant Physiology Departments and Thailand-IRRI Cooperative Deepwater Project

In 1981, 4,597 crosses were made and F_2 populations were grown from 916 cross combinations. Many crosses were made at the request of collaborating national scientists, to whom the F_2 seeds were sent for further selection work within appropriate environments. A total of 111,971 pedigree nursery rows were grown.

Irrigated rice *(Plant Breeding).* Many promising breeding lines with multiple disease and insect resistance, high yield potential, and varying growth duration were evaluated. For the first time, many intermediate-amylose-content breeding lines were evaluated in replicated yield trials. During the dry season, 368 breeding lines were evaluated in replicated yield trials and during the wet season, 391. More than 30 breeding lines were evaluated in nitrogen response trials at IRRI and at 3 BPI stations in the Philippines. Several promising breeding lines also were tested for yield and adaptability on farmers' fields (see Cropping Systems Program).

Some promising breeding lines for irrigated conditions are listed in Table 2. IR9729-67-3 and IR9752-71-3-2 have a growth duration of less than 100 days, and a yield potential comparable to that of IR36, and multiple disease and insect resistance. IR13429-209-2-2-1 and IR13429-299-2-1-3 have the same growth duration as IR36 but are resistant to all biotypes of brown planthopper. IR13429-299-2-1-3 has strong grain dormancy. IR13423-10-2-3 and IR13423-17-1-2-1, sister lines with multiple resistance, inherit tungro resistance from Pankhari 203.

IR13525-43-2-3-1, IR15314-43-2-3-3, IR19672-155-2-1-1-3, and IR19058-107-1 are high yielding lines with sturdy stems and multiple disease and insect resistance. They inherit resistance to three biotypes of brown planthopper from Rathu Heenati, Babawee, or PTB 33. IR22082-41-2, IR24632-60-3-3-2, and IR25588-32-2 are high yielding, multiple disease- and insect-resistant lines with intermediate amylose content.

Rainfed-dryland rice *(Plant Breeding).* Yield stability indexes (b) were computed from 21 dryland varieties and lines tested from 1977 to 1980 in

Table 2. Some promising breeding lines with multiple attributes suitable for irrigated wetland culture, IRRI, 1981.

Designation	Cross	Growth duration (days)	Amylose content (%)	Reaction[a] to							
				Blast	Bacterial blight	Tungro	Grassy stunt	Green leafhopper	BPH[b] biotype		
									1	2	3
IR9729-67-3	BG34-8//IR28//IR2071-625-1-252	98	26	6	1	3	1	3	1	1	7
IR9752-71-3-2	IR28/Kwang-chang-ai//IR2071-625-1-252	99	26	2	1	3	1	3	1	1	7
IR13429-109-2-2-1	IR4432-53/PTB 33//IR36	107	25	2	1	3	1	3	1	1	1
IR13429-299-2-1-3	IR4432-53/PTB 33//IR36	107	26	4	1	3	1	3	1	1	1
IR13423-10-2-3	IR44/IR2588-132//IR4417-177-1	120	27	4	1	3	1	3	1	1	7
IR13423-17-1-2-1	IR44/IR2588-132//IR4417-177-1	120	27	6	1	3	1	3	1	1	7
IR13525-43-2-3-1	PTB 33/IR30//IR36	120	26	4	1	3	1	3	1	1	1
IR15314-43-2-3-3	Babawee/IR4432-53//IR2061-628	130	27	3	1	3	1	3	1	1	5
IR19058-107-1	Babawee/IR7149-5-3//IR2071-625-1-252	107	26	4	1	3	3	3	1	1	1
IR19672-155-2-1-1-3	PTB 33/3*IR4432-53-3//IR4432-53-3	128	27	7	1	3	1	3	1	1	1
IR19735-5-2-3-2-1	IR9129-77-1-3/IR10176-79	100	26	4	1	3	1	3	1	1	7
IR19746-28-2-2-3	IR9129-192-2-3/IR10183-7	97	26	8	1	3	1	3	1	1	7
IR22082-41-2	IR5853-162-1-2-3/IR5657-33-2	125	23	8	1	3	1	3	1	1	7
IR24632-60-3-3-2	IR5657-33-2/IR4707-106-3-2//IR4570-83-3-3-2	110	23	4	1	3	1	3	1	3	1
IR25588-32-2	IR19657-37-3/IR9129-209-2-2	105	20	7	1	3	1	3	1	1	1

[a]Scoring based on the 1980 Standard Evaluation System for Rice. [b]Brown planthopper.

12 environments (4 years × 3 sites) in a farmer's field in Batangas Province and at 2 sites on the IRRI farm. The indexes derived from linear regression facilitate identification of breeding lines better adapted to different environments.

In drought-prone areas with low precipitation and short crop seasons, early-maturing lines with moderately high and stable yields are needed. IR3880-29, IR5178-1-1-4, and IR7790-18-1-2 are generally early maturing but average yields are only 1.56-1.97 t/ha. But average yield of the local check, Kinandang Patong, was only 1.40 t/ha. IR5178-1-1-4 performed well under unfavorable conditions. IR3880-29 performed well in IRTP nurseries in several countries.

In areas with abundant rainfall or low but evenly distributed precipitation, or both, high yielding semidwarfs with moderate drought resistance and good recovery ability, such as IR43, IR5931-110-1, IR6115-1-1-1, and IR9669 selections, performed well. IR5931-110-1 and IR6115-1-1-1 gave good yields in international nurseries. Both lines were entered in the Philippine Seedboard trials of 1980 and 1981.

In areas with a longer rainy season or with bimodal rainfall patterns, which are also prone to occasional prolonged drought, varieties with both drought resistance and good recovery ability are needed for stable yield. IR3880-10, IR5929-12-3, and IR6023-10-1-1 performed well in droughty years. IR5929-12-3 and IR6023-10-1-1 were identified as promising in the 1980 Philippine Seedboard trials.

The prolonged drought stress at IRRI on 19 July-16 September helped identify promising lines that have drought resistance at both vegetative and reproductive growth as well as good recovery ability. Such lines were IR10011-16-3 (from the cross of IR1746-F5B-24/IR3179-25//MRC 172-9), IR10110-23-1 (from IR1754-F5B-23/IR3179-25 //BPI-76*9/Dawn), and IR12721 lines (from IR2735-F3B-6-2/IR9575//B541B-KN-19-3-4). IR1011-16-3 and IR10110-23-1 are resistant to blast and bacterial blight. IR10110 lines thrived well in iron-deficient soil and were the only lines that showed no chlorosis among the 120 entries in replicated trials at IRRI.

The cross breeding program for rainfed-dryland rice focuses more on needs of collaborating scien-

tists in drought-prone areas. Of 337 crosses, 16 were designed for the rainfed-wetland areas of Thailand, 105 for drought-prone rainfed-dryland areas of north central India, 11 for Brazil, and 5 for the International Institute for Tropical Agriculture in Nigeria. Most crosses involved at least one drought-resistant parent adapted to the local environment.

Deepwater rice *(Thailand-IRRI Cooperative Deepwater Project).* Numerous improved breeding lines with tolerance for deepwater conditions were evaluated. Some are tolerant of submergence, others have elongating ability (Table 3). Most have long, slender, and translucent grains. Many are photoperiod sensitive, but some are photoperiod insensitive.

Breeding for submergence tolerance and elongation ability *(Thailand-IRRI Cooperative Deepwater Project, and Plant Breeding).* To determine whether the excellent tolerance for flash floods of FR13A can be combined with elongation ability, F_3 lines obtained from the F_2 populations grown in 1980 were evaluated. One set of each line was subjected to a standard 8-day submergence treatment in a deepwater tank and a second set to a standard elongation test. Table 4 gives the number of lines with good elongation ability, those with good submergence tolerance in flash floods, and those combining these attributes. Expected and observed frequencies did not differ materially, supporting the belief that elongation ability can effectively be put into the same types that tolerate flash floods, since the two traits appear to segregate independently.

Inheritance of submergence tolerance *(Plant Breeding and Plant Physiology).* To find optimum seedling age and submergence duration for genetic differentiation of varieties, 9 treatment combina-

Table 3. Promising advanced lines with tolerance for deep water. IRRI, 1981.

Designation	Best yield 1981	Flowering duration or date	Plant ht (cm)	Grain length (cm)	Endosperm chalkiness[a]
Photoperiod insensitive, tolerant of some submergence					
IR8234-OT-9-2	4.0	± 120 days	96	7.3	1
IR8234-OT-21	4.0	± 120 days	97	7.4	2
Photoperiod insensitive, elongating					
BKNFR76020-122-1-1-2	3.4	132 days	136	7.2	3
DWCT 156-1-2	2.6	133 days	146	7.5	1
Glutinous, photoperiod sensitive, medium deepwater					
BKNFR76026-3-2-2-2	4.1	20 Nov	140	7.1	9
BKNFR76026-29-2-1-3	4.2	21 Nov	143	6.6	9
BKNFR76026-37-1-4-1	2.9	22 Oct	138	6.7	9
BKNFR76035-106	3.4	27 Oct	86	6.8	9
BKNFR76035-106-OL	3.5	6 Nov	93	6.3	9
BKNFR76035-118	3.8	1 Nov	94	7.1	9
Medium stature deepwater, photoperiod sensitive					
IR4954-K23-1-0-0-2	4.1	22 Oct	108	7.4	3
BKNFR76035-108-1	3.8	10 Nov	137	7.1	4
BKNFR76035-108-2	3.9	9 Nov	140	7.4	4
BKNFR76035-108-3	3.3	9 Nov	139	7.4	4
SPR7297-343	3.8	13 Nov	115	7.6	4
BKNFR76-14-51-5-1	3.8	16 Nov	152	7.2	5
SPR7233-32-1-6-1	3.8	22 Nov	149	7.4	1
SPR7299-2	3.9	25 Nov	145	7.5	3
IR11185-RGA-416-1		9 Nov	120		3
Tall stature deepwater, photoperiod sensitive					
SPR7282-2-0-1-1-2	3.3	20 Nov	179	7.2	5
SPR7282-2-0-1-1-2	3.4	20 Nov	185	7.2	5
SPR7411-7-2-2	2.8	9 Nov	196	7.4	5
SPR7270-18	3.7	27 Nov	165	7.4	2

[a]Standard Evaluation System for Rice: 0 = none, 9 = more than 20%, or glutinous.

Table 4. Classification for deepwater adaptation of 229 F_3 lines. IRRI, 1981.

Cross	Lines (no.)				
	Tolerant of flash floods	Elongating in slowly rising water	Tolerant of flash floods and able to elongate		Total
			Expected	Obtained	
BKN6986-108-3/FR 13A	12	17	9	11	23
DWCT 156/FR 13A	8	21	3	2	50
SPR7297-405/FR 13A	20	39	14	15	56
BKN6988-52-1/FR 13A	4	22	4	4	22
DWCT 134/FR 13A	14	43	11	13	56
BKN6986-161-7/FR 13A	0	4	0	0	22
Total	58	146	41	45	229

tions involving 10-, 15-, and 20-day-old seedlings submerged in 90-cm water in diesel barrels for 10, 12, and 14 days each were used. The weather during the experimental period was dry, with clear sky. The treatment of 10-day-old seedlings submerged for 12 days was most effective, followed by 20-day-old seedlings submerged 15 days.

Seedling submergence tolerance showed dominance in four tolerant/nontolerant F_1 hybrids, FR13A/IR42, FR13A/RD19, FR13A/Mahsuri, and FR13A/Jagannath. There were no differences in reciprocal crosses, suggesting that cytoplasm was not very important in inheritance of the trait.

Genetic analysis of F_2 and backcross populations in FR13A/IR42 confirmed the dominance of tolerance. It was not possible to work out Mendelian ratios, as a few plants of the tolerant parent were killed during the submergence test and a few plants of the nontolerant parent survived.

Inheritance of submergence tolerance was studied in a 10 × 10 diallel set of crosses consisting of 4 tolerant parents — FR13A, FR43B, Kurkaruppan, and Goda Heenati — and 6 nontolerant parents, of which 3 are photoperiod insensitive — IR42, IR17494-32, and IR19672-24-3 — and 3 photoperiod sensitive — RD19, Jagannath, and CR1009. Results confirmed earlier findings showing the high significance of both general and specific combining ability effects and concentration of dominant alleles in FR13A, followed by Kurkaruppan and FR43B. The 10 × 10 diallel analysis differed from previous analyses in showing the presence of low-intensity nonallelic interaction.

In repeated screening tests in greenhouse tanks and diesel barrels, several improved-plant type selections showed consistently high levels of submergence tolerance (Table 5).

Using male-sterile facilitated composites to breed photoperiod-sensitive rainfed rices *(Plant Breeding and Plant Physiology).* Progress in breeding photoperiod-sensitive rices for rainfed wetland areas has been slow because many additional char-

Table 5. Some improved-plant type lines with submergence tolerance. IRRI, 1981.

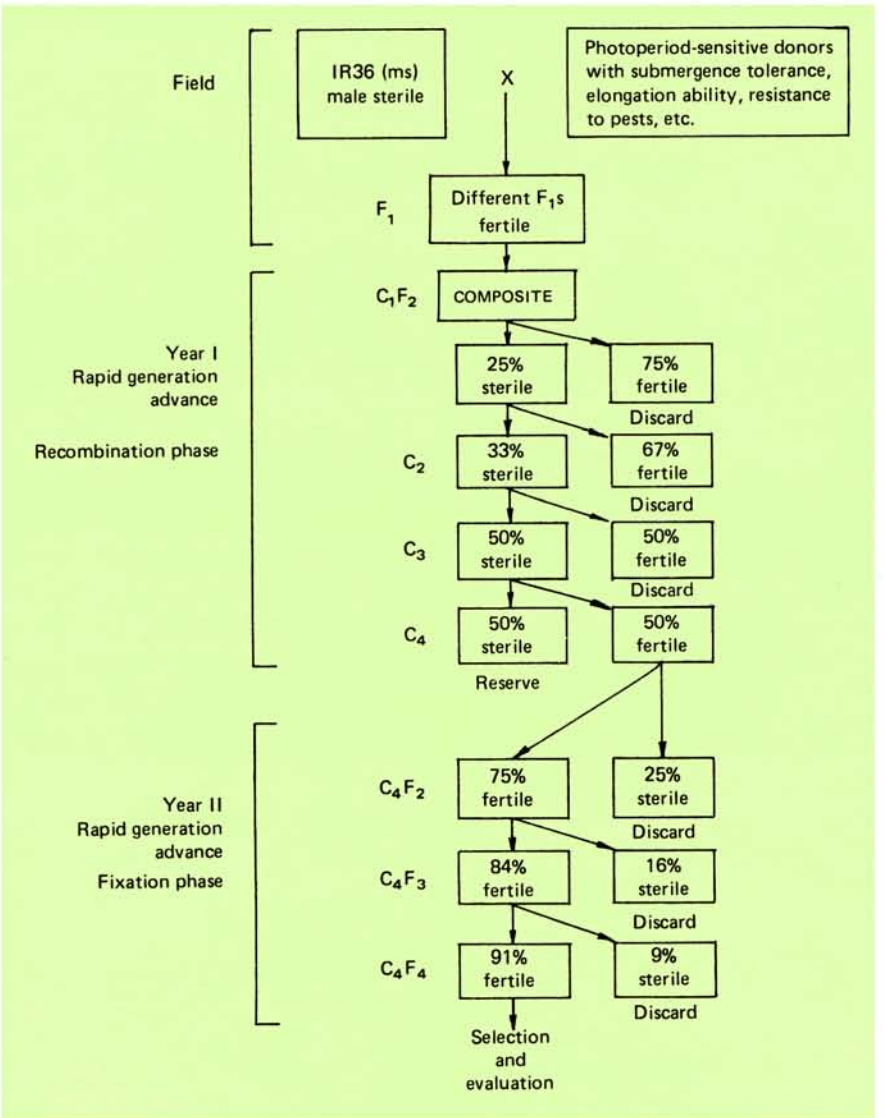
Selection	Cross	Submergence score[a]	Plant ht	Grain	Kernel
IR31406-333-1	Kurkaruppan/CR1002//IR13415-9-3	1-3	Short	Medium bold	White
IR29015-1	Jagannath/IR4570-83-3-3-2//FR13A	1-4	Short	Medium slender	White
IR26702-25-3	FR13A/IR4570-83-3-2//IR42	1-4	Short	Medium slender	White
IR26702-51	FR13A/IR4570-83-3-2//IR42	1-4	Short	Short slender	White
IR26702-52-1	FR13A/IR4570-83-3-2//IR42	1-4	Intermediate ht	Medium slender	White
IR31031-1	FR13A/CR1002//IR4570-83-8-8-2	1-4	Short	Short bold	Red
IR31031-43-2	FR13A/CR1002//IR4570-83-8-8-2	1-4	Intermediate ht	Medium bold	White
IR31023-44-1	FR13A/B2360-6-9-5//IR4570-83-3-3-2	1-4	Short	Medium slender	White
IR31023-45-1	FR13A/B2360-6-9-5//IR4570-83-3-3-2	1-4	Short	Medium slender	White

[a] FR13A scored from 1-3 and IR42 from 8-9.

acters are needed for adaptation of photoperiod-sensitive varieties to particular sites. These characters cannot be easily combined by conventional breeding procedures. A male-sterile facilitated composite breeding scheme, in which a number of parents can be used to develop a base population for selection of photoperiod lines, was devised (Fig. 2).

A number of photoperiod-sensitive donors are crossed with a genetic male-sterile mutant of IR36 (IR36 ms). The fertile F_1s are grown in the field. An equal quantity of seeds from each F_1 is bulked to produce the C1 F_2 composite, which gives 25% male-sterile segregants. Seed set on male-sterile plants is harvested and bulked to grow C2.

In the C2 population, 33% of the plants are sterile and seed set on those is harvested to grow C3 and C4 populations. By the C4, enough intermating has occurred to allow the selection of fertile plants to grow C4 F_2 population. By continued selection, the frequency of fertile plants would be 91% by C4 F_4. Selected plants can then be grown in



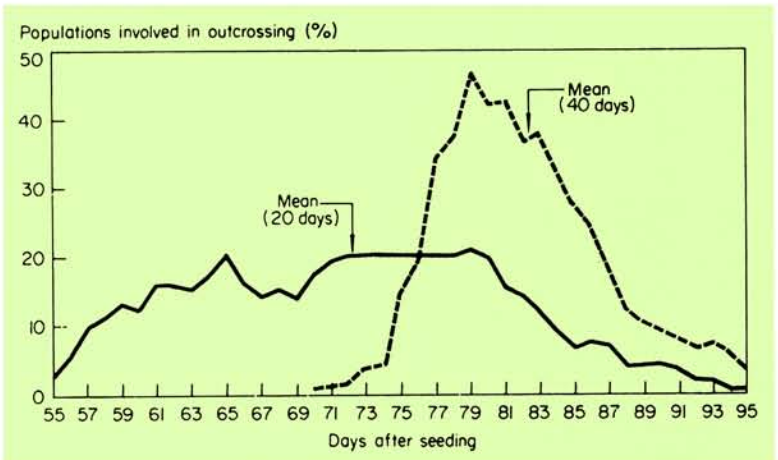
2. Scheme to develop and handle male-sterile facilitated composites. IRRI, 1981.

the field for further screening, evaluation, and selection.

In handling the male-sterile facilitated composites, the crucial points are synchronization of flowering and close planting to obtain maximum cross pollination. If C1 F_2 to C4 F_4 are grown in rapid generation advance (RGA) — in which plants are subjected to long days in the early stage to prevent flowering and to short days later to induce flowering — it should be possible to make flowering of the various segregants coincide.

The main advantages of this breeding procedure are:

- Increased outcrossing — the population is temporarily converted into an outcrossing system, allowing for random mating and generation of new recombinants at each intermating generation.
- Shortened generation time — flowering is speeded by short-day treatment using RGA facilities.
- Synchronized flowering — a 40-day exposure to long days, followed by short-day treatment, gave better synchronization of flowering.
- Increased space use — The composite cross components can be planted at 500 plants/m^2 in the RGA facilities.



3. Long-day treatment before floral inductive short-day treatment and composite population (%) involved in outcrossing. IRRI, 1981.

In an experiment with five F_2 populations and their composite, IR38497-CP101, the optimum plant age to start the short-day RGA treatment was studied. Half the population was grown for 20 days and half for 40 days under long day lengths, before exposure to short days to induce flowering. Flowering was recorded daily. In the plants grown for 20 days under long day length, 75% or more flowered within 13-21 days; in those grown for 40 days under long day length, 75% or more flowered within 4-9 days. The shorter flowering range ensured a better chance of random mating.

The advantage of a shorter flowering range is illustrated in Figure 3. A plant flowering on a given day would most likely be pollinated by other plants heading 2 days before and 2 days after. A plant population grown for 40 days before being subjected to flower induction had a narrower flowering range, causing more of the population to be involved in outcrossing.

Table 6. Parents used in composite crosses. IRRI, 1981.

IR38497-CP101		
Jalaj	Leb Mue Nahng III	RD 19 CN 540
IR38498-CP102		
BKNFR76059-16-2	Badhaia Chikon	Dahanala
FRG 10	Bahagira	Kalutalawee
Jagannath	Binni	Ptb 21
Jalaj	Bunajota	Thavalu
Leb Mue Nahng III	Burabazal	CN540
Lambayque I	Digha	Cultivar 956
Padi Sasahal	Kalahaia	Dudmona
Beak Ganges	Kalo Mota	Goda Heenati
FR13A	Pankiraj 1170	IR1060-90
FR43B	Sulpan	KLG6986-165-P
Sungail	RD 19	Kurkaruppan

Two composites, IR38497-CP101 and IR38498-CP102, were established by hybridizing 4 and 33 rainfed rices with IR36 (Table 6). The populations will be converted back to self-fertilization (fixation phase) after four generations of random mating.

INTERNATIONAL RICE GENETIC SURVEY

Information Services Department

The computerization of the complete genetic ancestry of about 40,000 hybridizations made in national rice improvement programs, 600 post-IR8 varieties, and 1,150 older varieties began in 1980. The data are being incorporated into the present *History of IRRI crosses (1-40,000)* computer program to make it an international rice genetic ancestry program.

Control and management of rice pests

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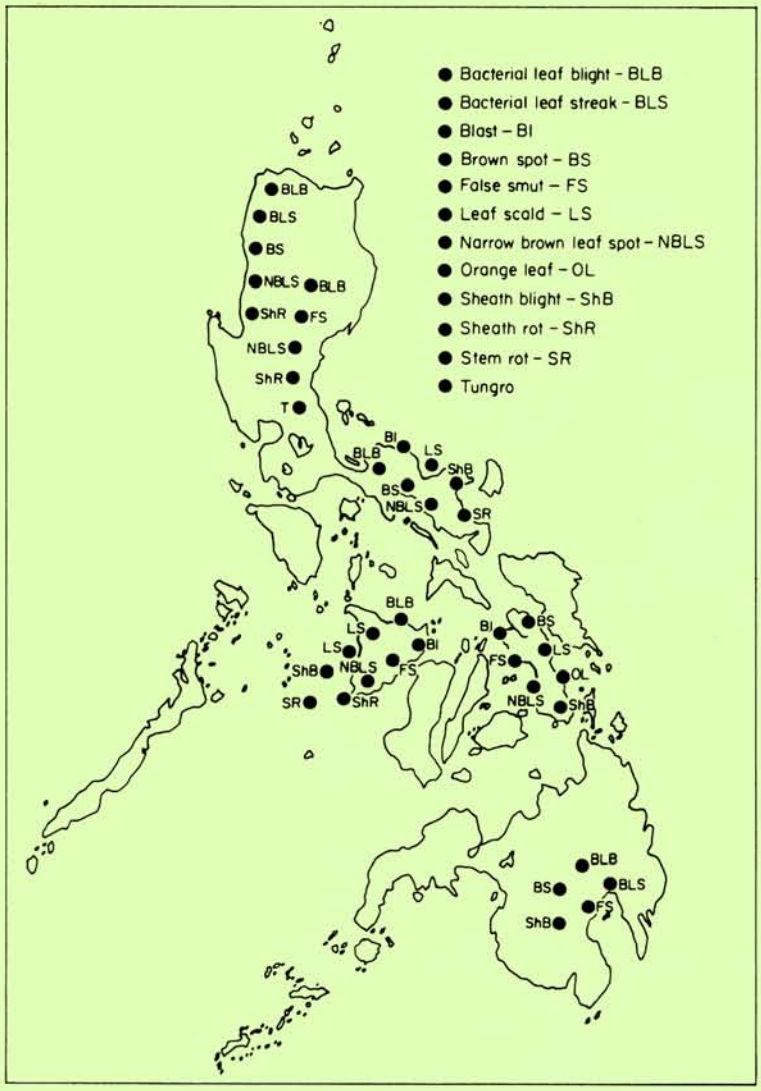
MONITORING RICE DISEASES

Monitoring of rice diseases was initiated in the Philippines this year to determine the occurrence of diseases. In a November-December survey, 12 diseases were found in Northern Luzon, Central Luzon, Southern Luzon, Leyte, Iloilo, and Davao. Bacterial blight, bacterial leaf streak, blast, brown spot, false smut, leaf scald, narrow brown leaf spot, orange leaf, sheath blight, sheath rot, stem rot, and tungro found in the surveyed rice fields caused disease in 15 varieties — C4, C12, IR36, IR42, IR44, IR48, IR50, IR52, IR54, IR747, IR1561, B3, Apollo, Los Baños-Macapuno, and Malagkit. Bacterial leaf blight, narrow brown leaf spot, and sheath blight were the most prevalent (Fig. 1).

Periodic monitoring will accumulate data to evaluate disease importance, distribution, and situation on different cultivars.

Tungro. In 1981, IRRI and the Philippine Bureau of Plant Industry (BPI) initiated the collaborative tungro monitoring project to share the knowledge and technology with local plant protection workers. It eventually will cover the entire country, to help prevent tungro outbreaks.

Eight Regional Crop Protection officers were



1. Occurrence of rice diseases in the Philippines (Nov-Dec 1981).

trained in aspects of tungro monitoring, so that they could implement the project in eight regions.

The monitoring covered 23 municipalities. Fields were planted to 9 known rice varieties and an unknown variety. Most of the fields were planted to IR36 and IR42 (Table 1). At the time of data collection, most plants were in seedbed or at early growth stage.

Insect populations were determined by 10-sweep strokes with a 42-cm-diameter insect net in each field. An average of 5.7 and a high of 30 insects/10 sweeps, were collected.

Of the 696 tungro vectors collected, 52% were *Nephotettix virescens,* 30% *N. nigropictus,* and 18% *Recilia dorsalis* (25% were nymphs and 75% adults).

Few infective insects were found. Only 5 adult *N. virescens* of the 696 insects tested were infective. No infective insects were found in Babatngon, Leyte, where 30% tungro incidence was observed, nor in Pagsanjan, Laguna, with 40% incidence. Of 38 insects collected from Abuyog, Leyte, which had

Table 1. Tungro incidence and vector insects in the 1981 tungro monitoring project in the Philippines.

Province-region	Municipality	Fields (no.)	Variety	Growth stage[a]	Tungro incidence (%)	Insects (no./10 sweeps)	Infective/ tested
Pangasinan – 1	Asingan	1	IR50	S	0	5	0/20
	San Manuel	1	IR36	E	1	11	0/23
	Urdaneta	1	IR36	E	3	0	0/11
N. Ecija – 3	Santa Rosa	1	IR42	R	0	2	0/2
	Santo Domingo	1	IR36	S	1	4	0/17
	Zaragosa	1	IR2307	S	1	12	0/20
		2	IR2307	R	5	0	–
Laguna – 4	Calamba	1	IR42	M	5	–	–
	Pagsanjan	1	IR54	R	40	0	–
	Siniloan	1	Unknown	E	1	6	0/17
	Santa Maria	1	IR29	L	10	6	3/17
		2	IR48	L	30	2	0/7
Camarines Sur – 5	Baao	1	IR42	S	0	0	–
	Bula	1	IR42	E	0	0	0/39
	Ocampo	1	IR36	L	0	7	0/40
	San Jose	1	IR42	L	0.5	2	0/39
Iloilo – 6	Pototan	1	IR54	L	0	4	0/38
		2	IR36	E	0	11	0/28
		3	IR36	L	0	6	0/29
		4	IR36	L	0	9	0/27
Leyte – 8	Abuyog	1	IR42	B	35	10	2/38
		2	IR36	E	0	2	0/2
		3	IR50	E	0	2	0/2
	Babatngon	1	IR54	L	0	0	–
		2	IR54	B	30	0	–
	Carigara	1	IR42	L	0	6	0/11
		2	IR42	L	0	10	0/15
	Tacloban	1	IR42	S	3	14	0/29
	Tanauan	1	IR52	E	0	2	0/2
Bukidnon – 10	Malaybalay	1	IR36	S	0	7	0/39
		2	IR36	S	0	30	0/38
	Valencia	1	IR36	S	0	6	0/4
		2	IR36	S	0	6	0/19
Cotabato –12	Don M. Marcos	1	IR36	E	0	8	0/27
		2	IR36	S	0	3	0/32
		3	IR54	L	0	3	0/34
		4	IR20	L	0	10	0/30

[a] S = seedbed, E = early tillering, L = late tillering, B = booting, M = maturing, R = ratoon.

35% tungro incidence, only 2 (5%) were infective. In Santa Maria, Laguna, which had 10% tungro incidence, only 3 (18%) infective insects were found.

Pagsanjan, Laguna, had the highest estimated tungro incidence (40%). One field in Santa Maria and two in Leyte (Abuyog and Babatngon) had an estimated 30-35% tungro incidence. Tungro incidence was 0-35% on IR42 and 0-40% on IR54. IR36 had only 0-1% tungro incidence.

The monitoring showed a net negative prediction of tungro outbreak in the areas monitored in 1981.

Light trapping at IRRI. Weekly light trapping of virus vectors continued at the IRRI farm. Infectivity of a portion of the trapped vectors was tested by serial transmission method.

The number of vectors collected and percentage of infective insects declined in January and February (Table 2). Overall incidence of tungro was low, of grassy stunt trace, and of ragged stunt moderate. The ratio for tungro vectors *N. virescens, N. nigropictus,* and *Recilia dorsalis* was 41:20:39.

CHEMICAL CONTROL

Blast. *Seed treatment.* Evaluation of systemic fungicides continued. Two chemicals, CGA49104 (50% WP) and PP389JF5816 (50% WP), are outstanding for leaf blast control. As seed dressing, PP389JF5816 dry powder or slurry preparation at 20 g/kg seed and 40 g/kg seed and CGA49104 at 8 g/kg seed effectively controlled leaf blast to 8 weeks after seeding (Table 3, 4). Systemic chemicals, tricyclazole (75% WP) at 5.3 g/kg seed and thiophanate-methyl (70% WP) at 20 g/kg seed and 40 g/kg seed, were moderately effective. In general, PP389JF5816 and thiophanate-methyl were more effective at higher rates than at lower.

Seed soaking. CGA49104 and PP389JF5816 were tested at 1.0, 2.0, and 4.0 g formulation/liter suspension for 24-hour seed soaking. CGA49104 effectively controlled leaf blast to 8 weeks after seeding on seedlings grown in either dapog or blast nursery beds (Table 5). PP389JF5816 exhibited only moderate control. Efficacy of both compounds increased with rate of application.

However, CGA49104 showed only moderate control on dapog-raised seedlings grown from seeds soaked for 24 hours and transplanted at 12-14 days after seeding into plastic trays containing soil (Table 6). That result indicates that CGA49104 is less effective on transplanted seedlings than on seedlings that remain crowded and undisturbed in the dapog beds.

Seedling root dipping. Suspensions of CGA49104 and PP389JF5816 at 1.0, 2.0, and 4.0 g formulation/liter were evaluated as seedling root dips for 1, 3, 6, 12, and 24 hours. CGA49104 effectively controlled leaf blast to 8 weeks after seeding on seedlings transplanted immediately after treatment at all 3 chemical concentrations and dipping durations

Table 2. Infective vectors of 3 rice virus diseases collected by light trap at IRRI farm, 1980-81.[a]

Month	Insects (av no./collection)		Infective insects (%)		
	Tungro vectors[b]	Grassy stunt and ragged stunt vector	Tungro	Grassy stunt	Ragged stunt
November 1980	99	93	2.2	0.5	8.3
December	12	17	0.0	0.0	9.7
January 1981	1	1	0.0	0.0	0.0
February	20	5	0.0	0.0	0.0
March	50	49	0.5	0.5	3.4
April	184	339	0.9	0.0	3.2
May	22,872	33,107	0.7	0.0	3.9
June	490	6,564	0.8	0.0	6.4
July	891	911	0.9	0.0	3.5
August	221	389	0.9	0.7	4.2
September	4,296	8,936	0.9	0.4	3.7
October	6,547	44,381	1.1	0.0	3.7

[a]From 1700 hours to 2 hours after sunset. [b]Av total number of *Nephotettix virescens, N. nigropictus,* and *Recilia dorsalis.*

Table 3. Effect of treating seeds with systemic fungicides (slurry and dry powder methods) on seedling leaf blast control.[a] IRRI blast nursery. IRRI, 1981.

Chemical	Application method	Rate (g formulation/ kg seed)	Blast lesions[b] (no./seedling)					Blast control[c] (%)
			4 WS	5 WS	6 WS	7 WS	8 WS	
PP389JF5816 (50% WP)	Slurry	40.0	0.1	0.2	0.3	0.3	0.3	99.6
	Dry powder	40.0	0.3	0.3	0.5	0.6	0.7	99.0
	Slurry	20.0	0.9	1.2	1.7	2.2	2.2	97.0
	Dry powder	20.0	1.2	1.6	2.7	3.0	3.1	95.8
Thiophanate methyl (70% WP)	Slurry	40.0	9.4	10.5	23.8	26.5	28.3	61.4
	Dry powder	40.0	12.6	28.1	32.4	35.6	38.4	47.7
	Slurry	20.0	15.6	35.1	38.9	41.5	44.3	39.6
	Dry powder	20.0	18.6	37.7	42.6	44.6	48.8	33.5
No chemical		0.0	22.0	54.9	61.2	66.9	73.4	–

[a]Treated and untreated IR442-2-58 seeds were sown in a 5-row plot/treatment per replication in the blast nursery; the seedlings were continuously exposed to *Pyricularia oryzae* for infection. [b]Mean of 3 replications; 25 seedlings were picked at random from the 5 rows of seedlings, marked, and used for disease readings. WS = weeks after seeding. [c]Based on infection 8 WS.

Table 4. Effect of treating seeds with systemic fungicides on leaf blast control in the blast nursery. IRRI, 1981.

Chemical	Rate (g or ml formulation/ kg seed)	Lesions[a] (no./seedling)			Leaf blast control[b] (%)	Phyto-toxicity[c]
		4 WS	6 WS	8 WS		
CGA49104 (50% WP)	8.0	2.2	3.1	4.2	95.4	–
Tricyclazole (75% WP)	5.3	21.3	27.8	31.6	65.1	–
Isoprothiolane (40% E.C.)	10.0	30.1	41.9	44.9	50.4	+
LS 65-255 (50% WP)	8.0	45.8	52.6	54.7	39.6	–
EL-228 (70% WP)	5.7	36.8	56.6	61.5	32.1	+
EL-222 (50% WP)	8.0	43.5	56.7	62.6	30.9	+
No chemical	0.0	71.3	81.9	90.6	–	

[a]Mean of 3 replications; 25 seedlings were picked at random from 10 rows of seedlings/replication, marked, and used for disease readings. WS = weeks after seeding. [b]Based on infection 8 WS. [c]– = none; + = with reduction in seed germination and stunting of seedlings.

Table 5. Leaf blast control with systemic fungicide suspensions as presprouting treatment in blast nursery beds.[a] IRRI, 1981.

Chemical	Concn (g formulation/liter suspension)	Blast lesions[b] (no./seedling)						Blast control[c] (%)
		3 WS	4 WS	5 WS	6 WS	7 WS	8 WS	
CGA49104 (50% WP)	4.0	0.0	1.7	12.6	21.1	22.5	25.0	83.9
CGA49104 (50% WP)	2.0	0.2	13.4	38.5	44.8	46.4	49.0	68.4
CGA49104 (50% WP)	1.0	0.9	26.7	64.2	72.0	73.0	76.0	51.0
PP389JF5816 (50% WP)	4.0	8.2	72.1	94.9	103.4	105.5	107.9	30.4
PP389JF5816 (50% WP)	2.0	11.8	81.3	106.6	111.7	112.8	114.3	26.3
PP389JF5816 (50% WP)	1.0	12.4	81.6	111.9	120.1	120.9	122.3	21.1
No chemical	0.0	26.8	114.0	144.2	152.0	152.8	155.0	–

[a]150 g IR442-2-58 seeds/treatment were soaked for 24 hours in a fungicide suspension; untreated seeds (no chemical) were likewise soaked for 24 hours in water; the seeds were presprouted, then seeded in rows (5 g seeds/row) with 10 rows/treatment per replication in the blast nursery beds. [b]Mean of 3 replications; 25 seedlings were picked at random from 5 rows/replication, marked, and used for disease readings. WS = weeks after seeding. [c]Based on infection 8 WS.

Table 6. Leaf blast control with CGA49104 (50% WP) systemic fungicide suspensions as presprouting treatment on dapog-raised seedlings.[a] IRRI, 1981.

Concn (g formulation/ liter suspension)	Blast lesions[b] (no./seedling)							Blast control[c] (%)
	13 DS	19 DS	26 DS	33 DS	40 DS	47 DS	54 DS	
4.0	0.0	0.0	12.0	41.1	81.4	92.2	104.6	46.1
2.0	0.0	0.0	16.5	56.7	114.7	126.7	135.0	30.4
1.0	0.0	0.5	18.5	66.7	121.1	140.5	147.0	24.2
0.0	1.7	15.1	38.7	78.7	142.1	174.8	194.0	–

[a]150 g IR442-2-58 seeds/treatment were soaked for 24 h in a fungicide suspension; untreated seeds were similarly soaked for 24 h in water; the seeds were presprouted, then seeded in a 40- x 20-cm dapog bed (150 g seeds/bed); 6 days after seeding (DS), the seedlings were exposed continuously to *Pyricularia oryzae* in the blast nursery for infection. [b]Mean of 3 replications; each replication with 25 seedlings picked at random from 100 seedlings (previously taken from the exposed dapog bed seedlings) transplanted (at 12 DS) in 5 rows/plastic tray containing soil and continuously exposed to blast inoculum in the blast nursery for infection. [c]Based on infection 54 DS.

Table 7. Leaf blast control with systemic fungicide suspension as seedling root dips for 1, 3, 6, 12, and 24 hours on 10-day-old dapog-raised seedlings, 8 weeks after seeding.[a] IRRI, 1981.

Chemical	Concn (g formulation/ liter suspension)	Lesions[b] (no./seedling)				
		1 h	3 h	6 h	12 h	24 h
CGA49104 (50% WP)	4.0	2.5	2.2	1.3	0.0	0.0
CGA49104 (50% WP)	2.0	12.2	9.1	6.1	2.7	0.2
CGA49104 (50% WP)	1.0	33.4	21.0	18.4	9.2	0.2
PP389JF5816 (50% WP)	4.0	68.9	65.6	64.5	18.3	8.1
PP389JF5816 (50% WP)	2.0	73.9	68.1	66.8	22.7	19.5
PP389JF5816 (50% WP)	1.0	77.7	73.3	70.9	29.4	26.2
No chemical	0.0	89.8	89.8	89.8	89.8	89.8

[a]After the dipping treatment, 100 seedlings were picked at random from each dapog bed and transplanted in 5 rows (20 seedlings/row) in plastic trays containing soil, then exposed continuously to blast inoculum in a blast nursery. [b]Mean of 3 replications; 25 seedlings (5 seedlings/row) per replication were picked at random, marked, and used for disease reading.

(Table 7). PP389JF5816 showed effective control with 12- and 24-hour root dips. In general, control was more effective as duration of dipping treatment lengthened and as chemical concentration increased.

Sheath blight. *Foliar sprays.* In a greenhouse evaluation of fungicides to control sheath blight, Serinal (50% WP) and NTN19701 (25% WP) were applied as foliar sprays three times at weekly intervals. Both chemicals effectively reduced sheath blight severity on IR1317-392-1-8 test seedlings (Table 8). PP296JF7168 (12.5% wt/vol) at 1.0 kg/liter also reduced disease severity, but it suppressed the height of test plants.

Triphenyltin acetate (60% WP) used as foliar spray controlled sheath blight on IR50 more effectively than thiophanate-methyl (Table 9).

Bakanae. *Artificial infestation of seeds.* Evaluation of fungicides as seed-soaking treatments necessitates the availability of infested seeds. IR42 was inoculated artificially at flowering in the field with a spore suspension of *Fusarium moniliforme.* The percentage of infested seeds was 3-10 times (average, 7 times) more than that from uninoculated plants (Table 10).

Natural infestation of seed. IR42 seeds from apparently bakanae-free and bakanae-infected fields were grown in dapog beds. Seedlings grown from seeds obtained from bakanae-infected fields showed about 17% infection; those grown from seeds from apparently bakanae-free fields showed less than 1% infection (Table 11). Seeds of other varieties, including IR36 and IR40, obtained from both apparently bakanae-free and bakanae-infected

Table 8. Sheath blight control with fungicide sprays on IR1317-392-1-2 seedlings artificially inoculated 1 day after the first spray application.[a] IRRI, 1981.

Chemical	Rate (kg or liter formulation/ 2,000 liters suspension per application)	Infection[b] (%)				Mean infection (%)	Sheath blight control[c] (%)
		4 WS	5 WS	6 WS	7 WS		
NTN19701 (25% WP)	1.0 kg	3.6	4.6	2.7	1.1	3.0	,94.6
PP296JF7168 (12.5% w/v.)	1.0 liter	16.4	28.6	22.7	18.9	21.7[d]	61.0
Serinal (50% WP)	1.0 kg	24.4	23.0	19.3	22.4	22.3	60.0
M6953 (50% WP)	1.0 kg	39.3	32.5	28.3	25.3	31.4	43.6
Galben (25% WP)	1.0 kg	35.8	37.7	34.7	30.7	34.7	37.7
H719 (8% E.C.)	1.0 liter	43.9	41.8	40.0	38.5	41.1	26.2
No chemical	0.0	51.3	55.4	61.2	54.8	55.7	–

[a]The first spray was applied 3 weeks after seeding, 2 subsequent applications were made at weekly intervals on seedlings grown in plastic trays. [b]Mean of 3 replications; each replication with 5 rows of test seedlings; based on the average infection of leaf sheaths and leaf blades of 25 seedlings picked at random at every disease reading schedule. WS = weeks after seeding. [c]Based on the average infection from the 4 disease readings. [d]Seedlings sprayed with the fungicide were shorter (stunted) than the normal growing seedlings from the other treatments.

Table 9. Sheath blight control with fungicide sprays on IR50 seedlings artificially inoculated 1 day after the first spray application.[a] IRRI, 1981.

Chemical	Rate (kg formulation/ 2,000 liters suspension per application)	Infection[b] (%)				Mean infection (%)	Sheath blight control[c] (%)
		6 WS	7 WS	8 WS	9 WS		
Triphenyltin acetate (60% WP)	1.0	0.3	1.5	2.6	1.4	1.5	96.6
	0.75	3.1	3.9	3.4	4.0	3.6	91.9
	0.50	4.2	6.0	5.8	5.0	5.3	88.0
Thiophanate methyl (70% WP)	1.00	9.8	11.3	9.3	7.4	9.5	78.6
Copper oxychloride (35% Cu)	3.00	27.3	32.6	32.7	31.2	31.0	30.0
	1.50	35.0	33.6	36.1	35.1	35.0	21.0
No chemical	0.00	35.0	45.0	49.0	48.2	44.3	–

[a]The first spray was applied 5 weeks after seeding, 2 subsequent applications were made at weekly intervals. [b]Mean of 4 replications; each replication with 5 rows of IR50 test seedlings; based on the mean of infections on leaf sheaths and leaf blades of 25 seedlings picked at random at every disease reading schedule; seedlings were grown in plastic trays. WS = weeks after seeding. [c]Based on the mean infection (%) of the 4 disease readings.

fields, appeared to be slightly infested (0.3-2.0% infection of seedlings).

Soaking naturally infested seeds in fungicide. The 24-hour seed-soaking treatment was used to evaluate the effectiveness of benomyl (50% WP) and thiophanate-methyl for bakanae control. Benomyl at 0.5, 1.0, and 1.5 g/liter, and thiophanate-methyl at 1.0, 2,0, and 3.0 g/liter effectively controlled bakanae on IR42 seedlings grown in the dapog beds and transplanted in the field (Table 12). Treated seeds had less than 1% infection and untreated seed about 13%.

HOST NUTRITION AND DISEASE DEVELOPMENT

Nutrition directly affects plant growth and indirectly disease development.

Nitrogen. *Blast* lesions increased as rates of nitrogen from two sources increased (Table 13). Lesion numbers were higher in the nitrate nitrogen treatment than in the ammonium nitrogen treatment.

Sheath blight incidence was significantly affected by nitrogen rate. Increasing nitrogen from 20 to 120 ppm increased the incidence of infected tillers

Table 10. Effect of inoculating 3 times with *Fusarium moniliforme* at flowering stage of IR42 plants grown from fungicide-treated and untreated seeds on infestation of seeds harvested from the uninoculated and inoculated plants. IRRI, 1981.

Seed source	Concn (g formulation/liter suspension)	Infested seeds[a] (%)	
		Unino-culated	Ino-culated
Plants grown from seeds treated with thiophanate-methyl-thiram (80% WP)	2.0	1.0	3.0
	1.0	1.5	4.0
Plants grown from seeds treated with thiophanate-methyl (70% WP)	2.0	1.0	4.0
	1.0	0.5	7.0
Plants grown from seeds treated with benomyl (50% WP)	2.0	1.5	6.0
	1.0	0.5	5.0
	0.5	0.0	10.5
Plants grown from seeds not treated with any fungicide	0.0	0.5	7.5
Mean		0.8	5.9

[a]Mean of 2 replications; each replication with 100 seeds surface-disinfested for about 30 seconds in 25% calcium hypochlorite then plated in Komada's selective medium for species of *Fusarium*.

Table 11. Dapog bed bakanae infection on seedlings grown from seeds of varieties and lines harvested from fields naturally infected and fields apparently free from infected plants. IRRI, 1981.

Variety or line	Seed source[a]	Infected seedlings[b] (no./200 cm² dapog bed)		Infection[e] (%)
		8 DS[c]	10 DS[d]	
IR36	AHP	0.0	4.3	0.7
IR36	NIP	0.5	2.8	0.3
IR442-2-58	AHP	2.8	5.8	0.6
IR40	AHP	0.5	11.0	1.3
IR40	NIP	2.5	9.5	1.9
IR9846-215-3	AHP	5.3	15.5	2.2
IR42	AHP	1.3	6.5	0.8
IR42	NIP[f]	81.5	185.5	17.2

[a]AHP = seeds harvested from fields apparently free (healthy) from bakanae infected plants; NIP = seeds harvested from fields with naturally-infected plants. [b]Mean of 4 replications; each replication with 25 g seeds seeded in a 20 x 10 cm dapog bed. DS = days after seeding. [c]With abnormal elongation symptoms only. [d]With abnormal elongation and foot rot symptoms. [e]10 DS. [f]At flower opening time, bakanae-infected and noninfected plants were artificially inoculated 3 times with spore suspension of the bakanae fungus.

from 28% to 77% (Table 14). Disease incidence with ammonium and nitrate nitrogen sources was not significantly different.

Brown spot lesions increased with nitrogen rate, regardless of nitrogen source (Table 15). Lesion numbers in the nitrate nitrogen treatment appeared to be slightly higher than those in the ammonium nitrogen treatment.

Bacterial blight lesion length slightly increased as rate of nitrogen increased in the ammonium-nitrogen treatment (Table 16). Plants grown in nitrate nitrogen usually had longer lesions than those grown in ammonium nitrogen.

Potassium. *Blast* and *brown spot* lesions increased as potassium rates were increased from 10 to 60 ppm, but tended to decrease at 100 ppm (Table 17).

Sheath blight incidence was highest at 10 ppm potassium but gradually decreased with 20- to 100-ppm applications.

Bacterial blight lesions in infected plants slightly increased with increased potassium.

Table 12. Effect of 24-hour soaking of naturally infested IR42 seeds in systemic fungicide suspensions on bakanae control. IRRI, 1981.

Chemical	Concn (g formulation/liter suspension)	Infected seedlings[a] (no./200 cm² dapog bed)			Bakanae control[e] (%)
		8 DS[b]	14 DS[c]	(%[d])	
Benomyl (50% WP)	1.5	0.0	1.3	0.1	99.2
Benomyl (50% WP)	1.0	0.0	2.8	0.3	97.6
Benomyl (50% WP)	0.5	0.0	4.8	0.5	96.1
Thiophanate methyl (70% WP)	3.0	0.0	3.3	0.3	97.6
Thiophanate methyl (70% WP)	2.0	0.0	4.5	0.5	96.1
Thiophanate methyl (70% WP)	1.0	0.0	8.0	0.8	93.7
No chemical	0.0	43.5	135.5	12.7	–

[a]Mean of 4 replications; each replication with 30 g seeds seeded in a 20- x 10-cm dapog bed. DS = days after seeding. [b]With abnormal elongation symptoms only. [c]With abnormal elongation and foot rot symptoms. [d]Based on infection 14 DS. [e]Based on percentage of infection 14 DS.

Table 13. Effect of nitrogen source and rate on blast lesion number on Tetep. IRRI, 1981.

N source ratio (NH_4:NO_3)	N rate (ppm)	Av lesion number
80:20	20	17.7
	60	27.6
	120	27.2
20:80	20	48.8
	60	52.7
	120	77.8

Table 16. Effect of nitrogen source and rate on length of bacterial leaf blight lesions. IRRI, 1981.

N source ratio (NH_4:NO_3)	N rate (ppm)	Av lesion length (cm)
80:20	20	4.6
	60	4.8
	120	5.2
20:80	20	7.6
	60	6.6
	120	6.9

Table 14. Effect of nitrogen source and rate on average sheath blight incidence on 2 cultivars. IRRI, 1981.[a]

N source ratio (NH_4:NO_3)	Av sheath blight incidence (%)			Mean
	20 ppm N	60 ppm N	120 ppm N	
80:20	39.7	72.3	76.6	62.9
20:80	16.2	68.9	76.7	54.1
Mean	27.9	70.6	76.7	

[a]LSD_{05} source = NSD, LSD_{05} rate = 14.2, LSD_{05} RxS = 20.1.

Table 15. Effect of nitrogen source and rate on number of brown spot lesions. IRRI, 1981.

N source ratio (NH_4:NO_3)	N rate (ppm)	Av lesion number
80:20	20	3.7
	60	4.3
	120	7.0
20:80	20	3.9
	60	10.0
	120	10.2

Nitrogen-silicon. In the absence of silicon, nitrogen source greatly affected blast development (Table 18). The number of lesions was slightly higher with nitrate-nitrogen than with ammonium nitrogen and greatly increased with an increase in rates from 20 to 60 ppm, particularly with 80% nitrate-nitrogen. The number of lesions did not increase when both ammonium-nitrogen and nitrate-nitrogen were increased from 60 to 120 ppm.

In general, in treatments without silicon the number of brown spot lesions increased as nitrogen rate increased (Table 19). With silicon, lesion numbers did not increase as nitrogen rate increased. In the absence of silicon, nitrate-nitrogen appeared to favor disease development more than ammonium nitrogen. Sheath blight disease incidence was not affected by silicon (Table 20). It was significantly increased by nitrogen at rates from 20 to 60 ppm, regardless of source (Table 21). However,

Table 17. Effect of potassium on 4 diseases of rice. IRRI, 1981.

Potassium rate (ppm)	Blast lesion (no./plant)	Sheath blight (%)	Brown spot lesions (no./plant)	Bacterial blight lesion length (cm)
10	8.0	40.0	26.8	13.3
20	16.2	34.8	36.2	14.5
60	75.0	33.3	36.6	15.4
100	38.0	26.2	30.2	16.7

Table 18. Influence of nitrogen source and rate and silicon rate on blast lesion. IRRI, 1981.

Nitrogen rate (ppm)	Blast lesions (no./plant)						Nitrogen rate mean
	0 ppm Si		10 ppm Si		20 ppm Si		
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	
20	3.1	2.6	5.6	3.4	3.8	1.5	3.3
60	3.6	23.8	11.3	20.6	11.3	14.7	14.2
120	5.5	13.9	14.7	12.9	11.2	13.0	11.7
Silicon mean	4.1	13.4	10.5	12.3	8.7	9.7	

Table 19. Influence of nitrogen source and rate and silicon rate on brown spot lesion per plant. IRRI, 1981.

Nitrogen rate (ppm)	Lesions (no./plant)						Nitrogen rate mean
	0 ppm Si		10 ppm Si		20 ppm Si		
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	
0	3.7	3.9	1.9	2.1	1.9	0.6	2.35
60	4.3	10.0	4.5	5.6	4.5	8.5	6.23
120	7.0	10.8	4.1	6.0	3.5	4.4	5.96
Silicon rate mean	5.0	8.2	3.5	4.6	3.3	4.5	

Table 20. Effect of nitrogen source and silicon rate[a] on percentage of sheath blight-infected tillers. IRRI, 1981.

N source ratio (NH_4:NO_3)	Sheath blight-infected tillers (%)			Mean
	0 ppm Si	10 ppm Si	20 ppm Si	
80:20	69.7	60.1	59.0	62.9
20:80	52.8	51.5	57.9	54.1

[a]Silicon rates – NSD, LSD_{05} Source x Si = 13.4; pooled data of 2 cultivars.

Table 21. Effect of nitrogen source and rate[a] on percentage of sheath blight infected tillers. IRRI, 1981.

N source ratio (NH_4:NO_3)	Sheath blight-infected tillers (%)			Mean
	20 ppm N	60 ppm N	120 ppm N	
80:20	39.7	72.3	76.6	62.9
20:80	16.6	68.9	76.7	54.1
Mean	28.2	70.6	76.7	

[a]LSD_{05} source = NSD, LSD_{05} rate = 14.2, LSD_{05} RxS = 20.1; pooled data of 2 cultivars.

increasing nitrogen rates to 120 ppm did not further aggravate its severity. Sheath blight was more severe at 20 ppm nitrogen with ammonium nitrate-nitrogen. In general, disease incidence was higher with ammonium-nitrogen than with nitrate-nitrogen.

Silicon markedly increased bacterial blight lesion length, especially with 80% nitrate-nitrogen (Table 22). Nitrogen source and rate also increased lesion lengths. Nitrate-nitrogen favored lesion elongation more than ammonium-nitrogen. Increasing nitrogen from 20 to 60 ppm increased disease severity.

Table 22. Effect of nitrogen source, rate and silicon rate on length (cm) of bacterial blight (BB) lesion. IRRI, 1981.

Nitrogen rate (ppm)	BB lesion length (cm)						Nitrogen rate mean
	0 ppm Si		10 ppm Si		20 ppm Si		
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	
20	8.9	12.9	11.8	13.4	13.2	13.9	12.3
60	11.9	14.8	13.5	15.2	14.8	15.1	13.7
120	12.0	14.2	13.9	14.6	15.0	15.8	14.2
Silicon mean	10.9	13.9	13.1	14.1	14.3	14.9	

Table 23. Effect of nitrogen source and rate, and silicon rate on tiller percentage with kresek symptoms.[a] IRRI, 1981.

Nitrogen rate (ppm)	Tillers with kresek (%)						Nitrogen rate mean
	0 ppm Si		10 ppm Si		20 ppm Si		
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	
20	39	42	40	59	52	62	49.0
60	68	48	65	69	57	70	62.8
120	85	76	74	75	70	100	80.0
Silicon mean	64	55.3	59.66	67.6	59.66	77.33	

[a]First column = 80% NH_4: 20% NO_3-N under each silicon rate; second column = 20% NH_4-N: 80% NO_3-N under each silicon rate.

Nitrogen at 120 ppm did not increase disease severity.

Kresek incidence did not differ among nitrogen sources and silicon rates (Table 23). Many plants developed kresek symptoms after inoculation and the percentage of tillers with kresek increased with nitrogen rate.

CLIMATE AND DEVELOPMENT OF *HELMINTHOSPORIUM ORYZAE*

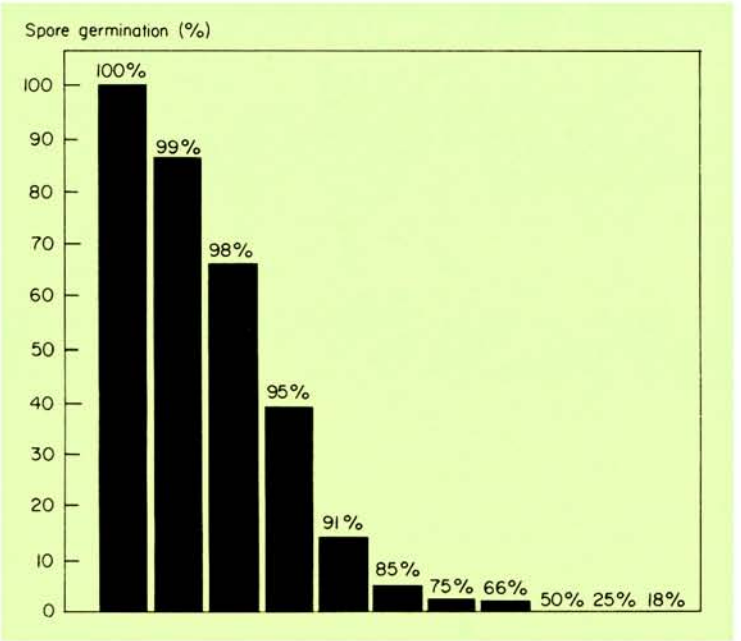
Relative humidity and conidial germination. Conidia started germinating 2 hours after incubation at 25° C and 86-100% relative humidity. Spore germination increased as relative humidity increased. No conidia germinated below 66% relative humidity (Fig. 2).

Leaf wetness and infection. Different dew periods at 25° C were used to determine the period of leaf wetness that favors fungus infection on rice. No lesion development was observed on inoculated seedlings with less than 8 hours of leaf wetness. Brown spot lesions increased as the period of leaf wetness increased from 8 to 20 hours (Fig. 3), then decreased up to 24 hours.

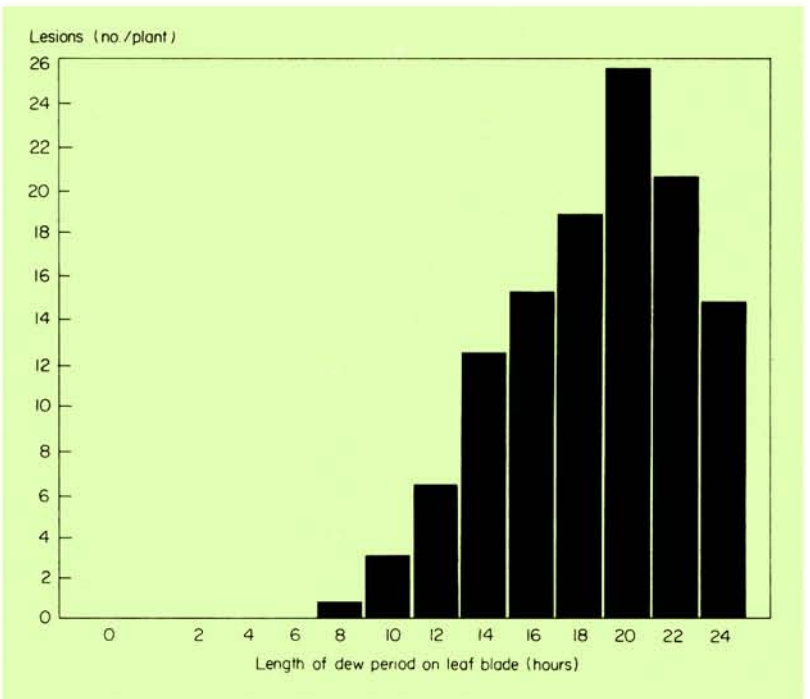
Constant temperature and infection. Three temperatures and 100% relative humidity were used to determine the temperature favoring lesion formation. At 15° C, the number of lesions was lowest, 3.3/plant. At 25° C, it was highest, 14.5/plant (Table 24). Three weeks after inoculation, lesions had increased from 3.3 to 5.2/plant at 15° C, from 3.6 to 5.3/plant at 20° C, and from 14.5 to 39.7/plant at 25° C.

ECOLOGY OF SHEATH BLIGHT PATHOGEN

Saprophytic survival. Rice straw pieces artificially infected with sheath blight pathogen were buried in sterilized and unsterilized soil (wetland origin) under submerged and dryland conditions. Recovery of the sheath blight fungus (*Thanatephorus cucumeris*) was lower in unsterilized than in sterilized soil, regardless of soil moisture conditions (Table 25). The number of sclerotial bodies increased up to 12 weeks, indicating that the fungus was still capable of producing dormant propagule with substrate decomposition (Table 26).



2. Effect of different relative humidities (numbers on bars) on spore germination of *Helminthosporium oryzae* Breda de Haan at constant temperature of 25° C. IRRI, 1981.



3. Effect of period of leaf wetness on brown spot development.

Table 24. Effect at 7 and 21 days after inoculation of constant temperatures on the increase of brown spot lesion on IR8 at 100% relative humidity. IRRI, 1981.

Temp (°C)	Brown spot lesions[a] (no./plant)	
	7 days	21 days
15	3.3	5.2
20	3.6	5.3
25	14.5	39.7

[a]Each figure is an average of 50 plants.

Table 25. Saprophytic survival[a] of *Thanatephorus cucumeris* in artificially infected rice straws[b] buried in soil of wetland origin. IRRI, 1981.

Incubation period (wk)	*Thanatephorus cucumeris* recovered (%)			
	Sterilized soil		Unsterilized soil	
	Submerged	Dryland	Submerged	Dryland
2	100.0	100.0	48.3	51.7
4	85.0	86.7	26.7	33.3
6	75.0	81.7	8.3	25.8
8	61.7	72.5	6.7	25.0
10	27.5	30.0	0.0	7.5
12	24.2	25.8	0.0	0.0

[a]Determined by plating on 2% water agar. [b]Mean of 4 replications, 30 rice straw pieces/replicate.

Table 26. Sclerotial bodies produced by *Thanatephorus cucumeris*, in infected rice straws buried in soil of wetland origin. IRRI, 1981.

Incubation period (wk)	Sclerotial bodies[a] (no.)			
	Sterilized soil		Unsterilized soil	
	Submerged	Dryland	Submerged	Dryland
2	9.0	10.5	7.3	7.5
4	9.3	31.5	8.3	15.0
6	40.0	56.5	10.0	20.5
8	40.0	75.0	10.0	26.3
10	40.0	81.3	10.0	26.3
12	41.8	82.5	10.8	26.8

[a]Mean of 4 replications. Counted from 300 g soil, based on oven-dry weight.

Competitive saprophytic ability of sclerotial bodies. The ability of *T. cucumeris* to colonize crop stubble in the presence of other soil microorganisms was studied. Competitive saprophytic colonization by sclerotial bodies of the pathogen was higher in soil of dryland origin under dryland condition than in wetland soil (Table 27).

Table 27. Competitive colonization[a] of rice straws by *Thanatephorus cucumeris* sclerotial bodies in soil of wetland and dryland origins. IRRI, 1981.

Sclerotial bodies[b] (no.)	Colonization (%)			
	Wetland		Upland	
	Submerged	Dryland	Submerged	Dryland
0	0.0	0.0	0.0	0.0
25	0.7	31.9	0.0	52.1
50	3.5	43.8	0.0	62.5
75	4.53	42.4	6.3	65.3
100	4.77	65.3	10.4	97.2

[a]Determined by plating on 2% water agar 1 month after incubation. [b]Per 300 g of oven-dry unsterilized soil.

Table 28. *Thanatephorus cucumeris* mycelial growth inhibition by saprophytic bacteria isolated from sclerotia collected from irrigated rice field. IRRI, 1981.

Bacterial isolate	Inhibition zone[a] (mm)	Fluorescent pigment production[b]
1n-b-17	12.5	–
1n-b-24	12.0	++++
1n-b-20	10.8	+++
1n-b-19	10.8	–
1n-b-16	8.8	–
1n-b-31	8.5	–
1n-b-26	6.8	–
1n-b-29	6.5	–
1n-b-23	6.5	+++
1n-b-30	6.0	–
1n-b-28	5.5	–
1n-b-25	5.0	–
1n-b-22	4.8	+++
1n-b-21	4.5	–
1n-b-27	4.0	++

[a]Determined by measuring the clearance between the tip of mycelial growth and margin of bacterial colony; mean of 3 replications. [b]Grown in King's B medium and observed under UV light; ++++ = intense; – = none.

Antagonists. Several saprophytic bacteria isolated from sclerotial bodies of *Thanatephorus cucumeris* inhibited the mycelial growth of the pathogen (Table 28). Some isolates showed strong antagonistic effect, producing fluorescent pigment at King's B medium. Potential use of the bacteria as biocontrol agents of sheath blight is being studied in the greenhouse.

XANTHOMONAS CAMPESTRIS P. V. *ORYZAE* TOXIN PRODUCTION

A study of toxin production by *X. campestris* p.v. *oryzae* was conducted in vitro. Bacterial culture

filtrates caused wilting and leaf yellowing in partially root-excised rice seedlings within 24-36 hours, indicating toxin production. Wakimoto's and Dye's modified media appeared to be almost equally as good for toxin production.

Aeration and age of culture affected filtrate toxicity. Filtrate from a 3-day-old aerated culture produced marked wilting symptoms; filtrate from a static culture of the same age did not. Wilting also occurred with the filtrates from 6- and 9-day-old static cultures. More wilt-inducing toxic component in the 3-day-old culture was produced under aerated (shaken) conditions than under static conditions. That corresponds to the multiplication of the bacterium under the two cultural conditions.

Filtrates from the 9-day-old static culture caused more pronounced yellowing of seedlings than filtrates from the aerated culture, indicating that the static (unaerated) condition is more favorable to the production of the toxic component that induces yellowing (Table 29).

The culture filtrates also delayed seed germination and caused partial root browning and growth reduction in young seedlings. Growth of roots and shoots was also affected.

Heating the culture filtrates partially reduced their toxicity to the germinating seeds but did not affect wilting and yellowing in the rice seedlings. The nonheated culture filtrates inhibited growth of young seedlings more than did the heated ones. However, on 2-week-old seedlings, there was no marked difference in wilting and yellowing. Within the 36-hour treatment, nonheated washed bacterial suspension caused slight wilting but heated cell suspension did not. Nonheated culture filtrate and bacterial cell suspension used to treat seeds and newly germinated seedlings also caused root-browning. Heated ones did not. However, heating the culture filtrate slightly minimized its growth-depressing effect.

Dilution of culture filtrates gradually reduced their phytotoxicity, as was shown by milder symptoms on seedlings treated with lower concentrations (Table 30). The ability of culture filtrates to induce wilting and yellowing gradually decreased when the filtrate was dialyzed against distilled water. That indicates that some of the symptom-inducing components were dialyzable and possibly of low molecular weight. The presence of the undialyzable high-molecular-weight components responsible for wilting was also indicated by the incomplete loss of toxicity, even after dialysis.

BACTERIAL STRIPE IDENTIFICATION

Symptoms resembling bacterial stripe were observed on rice seedlings at the IRRI farm. Water-soaked to brown longitudinal stripes appeared on leaf sheaths and leaves. A survey of 11 seedbeds showed a disease incidence of 0.5-7.5% on 14 rice varieties and lines (Table 31). Infection was lowest on IR42 and highest on IR50.

The organism isolated from naturally infected seedlings was pathogenic to rice seedlings. Analysis of symptomatology and morphological, cultural, and physiological characteristics showed that the causal organism was very closely related to *Pseudomonas setareae*, the causal organism of bacterial

Table 29. Effect of aeration and age of *Xanthomonas campestris* pv. *oryzae* cultures on toxicity of its filtrates to rice seedlings. IRRI, 1981.

Condition of culture and age (days)		Toxicity symptom score[a] on seedlings at							
		15 h		18 h		21 h		24 h	
		W	Y	W	Y	W	Y	W	Y
Static	3	1.0	0	1.0	0	1.0	0.0	1.0	0.0
	6	3.7	0	5.7	0	7.0	0.0	7.7	0.0
	9	5.7	0	7.0	0	9.0	2.0	9.0	2.7
Aerated	3	2.3	0	5.0	0	5.7	0.0	7.0	0.0
	6	2.3	0	5.0	0	5.7	0.0	7.0	0.0
	9	7.0	0	7.7	0	9.0	1.0	9.0	1.0
Water		0.0	0	0.0	0	0.0	0.0	0.0	0.0

[a]W = wilting (0-9 scale); Y = yellowing (0-3 scale).

Table 30. Effect of dilution of culture filtrate of *Xanthomonas campestris* pv. *oryzae* on its toxicity on rice seedlings. IRRI, 1981.

Filtrate	Toxicity symptom score on seedlings at					
	15 h		24 h		36 h	
	W	Y	W	Y	W	Y
Undiluted filtrate	3.0	0	5.5	0.5	8.5	2.0
Diluted at filtrate-water ratio of						
3:1	2.0	0	4.0	0.5	7.0	2.0
2:1	1.0	0	3.0	0.5	6.0	1.5
1:1	0.5	0	2.0	0.0	5.0	1.5
1:2	0.5	0	2.0	0.0	4.0	1.5
1:3	0.0	0	1.0	0.0	3.0	1.5
1:4	0.0	0	0.5	0.0	1.0	1.0
Water (check)	0.0	0	0.0	0.0	0.0	0.0

[a]W = wilting (0-9 scale); Y = yellowing (0-4 scale).

Table 31. Bacterial stripe incidence of rice seedlings on wetbeds at IRRI farm. IRRI, 1981.

Variety	Location	Disease incidence (%)	Variety	Location	Disease incidence (%)
IR50	S-631	7.5	IR38	H-10	2.5
	S-729	4.5	IR20	C-13	2.0
	C-13	4.0	IR-lines	UD	2.0
	H-10	3.5		S-100	1.5
Binato	H-10	5.5		S-700	1.5
C1121-4	UA	4.5	DGWG	C-13	1.5
IR1917	A-38	4.0	IR44	H-10	1.5
IR52	S-729	3.5	IR48	C-13	1.5
IR36	A-42	3.0	IR46	C-13	1.5
	H-10	2.5		S-729	1.0
	UA	2.0	IR42	H-10	1.5
				F-1	0.5

stripe of rice in Japan and of millet in Italy (Table 32).

Bacterial stripe occurred on the six varietal seedlings grown from seeds from different sources (Table 33). Disease development on seedlings from seeds grown in sterile soil indicated that the bacteria did not come from the soil. And, infection on seedlings from disinfected seeds sown in sterile soil indicated that the bacterium was not outside the seedcoats, but inside the seeds.

When IR40 and IR52 seeds were dipped for 5 seconds or soaked for 24 and 48 hours in bacterial suspension, bacterial stripe developed in seedlings at 2-leaf stage. Water-soaked lesions appeared on the coleoptile and progressed to the leaf sheath or primary or secondary leaf. Disease incidence increased from 5-second dipping to 24-hour soaking (Table 34). Disease incidence in seedlings soaked 24 hours decreased. Severely infected seedlings eventually died.

Seeds collected from plants inoculated at booting and at flowering produced infected seedlings, indicating that the bacteria remained viable in the seed and infected the seedlings (Table 35).

BROWN PLANTHOPPER ON *LEERSIA HEXANDRA*

The ability of *L. hexandra*-reared insects to transmit ragged stunt virus and grassy stunt virus was tested. The life span and number of insects pro-

Table 32. Differences in characters among 4 pathogenic bacteria causing stripe diseases. IRRI, 1981.

Character	*P. panici-milliacei* (Ikata et Yamauchi) Savulescu	*X. panici* (Elliott) Savulescu	*P. setariae* (Okabe) Savulescu	Studied species
Flagellum	1	1-3	1-2	1-2
Capsule	–	+	–	–
Oxygen relation	±	+	+	+
Gelatin liquefaction	–	+	+	+
NH_3 production	–	+	+	+
H_2S production	–	+	–	–
Indole production	–	–	+	–
Acid from carbohydrates	–	–	+	+
Reduction of litmus milk	–	+	+	+

Table 33. Seedlings of 6 rice varieties showing bacterial stripe infection. IRRI, 1981.

Variety	Seed	Seedling infection (%)				Mean
		Disinfested seeds		Nondisinfested seeds		
		Sterile soil	Non-sterile soil	Sterile soil	Non-sterile soil	
Binato	Agronomy	7.8	8.7	6.4	6.3	7.3
IR40	Plant Pathology	3.7	5.8	5.2	4.0	4.6
IR50	Plant Pathology	4.0	3.9	2.9	4.9	3.9
IR40	Plant Breeding	1.2	2.5	2.0	2.0	1.9
IR46	Agronomy	1.0	1.4	1.0	1.6	1.2
IR42	Multiple Cropping	1.2	1.0	1.4	1.7	1.3
IR46	Multiple Cropping	0.5	0.8	1.7	1.5	1.1
IR44	Agronomy	0.5	0.5	1.2	0.7	0.7
IR42	Agronomy	0.5	0.3	0.5	0.3	0.4
	Mean	2.2	2.7	2.4	2.5	

duced by *L. hexandra*-reared brown planthoppers (BPH) were compared with those of TN1-reared insects.

Average life span of adults and number of progeny from colonies that survived 30 days after oviposition differed markedly (Table 36). Transmission tests showed that the *L. hexandra*-reared insects transmitted the causal agents of grassy stunt and ragged stunt diseases in a persistent manner (Table 37).

TUNGRO VIRUS COMPLEX

Diseased specimens were sent to the Laboratorio di Fitovirologia Applicata del Consiglio Nazionale

Table 34. Effect of different intervals of soaking seeds in bacterial suspension on bacterial stripe disease incidence on IR40 and IR52 seedlings. IRRI, 1981.

Soaking time	Seedling infection[a] (%)	
	Inoculated	Un-inoculated
	IR40	
Instant dipping (5 sec)	15.4	3.7
24 h	27.7	2.9
48 h	12.3	1.2
	IR52	
Instant dipping (5 sec)	18.9	2.4
24 h	52.1	0.6
48 h	16.6	2.3

[a]Each figure is a mean of 3 replications, with 100 seeds/replicate.

Table 35. Bacterial stripe infection in IR50 seedlings grown from seeds from plants inoculated at booting and flowering. IRRI, 1981.

Seed source	Seedling infection (%)	
	Disinfested seeds	Nondisinfested seeds
Plants inoculated at booting stage	1.8	1.6
Plants inoculated at flowering stage	5.6	4.3
Uninoculated plants	0.0	0.0

delle Richerche, Turino, Italy. When the specimens were negatively stained in 2% uranyl acetate (UA), isometric particles 27-28 nm in diameter were revealed. When stained in 1% neutral sodium phosphotungstate (PTA), isometric particles were 30 nm in diameter. The bacilliform particles had diameters of 23 nm in UA and 31-33 nm in PTA, with variable lengths. Apparently undamaged particles with rounded ends were 110-190 nm long in UA (Fig. 4). No modal length was detected.

INTERNATIONAL COLLABORATION

IRRI-Tropical Agriculture Research Center. *Temperature and bacterial blight development.* The effect of five day/night temperatures (20°/16° C, 25°/20° C, 29°/21° C, 33°/25° C, 35°/27° C) on lesion development was studied. Eight varieties grown to the reproductive stage in the greenhouse were transferred to the phytotron a week before inoculation.

Lesion development on compatible variety-isolate combinations increased with temperature. Kinmaze and CAS 209, rice varieties compatible with isolate strains PX061 and PX071, showed similar trends in lesion development (Fig. 5). On IR28 varieties with the *Xa-4* gene for resistance to incompatible strain PX061, lesion length did not increase significantly with temperature. Lesion expression by Asominori, IR26, and IR28 (reported to possess horizontal resistance) was less affected by increasing temperatures (Fig. 6).

Collaboration on tungro virus. The Rice Tungro Virus Collaborative Project, with 7 collaborators in 5 countries, was established to determine causes of variation in varietal reaction to tungro.

Forty adult insects — 20 females and 20 males per variety for each trial — were allowed 4 days' acquisition access on tungro-diseased plants.

Insects survived 1-21 days on 7-day-old seedlings in test tubes. When average life span was used to indicate the effect of the variety on the insect, IR34, Pankhari 203, and Ptb 18 were more resistant than the other seven varieties (Table 38). Average insect

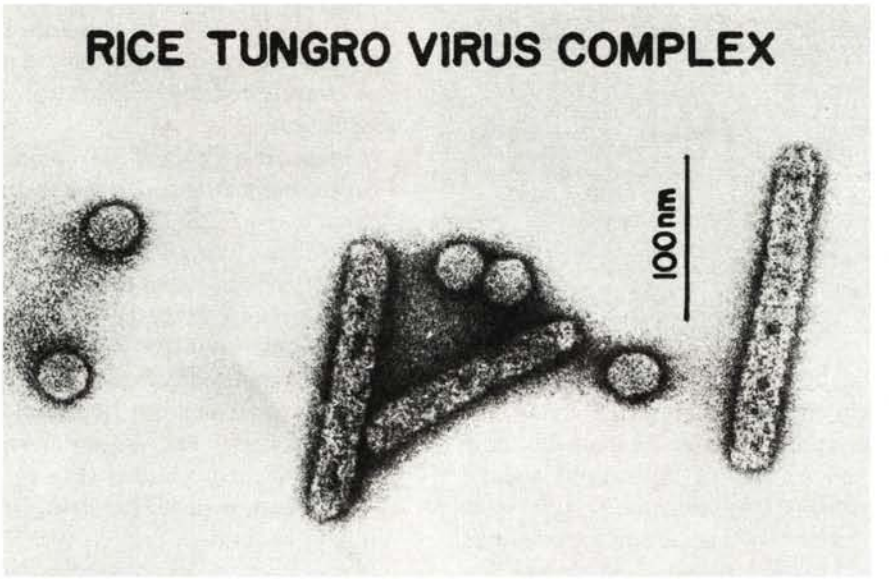
Table 36. Life span and number of progenies of adult brown planthoppers (BPH) from 2 sources tested on 2 plant species. IRRI, 1981.

BPH source[a]	Life span (days)		Progenies (no.)	
	L. hexandra	TN1	*L. hexandra*	TN1
Greenhouse reared/ *L. hexandra*	8	4	332	0
N. lugens greenhouse-reared/TN1)	2	6	0	592

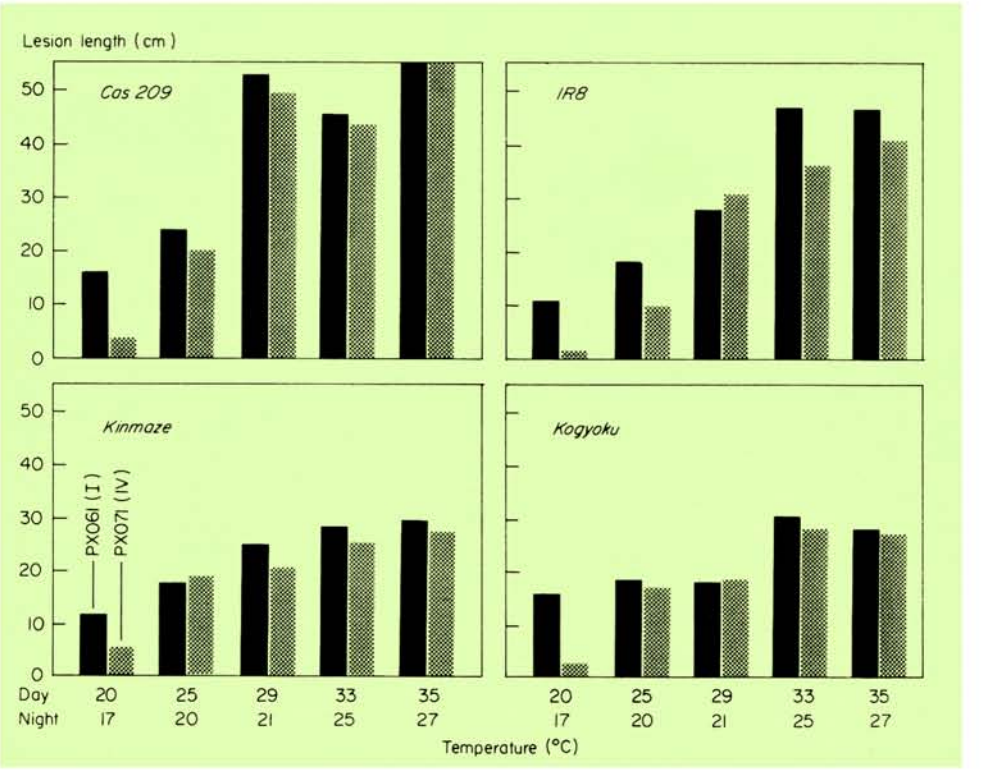
[a]Tested 3 times, with 1 replication/test.

Table 37. Ability of *Leersia hexandra* (BPH) colonies to transmit ragged stunt virus and grassy stunt virus, tested by daily serial transmission method. IRRI, 1981.

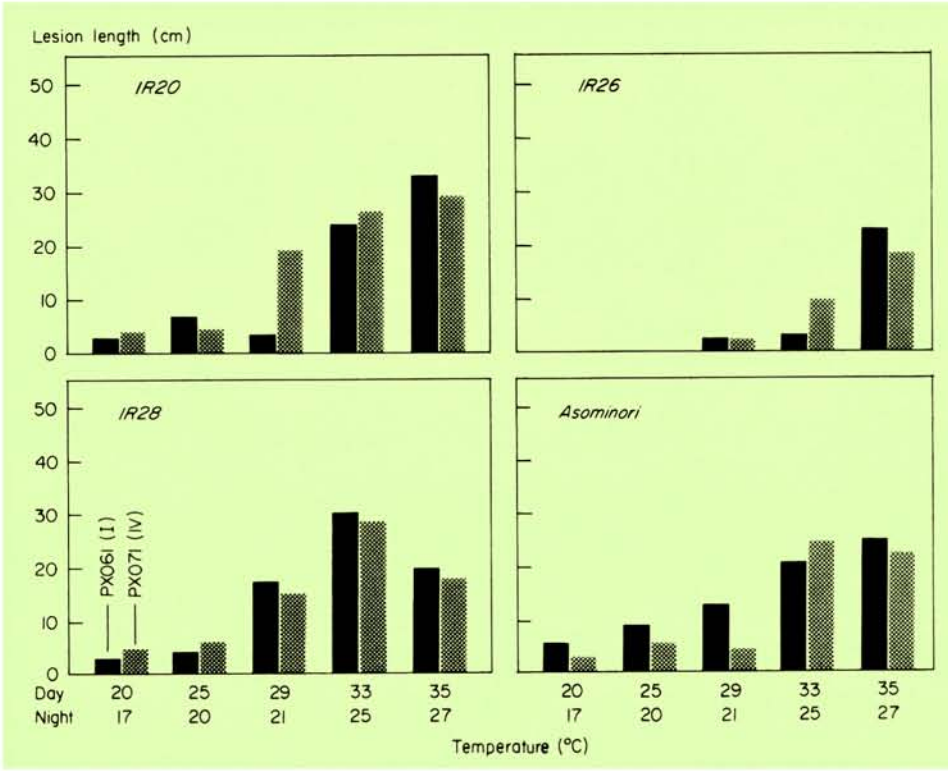
Virus disease transmitted	Active transmitters (%)	Latent period (days)	Retention period (days)	Disease-transmitting days (%)	Infected seedlings (no./ infective insect)
Grassy stunt	25	9	10	96	2
Ragged stunt	13	10	11	98	2



4. Isometric and bacilliform particles of rice tungro virus complex.



5. Influence of temperatures on lesion development caused by 2 strains of *Xanthomonas campestris* pv. *oryzae* on 4 rice varieties compatible to bacterial blight.



6. Influence of temperatures on lesion development caused by 2 strains of *Xanthomonas campestris* pv. *oryzae* either virulent or less virulent to 4 rice varieties differing in resistance to bacterial blight.

Table 38. Life span of tungro-viruliferous *Nephotettix virescens* on 10 rice varieties at IRRI, 1981.

Variety	Insects tested (no.)	Life span (days)	
		Longest	Av[a]
Ambemohar	80	15	7.0 a
TN1	80	21	6.6 a
Kataribhog	78	18	6.1 ab
Habiganj DW8	80	20	6.1 ab
Latisail	78	15	4.6 bc
IR26	80	15	4.0 cd
Gam Pai 30-12-15	80	9	4.0 cd
Ptb 18	78	7	3.0 d
Pankhari 203	80	9	2.9 d
IR34	80	6	2.9 d

[a]Separation of means by Duncan's multiple range test at the 1% level.

Table 39. Life span of female and male tungro-viruliferous *Nephotettix virescens* on seedlings of 10 rice varieties at IRRI, 1981.[a]

Sex	Trial I	Trial II	Mean
Female	4.8 a	5.2 a	5.0 a
Male	4.6 a	4.3 a	4.5 a

[a]Separation of means in a column by Duncan's multiple range test at the 1% level.

Table 40. Tungro transmission and seedling infection by *Nephotettix virescens* on 10 rice varieties at IRRI, 1981.

Variety	Insects		Av retention (days)	Seedlings		Infected seedlings	
	Tested (no.)	Infective (%)		Inoculated (no.)	Infected (%)	No./ insect	No./ infective insect
TN1	80	92	1.47	276	37	1.3	1.40
Kataribhog	78	55	1.51	247	23	0.7	1.33
IR26	80	55	1.21	228	23	0.7	1.16
Ambemohar 159	80	57	1.21	277	19	0.7	1.13
Latisail	78	44	1.10	261	14	0.5	1.07
Ptb 18	78	34	1.07	209	14	0.4	1.03
IR34	80	28	1.04	220	10	0.3	1.04
Gam Pai 30-12-15	80	28	1.00	264	8	0.3	1.00
Pankhari 203	80	14	1.09	205	6	0.2	1.00
Habiganj DW8	80	10	1.00	271	3	0.2	1.00
Total/av	794	42	1.17	2458	16	0.5	1.12

life span was 4.8 days; 5.0 days for females and 4.5 days for males. Differences between life spans of males and females were not significant (Table 39).

The lower proportion of tungro-infected seedlings in Pankhari 203, Habiganj DW8, Gam Pai 30-12-15, and IR34 suggests that these varieties are more resistant to tungro than the other six varieties (Table 40).

Control and management of rice pests

Insects

Entomology Department

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Aquatic invertebrate fauna in rice fields. The aquatic rice field habitat has been overlooked as a resource in the biological control of rice insect pests. Control could be directly through potential new natural enemy species, or indirectly, through manipulation of components of the food web. In developing a food web, the first step is to compile a list of aquatic invertebrate species found in paddies, canals, and reservoirs. In 1981, nets and sieves were used to intensively sample IRRI farm fields. Eighty-eight species of invertebrates, half phytophagous and half predatory, were identified.

A. Phytophagous
- Arachnida
  - — Acarina (immatures, adults)
    - Oribatidae (beetle mites)
      - 2 undetermined spp.
- Insecta
  - — Coleoptera (larvae, adults)
    - Curculionidae (weevils)
      - *Bagous* (2 undetermined spp.)
      - *Nanophyes* sp.[b]
  - — Collembola (immatures, adults)
    - Sminthuridae (springtails)
      - *Sminthurus* sp.
    - Isotomidae (springtails)
      - ? *Isotoma* sp.
  - — Diptera (larvae)
    - Cecidomyiidae (gall midges)
      - ? *Contarinia* sp.
  - — 1 undetermined sp.
    - Chironomidae (midges)
      - *Chironomus kiiensis* Tokunaga[a,b]
      - *Chironomus crassiforceps* Kieffer[a,b]
      - *Chironomus javanus* Kieffer[a,b]
      - *Clynotanypus claripennis* Kieffer[a]
      - *Cricotopus bicinctus* Meigen[a]
      - *Cryptochironomus javae* Kieffer[a]
      - *Tanytarsus* sp.[a]
    - Ephydridae (shore flies)
      - *Ephydra* nr. *riparia* Fallen[a]
      - *Brachydeutera longipes* Hendel[a]
      - *Notiphila spinosa* Meigen[a]
    - Psychodidae (moth flies)
      - *Psychoda* sp.[a]
    - Tipulidae (crane flies)
      - *Tipula* nr. *aino*[a]
    - Ceratopogonidae (biting midges)
      - *Culicoides* sp.
    - Culicidae (mosquitoes)
      - *Anopheles* nr. *pseudosinensis* Baisas
      - *Culex* nr. *quinquiefasciatus* Say
    - Mycetophilidae (fungus gnats)
      - 1 undetermined sp.
    - Simuliidae (black flies)
      - ? *Simulium* sp.
    - Stratiomyidae (soldier flies)
      - ? *Eulalia* sp.
      - *Hermetia illucens* L.
      - *Odontomyia* sp.
    - Syrphidae (flower flies)
      - *Eristalis* sp.
  - — Ephemeroptera (nymphs)
    - Baetidae (may flies)
      - *Baetis* sp.
  - — Hemiptera (immatures, adults)
    - Corixidae (water boatman)
      - *Micronecta quadristrigata* Breddin[a]
  - — Trichoptera (larvae)
    - Leptoceridae (caddis flies)
      - 1 undetermined sp.
- Crustacea (immatures, adults)
  - — Copepoda
    - Cyclopidae (copepods)
      - *Cyclops* (2 undetermined spp.)[a]
  - — Ostracoda
    - Cypridae (ostracods)
      - *Cypris* sp.[a]
      - 3 undetermined spp.
    - Sididae (ostracods)
      - 1 undetermined sp.
  - — Decapoda
    - Palaemonidae (rice field prawns)
      - 1 undetermined sp.
    - Parathelphusidae (rice field crabs)
      - 1 undetermined sp.
- Mollusca (immatures, adults)
  - — Gastropoda (snails)
    - Pilidae (ampullariids)
      - 2 undetermined spp.

[a] Feeds on rice. [b] Feeds on *Azolla*.

B. Predators
Insecta
— Coleoptera (larvae, adults)
Carabidae (ground beetles)
Egadroma quinquepustala W.
Adacanthao nr. *aegrota* (Bates)
Ophionea ishii Habu
Ophionea nigrofasciata S. G.
Dystiscidae (predacious diving beetles)
? *Agabus* sp.
Cybister sp.
Laccophilus nr. *philippinensis* Gent.
1 undetermined sp.
Gyrinidae (whirligig beetles)
? *Dineutus* sp.
Hydrophilidae (water scavenger beetles)
Hydrophilus (2 undetermined spp.)
Berosus sp.
Noteridae (burrowing water beetles)
Hydrocanthus sp.
Staphylinidae (rove beetles)
Paederus fuscipes Curtis
1 undetermined sp.
— Diptera (larvae)
Dolichopodidae (long-legged flies)
Capsicnemus sp.
Dolichopus sp.
Empididae (dance flies)
Drapetis (3 undetermined spp.)
— Hemiptera (nymphs, adults)
Belostomatidae (giant water bugs)
Diplonychus rusticus Fabr.
Lethocerus indicus (Le Pelet. et Serv.)
Gerridae (water striders)
Limnogonus fossarum (F.)
Limnogonus nitidus (Mayr)
Hebridae (velvet water bugs)
Hebrus sp.
Hydrometridae (water measurers)
Hydrometra lineata Eschsch.
Naucoridae (creeping water bugs)
? *Naucoris* sp.
Nepidae (water scorpions)
Ranatra diminuta Montadon
Notonectidae (back swimmers)
Anisops kuroiwae Matsumura
Ochteridae (velvet shore bugs)
Octerus marginatus (Latreille)
Pleidae (small back swimmers)
Paraplea sobrina Stal
Veliidae (ripple bugs)
Microvelia douglasi atrolineata (Bergroth)
? *Strongylovelia* sp.
— Odonata (naiads) (dragon flies)
Aeschnidae (darners)
Aeschna sp.
Coenagrionidae (narrow-winged damselflies)
Agriocnemis femina femina Brauer
Agriocnemis pygmaea Rambur
? *Ischnura* sp.
Libellulidae (common skimmers)
Diplacodes trivialis Rambur
Pantala flavescens (Fabr.)
Orthethrum testaceum Burm.
Mollusca
— Gastropoda (immatures, adults)
Lymnaeidae (snails)
Lymnaea viridis L.
Lymnaea sp.
Annelida
— Hirudinea (adults)
Hirudidae (leeches)
Hirudo (2 undetermined spp.)

Among the phytophagous species, 14 were feeding on rice and 5 on *Azolla*. Some of the plant-feeding species may act as alternative hosts of key natural enemies of rice insect pests.

The role of the species classified as predators has not been determined.

DAMAGE ASSESSMENT AND SAMPLING METHODS

Yield losses to whorl maggot. Studies to determine whether the whorl maggot causes yield losses continued. Whorl maggot flies were infested in cages at 800/49 hills 3-5 DT. Treatments consisted of shaded and unshaded plots. Yields in plots with and without whorl maggot did not differ (Table 1), although plots with whorl maggots were severely damaged. This indicates that rice plants can recover from whorl maggot damage.

Plant injury by green leafhoppers (GLH). GLH transmit virus diseases. They also can cause direct damage by feeding on leaves. Direct yield losses were shown in 1981.

GLH *Nephotettix virescens* nymphs were caged

Table 1. Yield components of IR36 as affected by shading and whorl maggot infestation[a] under field conditions. IRRI, 1981.

	Without whorl maggot	With whorl maggot[b]	Difference
	Panicle length (cm)		
Open	22.2	21.7	0.5
Shaded	21.5	20.9	0.6*
Difference	0.7*	0.8*	
	Unfilled grains[b] (%)		
Open	16.2	16.7	-0.5
Shaded	19.0	16.3	2.7
Difference	-2.8	0.4	
	Grain yield[b] (g/m²)		
Open	567.7	550.9	16.7
Shaded	401.0	398.6	2.4
Difference	166.6**	152.3**	

[a]Av of 8 replications. [b]In each plot 49 hills were infested with 800 whorl maggot adults at 3-5 days after transplanting.

on IR42 rice plants for 30-day periods at densities and in a growth pattern simulating natural field populations. Significant reduction in grain weight occurred when insect density exceeded 10/hill during the early and middle crop growth stages (Fig. 1).

Root pests of seedlings. Aquatic invertebrate species to be screened were placed in 50-cm-deep glass aquaria. Rice seedlings were set in holes bored in sheets of foam floating on the water surface, with their roots falling free under the water surface.

Three groups of invertebrates fed on rice roots:

Table 2. Root damage to 10- to 15-day-old IR36 rice seedlings by different densities of 3 groups of aquatic invertebrates.[a] IRRI, 1981.

Aquatic invertebrate	Damaged root hairs[b] (%)		
	20 adults/ seedling	40 adults/ seedling	500 adults/ seedling
Micronecta quadristrigata	42	33	47
Chironomus kiiensis	13	16	31
Cypris spp.	3	15	23

[a]Av of 3 replications. [b]Root hairs counted at time of infestation, number of damaged hairs recorded after 72 h.

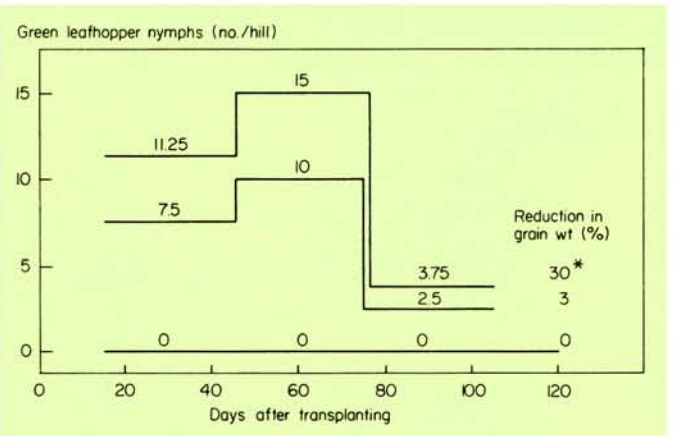
larvae of seven species of chironomid midges (principally *Chironomus kiiensis* Tokunaga), nymphs and adults of a corixid water boatman *Micronecta quadristrigata* Breddin, and an Ostracod crustacean *Cypris* sp.

Various pest densities per 10- to 15-day-old rice seedling were caged for 72 hours. The corixid caused the most cut root hairs (Table 2). Damage did not increase beyond 20 adults/seedling.

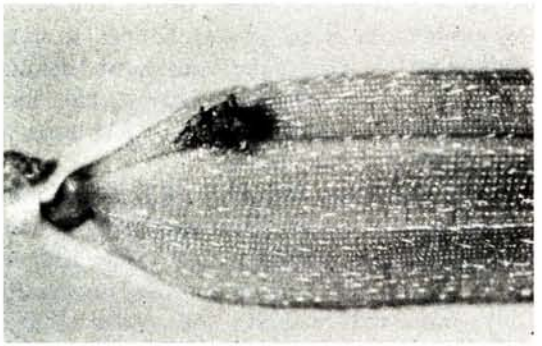
Damage from both the chironomid and the ostracod increased at higher densities. Chironomid larvae showed a greater potential to damage roots than the ostracod.

The root pests were caged with potential aquatic natural enemies. Dytiscid beetles, belostamatid giant water bugs, pleid water bugs, nepid water scorpions, coenagrionid damselfly naiads, and libellulid dragonfly naiads showed high predator activity.

Rice bug feeding behavior. During feeding, the



1. Levels of infestation by GLH *Nephotettix virescens* nymphs on IR42 plants in field cages and consequent reduction in grain weight. IRRI, 1981 dry season.



2. The proteinaceous stylet sheath produced by the rice bug during feeding can be stained with acid fuchsin dye. Rice bug prefers to feed on the rice spikelet at opening of the lemma and palea.

rice bug *Leptocorisa oratorius* (Fabricius) secretes a proteinaceous stylet sheath to form a feeding tract for its sucking mouth parts. Stylet sheaths can be stained red with acid fuchsin dye, facilitating detailed examination. To stain the sheaths, panicles are immersed for an hour in dye solution (1 part each phenol, lactic acid, and water; 2 parts glycerine; and enough acid fuchsin to produce a dark-red color), rinsed, and air dried.

Adults produce larger stylet sheaths than fifth-instar or younger nymphs. Averaged over panicles at the milk, soft, and hard dough stages, 94% of the stylet sheaths produced by adults and nymphs occur between the lemma and palea (Fig. 2). Only 3% of the feeding sheaths were in the lemma and less than 1% each in the palea, sterile lemma, pedicle, panicle axis, and branch.

When rice plants at five stages (booting, flowering, milk, soft dough, and hard dough) were offered to each of the five nymphal instars, males, and females, no stylet sheaths were found on plants at booting and flowering stage.

Nymphs showed no preference for panicles in the milk, soft-dough, or hard-dough-stages (Table 3). Male adults preferred panicles in the milk stage or soft-dough to hard-dough stages. Female adults produced significantly more stylet sheaths on milk-stage panicles than did nymphs. Because females preferred rice in the hard-dough stage less, the difference between females and first- to third-instar nymphs in number of stylet sheaths in panicles in the hard-dough stage was significant.

Rice bugs preferred to feed at the top portion of rice panicles in the milk stage and at the middle and bottom portions in the soft- and hard-dough stages (Table 4). Because the panicle emerges from the boot over time, there is an age gradient from older to younger spikelets from top to bottom within any panicle. Preference for the topmost spikelets at the milk stage reinforces the finding that rice bugs do not prefer to feed on spikelets at earlier than milk stage. Their choice of spikelets at the lower portions of panicles in the soft- and hard-dough stages shows their preference for spikelets in the milk and soft-dough stages.

There was no difference in survivorship among rice bugs reared on rice panicles in the milk-, soft-, and hard-dough stages from first instar to adulthood and to death. However, because of differences in life span, significantly more stylet sheaths were produced by female and male adults and fifth-instar bugs. First- to fourth-instar bugs produced similar numbers (Table 5).

Although rice bugs fed over a 24-hour period, 6 times more stylet sheaths were produced by all rice bugs at 7 stages during the day (0900-1500) than during the night (1900-0500). The largest number of stylet sheaths per hour was produced during the

Table 3. Stylet sheaths produced by rice bug (av of nymphs and adults) on IR36 rice panicles in milk, soft-dough, and hard-dough stages.[a] IRRI, 1981.

Stage	Stylet sheaths (no./day)		
	Milk	Soft dough	Hard dough
First instar	0.09 a (d)	0.09 a (d)	0.07 a (b)
Second instar	0.10 a (cd)	0.14 a (cd)	0.07 a (b)
Third instar	0.27 a (bcd)	0.10 a (d)	0.12 a (b)
Fourth instar	0.35 a (bc)	0.77 a (ab)	0.19 a (ab)
Fifth instar	0.44 a (bc)	0.50 a (bc)	0.29 a (ab)
Male	0.90 a (ab)	0.70 ab (ab)	0.34 b (ab)
Female	1.72 a (a)	1.59 a (a)	0.45 b (a)

[a]Av of 3 replications each with 10 rice bugs feeding for 2 days. Separation of means in a row or in a column (in parentheses) by Duncan's multiple range test at the 5% level.

Table 4. Stylet sheaths produced by rice bug (av of nymphs and adults) at top, middle, and bottom portions of IR36 rice panicles in milk, soft-dough, and hard-dough stages.[a] IRRI, 1981.

Panicle portion	Stylet sheaths (no./day)		
	Milk	Soft dough	Hard dough
Top	0.33 a	0.09 b	0.01 b
Middle	0.19 b	0.28 a	0.10 a
Bottom	0.04 c	0.18 ab	0.11 a

[a]Av of 3 replications each with 10 rice bugs feeding for 2 days. Separation of means in a column by Duncan's multiple range test at the 5% level.

early morning (0500-0900) and late afternoon (1500-1900).

Deepwater rice project survey. The deepwater rice pest management project in Thailand began March 1981. Surveys indicated that major pests are rats, stem borers, and ragged stunt virus; minor pests are gall midge, before flooding, and a leaf-eating gryllid.

Damage by stem borers was low during the preflood period, increasing steadily to high levels before harvest. At Huntra, 10% of the stems were damaged by early November; 42% had been attacked by harvest. Mean levels of damaged stems in 63 fields surveyed were: September, 6%; October, 11%; November-December (heading), 27%; and at harvest, 39%. Near the regional yield trial fields, 18% of the stems in 2 early varieties were damaged by heading; these levels were 29% at heading and 40% at harvest for LMN 111 and PG 56. The yellow rice borer is the predominant species.

Clear symptoms of ragged stunt virus were found in virtually every field, despite apparently low populations of brown planthopper. In some fields, more than 20% of the stems showed definite symptoms, which persisted to harvest. They produced little or no grain. Estimated yield losses in those fields were 1.0-1.5 t/ha.

Green leafhopper sampling. GLH distribution was characterized after intensive sampling with the FARMCOP insect suction sampler (Annual report for 1978). Spatial distribution was aggregated, adults more than nymphs, and tended to fit a negative bionomial distribution.

The sample size required to achieve 20% precision varied considerably, depending on insect density and variance. Using the FARMCOP sampler, a sample of 40 hills was adequate if GLH density was at least 1/hill (Fig. 3).

ECOLOGY AND BIOLOGY

Population dynamics. *Stem borers.* Use of a surveillance tool such as a light trap to predict pest densities would make pest control operations simpler and more effective. To predict stem borer density in the field from light trap catches, nightly catches of yellow borer *Scirpophaga incertulas* adults in a light trap were compared with egg, larval, and pupal densities in a nearby field. Eggs were sampled three times a week; the other stages, weekly.

Two generations of yellow borer developed in one crop. Moth (mostly female) catch peaks in the light trap occurred about 1 week later than egg density peaks in the field. Trap catches could not

Table 5. Damage and feeding behavior at different growth stages of rice bug reared from egg hatch to death on IR36 rice panicles in milk, soft-dough, and hard-dough stages.[a] IRRI, 1981.

Stage	Life span (days)	Stylet sheaths		Filled grains (%)
		Total no.	Area per sheath (mm)	
First instar	3	1.7 d	0.06 c	100
Second instar	3	1.1 d	0.05 c	100
Third instar	4	1.6 d	0.09 c	100
Fourth instar	4	1.8 cd	0.08 c	100
Fifth instar	6	4.0 c	0.17 b	100
Male adult	71	88.0 b	0.31 a	99
Female adult	94	178.0 a	0.34 a	99

[a]Values are means of 10 rice bugs in 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. There were no differences between milk, soft-dough, and hard-dough stages. Experiment performed in outdoor cages.

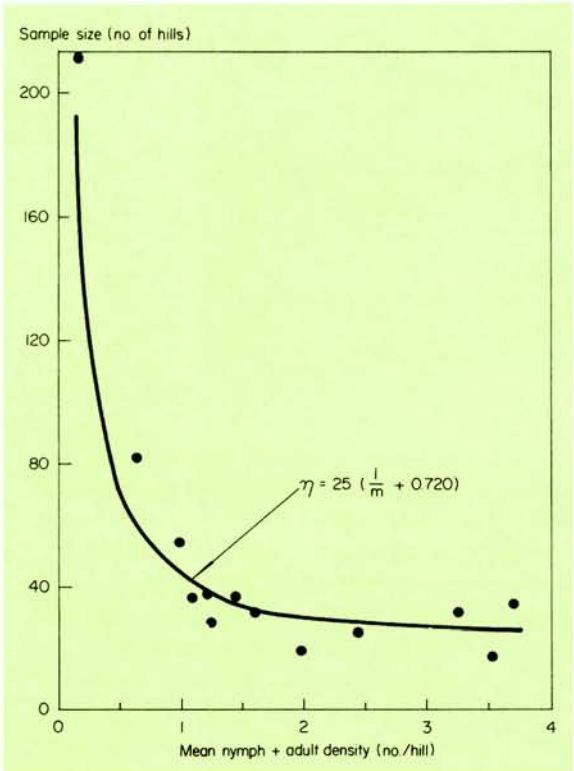
predict oviposition. But catch peaks preceded larval peaks and pupal peaks (Fig. 4). For maximum effectiveness, insecticides should be sprayed at, or very soon after, a light trap catch peak, when newly hatched larvae would be exposed and vulnerable to the chemicals.

Green leafhoppers. GLH populations in a series of flooded fields have been monitored for 3 years at IRRI and on nearby farmers' fields. Usually three, but sometimes two, generations developed in one crop period. The mean density of the first generation was 8.2 GLH/hill; that of the second, 11.4/hill; and that of the third, 3.3/hill.

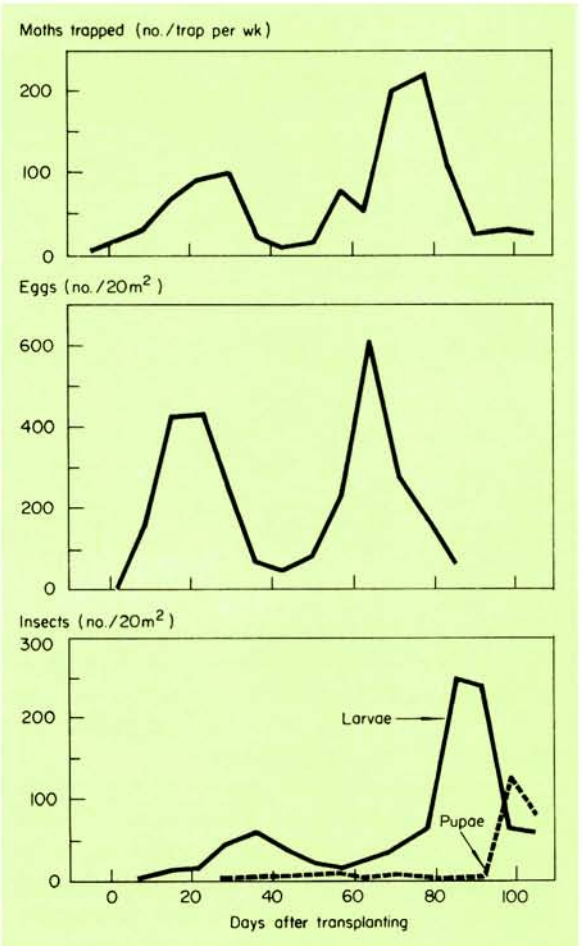
Immigration occurred at the beginning of the crop and probably at the end of the first and second generations. At those times, more adults were present in the field than would be expected by the number of fifth-instar nymphs. Female adults outnumbered males by three, four, or even five times.

Egg and nymph survival was very low. Only 7% of first-generation eggs, 4% of second-generation eggs, and 1% of third-generation eggs became adults (Table 6). This poor survival suppressed the pest population, which declined after the second generation. Survival decreased with each succeeding generation, probably because of increasing natural enemy action. Egg parasitization by *Gonatocerus* spp. increased from 32% in the first generation to 49% in the second and 55% in the third. Predators, the major cause of nymph mortality, were more abundant during the second half of the crop period.

An age-specific life table describing the extent and probable causes of death in one generation showed a very high mortality during the egg and



3. Relationship of sample size to mean density in the distribution of a population of green leafhopper *Nephotettix* spp. nymphs and adults in a wetland rice field. IRRI, 1977 wet season.



4. Comparison of yellow borer *Scirpophaga incertulas* density on transplanted rice selection IR127-80-1 and moth catches in a fluorescent-light trap. IRRI, 1980 dry season.

Table 6. Survival at each stage and generation of green rice leafhoppers *Nephotettix* spp. on susceptible rice variety IR42 and selection IR1917-3-17 in wetland IRRI and farmers' fields. 1978-81 dry and wet seasons.

Insect stage	Survival rate (mean ± S.E.)		
	First generation[a]	Second generation[b]	Third generation[c]
Egg	0.51 ± 0.08	0.38 ± 0.10	0.29 ± 0.11
Nymph	0.14 ± 0.01	0.09 ± 0.01	0.04 ± 0.00
1st-instar nymph	0.80 ± 0.01	0.75 ± 0.01	0.72 ± 0.04
2nd-instar nymph	0.76 ± 0.02	0.70 ± 0.03	0.67 ± 0.03
3rd- instar nymph	0.72 ± 0.01	0.61 ± 0.04	0.65 ± 0.03
4th-instar nymph	0.63 ± 0.03	0.57 ± 0.04	0.45 ± 0.08
5th-instar nymph	0.49 ± 0.00	0.47 ± 0.01	0.30 ± 0.04
Egg + nymph	0.07 ± 0.02	0.04 ± 0.01	0.01 ± 0.00

[a]Based on 4 generations. [b]Based on 5 generations. [c]Based on 2 generations.

Table 7. Age-specific life table of green leafhoppers *Nephotettix* spp. (2nd generation) on susceptible rice variety IR42 in a wetland field. IRRI, 1981 dry season.

Age interval (x)	Green leafhoppers		Factors responsible for dx	dx as % of lx	Accumulated mortality (%)
	Initial no./hill (lx)	No. dying during x (dx)			
Egg	384.7	13.8	Failure to hatch	3.6	
		7.3	Predation	1.9	
		215.8	Parasitization	56.1	
		140.3	Unknown	36.5	
				98.1	98.1
Nymph	7.5	0.2	Parasitization	2.2	98.2
		4.8	Unknown (predation?)	64.0	99.4
Adult	2.5	0.8	Males (sex ratio)	32.0	99.6
		0.3	Parasitization	14.3	99.7
♀ Adult	1.4				

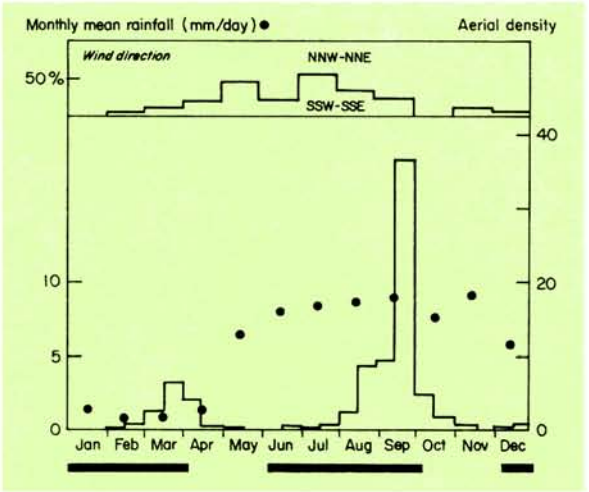
nymphal stages (Table 7). In this case, only 0.3% of the eggs developed into female adults capable of reproduction. The impact of natural enemies on GLH populations was dramatic, suppressing the pest densities to very low levels.

When initial estimates of adult mean longevity (6.5 days at 59 DT, and 1.6 days at 84 DT) and fecundity (8.7 eggs/female per day) were applied to adult GLH density data, the egg density in the next generation could be predicted. But preliminary predictions for 18 generations frequently did not agree with actual field densities.

Brown planthopper (BPH) migration. *Short-distance.* Field studies on a 2-ha farm in Liliw, Laguna, Philippines, of the role of migration in the population dynamics of BPH and other hopper pests of rice continued in 1981.

High-level suction-trap (12.2 m) catches confirmed previous observations that two annual BPH population peaks occur, one in March-April during the dry season and one in September-October during the wet season (Fig. 5). This suggests that climate is not a determining factor in BPH occurrence, although there is some indication that the peaks are associated with transitional conditions at the beginning and end of the influence of the southwest monsoon.

Other than climate, the major influence on the

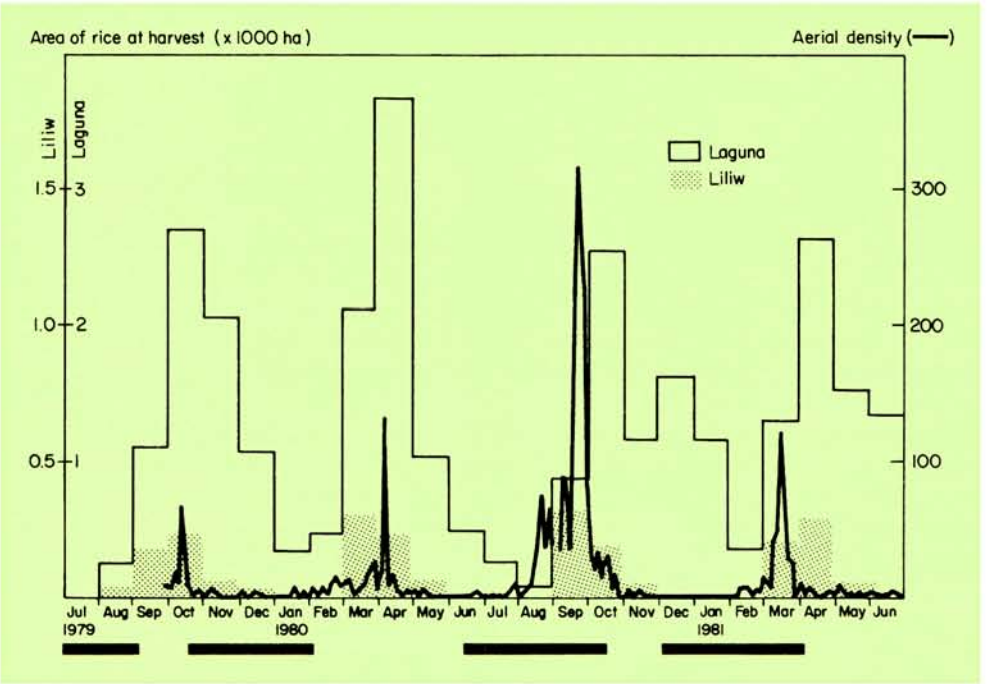


5. Annual fluctuations in aerial density of brown planthopper at 12.2 m shown in relation to rainfed culture (•), frequency of southern winds (upper box), and cropping season (black bars). Liliw, Laguna, Philippines.

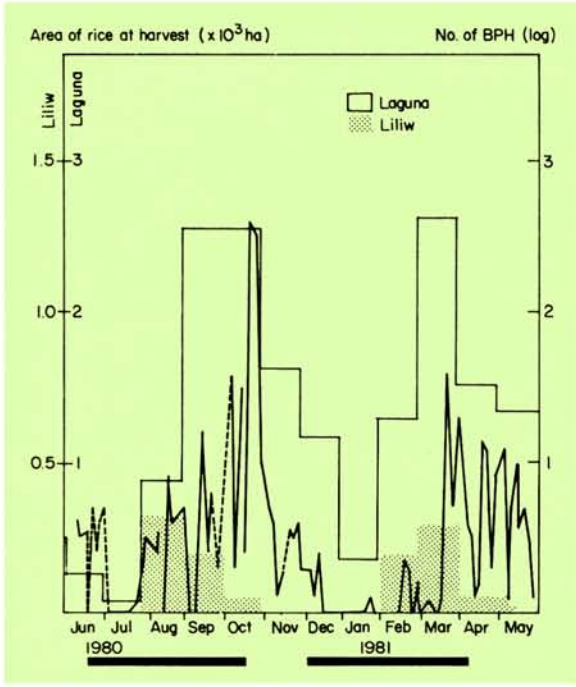
seasonal activity of BPH is cropping pattern. Data collected from the offices of the Ministry of Agriculture in Laguna Province were used to construct cropping profiles. Figure 6 shows the profiles for the province and for the municipality of Liliw in relation to BPH activity, recorded in the 12.2-m suction trap. Cropping seasons at the field site are also shown. Levels of aerial activity and area of rice at harvest correspond. This correspondence is marked for the municipality, much more so than for the site at which records were taken.

The provincial data show extended periods, such as December 1980-January 1981, during which rice was abundant at the appropriate stage to generate hoppers but no BPH were trapped at Liliw. This strongly suggests that insects remaining within the province disperse in relatively short distances. It is not possible to assess what proportion migrate long distances, leaving the province entirely. Light trapping has been conducted at Liliw since July 1980. Comparison of those catches with catches from traps designed to measure emigration from the site shows no correlation.

The light trap, which is constructed and positioned so that only insects in high-altitude flight are caught, probably measures migrant activity. Insects it traps may be potential immigrants to the site. Periodicity of light trap catches (Fig. 7) is much more closely associated with the provincial harvest-



6. Aerial density of BPH at Liliw in relation to area of rice at harvest in the province of Laguna and the municipality of Liliw, Philippines. Cropping seasons at the experimental site are shown by black bars.



7. Light trap catches of brown planthopper (BPH) at Liliw, Laguna, Philippines, in relation to area of rice at harvest in the municipality and the province (see also Fig. 6).

ing pattern than is periodicity of 12.2-m suction trap catches. The peak light trap catch occurs when few insects are caught in the suction trap and it could be assumed that those insects would not normally land at Liliw. They may represent the long-distance migrant component of the provincial population.

Since September 1980, a specially constructed segregating light trap (Fig. 8) has been in operation at Liliw to determine the time of night at which insects are caught. Take-off has been shown to occur over a limited period at dusk. The interval between take-off and capture may represent flight duration. Projections based on meteorological data can be used to determine range of flight and the possible source of insects.

Data collected to date show time of capture as well-demarcated but irregularly occurring peaks, frequently in the evening between 1950 and 2030 hours and in the morning at around 0320 hours. On some nights no clear peaks occur but on others peaks occur at different times.

In 1981 more attention has been given to studies at sites in Laguna chosen for location and cropping pattern. Yellow pan traps have been used to monitor patterns of immigration, and population estimates have been taken in both susceptible and resistant varieties to investigate the relationship between immigration rate and subsequent population development (Fig. 9). There is no relationship between amount of immigration early in the crop and size of BPH population that develops. This strongly suggests that within a field, factors such as predation and parasitism are more important determinants of population size than the level of initial immigration. This situation for tropical populations is markedly different from that shown for temperate populations.

Extensive studies on sampling efficiency have resulted in a standardized technique based on the D-Vac motorized suction sampler with an enclosure. Catches obtained by this method, corrected for efficiency, give good estimates of absolute population size (Table 8).

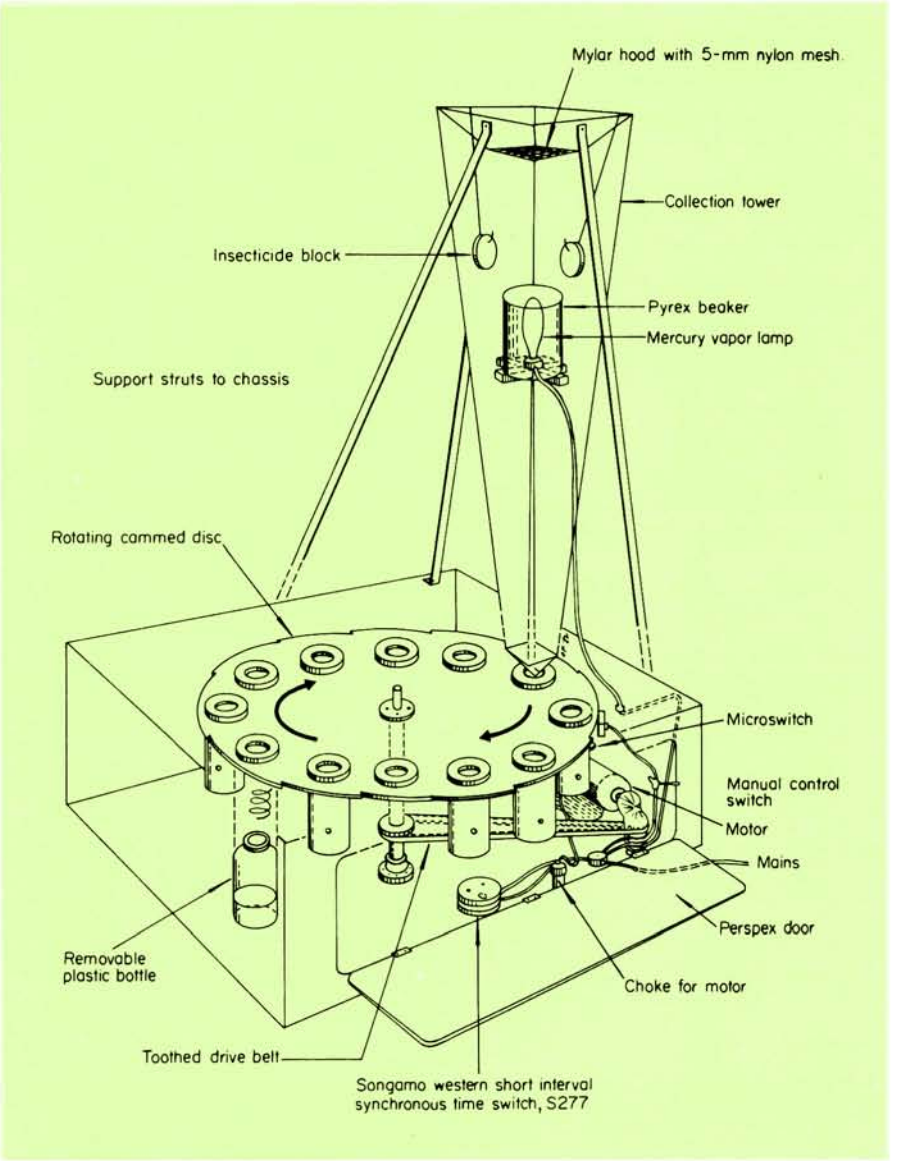
Long-distance. Long-distance migration studies, initiated in 1979, continued. During the 1981 dry season, migrating BPH and other insects were monitored using six wind-propelled, revolving-type nylon nets (0.5 m diam, 2 m long) and four cross-shaped, sticky traps (0.45 m × 0.45 m) on two successive interisland voyages made along fixed commercial routes.

The first voyage was on 14-22 February (Manila-Maasin-Surigao-Cagayan de Oro-Cebu-Manila). The second was on 21-29 May (Manila-Maasin-Cebu-Cagayan de Oro-Manila).

In February, 184 insects and 2 spiders (1 argiopid and 1 thomisid) were trapped. The most numerous insects were dipterans (48%), followed by hemipterans (26%), hymenopterans (14%), and coleopterans (9%). The remainder were lepidopterans and a collembolan.

Of the hemipterans, 29% belonged to Aphididae, 15% to Psyllidae, and 12% to Delphacidae. The remainder were representatives of Cicadellidae, Miridae, Saldidae, Lygaeidae, Cydnidae, Anthocoridae, and Meenoplidae. The delphacids represented three individuals of whitebacked planthopper (WBPH) *Sogatella furcifera,* two individuals of *Nilaparvata bakeri,* and a solitary *Harmalia* sp.

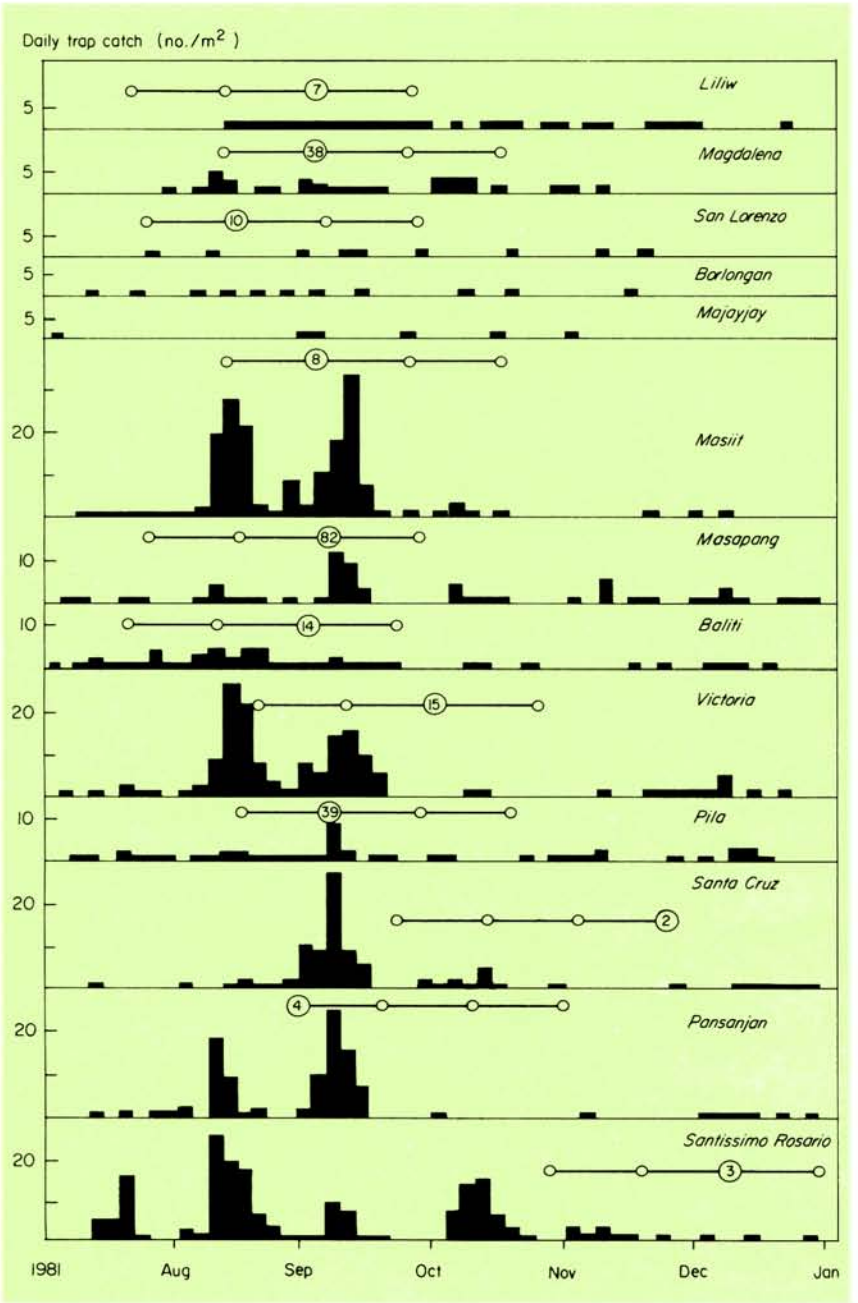
In May, 266 insects and 8 spiders (7 tetragnathids and 1 oxyopid) were collected. These were



8. Segregating light trap designed to determine the time of night at which insects are caught. The time switch causes the motor to rotate the disc and change the collecting bottle at a present interval. Liliw, Laguna, Philippines, 1981.

40% hemipterans, 37% dipterans, 12% coleopterans, 10% hymenopterans, and a solitary noctuid moth. The hemipterans included cydnids (55%), lygaeids (10%), mirids (9%), and delphacids (7%). The remainder represented cicadellids, mesoveliids, meenoplids, aphids, cixiids, a pentatomid, a saldid, and a tingid. The delphacids comprised two individuals of WBPH, two adults of *Opiconsiva dodona,* two individuals of *Nilaparvata* sp., one adult of *Harmalia anacharsis,* and one individual of *Harmalia* sp.

The February voyage had calm to variable (NE, N, NW, NNW, SE) winds, 20.5-32.5° C temperature, and 44-98% relative humidity (RH). The May voyage also had calm to variable (E, SSW, W) winds, 24.6-35.6° C, and 42-97% RH. No speci-



9. Yellow pan trap catches at sites throughout Laguna Province, Philippines, during 1981 in relation to population development of BPH on IR20. The open circles represent sampling occasions at 30, 51, 72, and 93 days after treatment with the maximum population for each site recorded in the appropriate circle.

mens of the BPH were caught in either voyage.

Sex pheromones. Research on sex pheromones in collaboration with the Tropical Products Institute, London, UK, continued.

For the first time, evidence that yellow borer *Scirpophaga incertulas* female moths produce a sex pheromone was obtained. Females with clipped wings were placed at crop height on 60- × 60-cm boards with 15-cm borders covered by sticky material. On an average two males were caught per board per night.

Actual disruption of striped stem borer *Chilo suppressalis* mating by a pheromone mimic in vials was demonstrated in 1978 and 1979 (Annual report for 1979). In 1980, the sex pheromone itself in a

Table 8. Correction factors (b) to adjust insect counts (x) using D-Vac with enclosure to give estimates of absolute population size (y) according to the regression equation $y = bx$.[a]

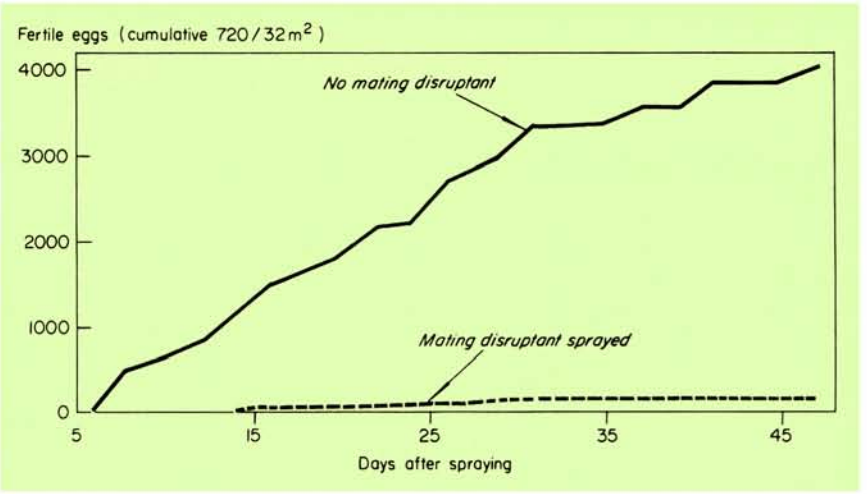
	Correction factor (b)	r^{2b}	n	Max observed (no./hill)
N. lugens				
adults ♂ m	1.20	0.97	53	18.8
♂ b	1.33	0.92	38	2.0
♀ m	1.31	0.94	41	14.6
♀ b	2.22	0.63	34	1.5
nymphs 2	1.20	0.96	45	52.1
3	1.37	0.89	49	24.6
4	1.48	0.89	48	17.1
5	1.65	0.86	45	8.7
S. furcifera				
adults ♂ m	1.06	1.00	66	14.6
♂ m	1.24	0.97	64	6.9
♀ b	1.81	0.79	39	1.0
nymphs 2	1.40	0.81	59	15.1
3	1.44	0.89	55	5.2
4	1.52	0.89	55	4.0
5	1.64	0.89	53	5.7
delphacid nymphs 1	1.13	0.95	58	85.5
Nephotettix spp.				
adults	1.48	0.95	64	17.8
nymphs 1	1.48	0.95	64	17.8
2	1.18	0.96	62	8.5
3	1.32	0.92	60	5.9
4	1.57	0.81	55	4.9
5	1.44	0.85	55	8.7
R. dorsalis				
adults	1.32	0.97	62	4.6
nymphs 1	1.08	0.98	53	4.8
2	1.16	0.96	54	2.8
3	1.25	0.92	50	2.8
4	1.34	0.86	49	3.0
5	1.47	0.91	46	2.0
M. striifrona adults	1.07	0.99	38	2.4
C. spectra adults	2.22	0.81	37	0.4
C. unimaculata adults	1.69	0.81	21	0.5
C. lividipennis adults	1.37	0.97	63	15.0
nymphs	1.18	0.98	55	32.2
M. atrolineata adults m	3.30	0.69	39	1.4
b	4.79	0.45	49	1.9
nymphs	2.37	0.41	53	9.8

[a]Data from bulk sampling of the same 20 hills/plot by D-Vac and then FARMCOP; 1980 wet season; rice varieties IR20 and IR36; samples from 8 plots on 11 occasions from 16 to 104 days after transplanting. [b]All r^2 values are significant at $p < 0.01$; m = macropterous, b = brachypterous.

stabilized microcapsule formulation was sprayed onto rice in cages. Moths released in the cages laid virtually no eggs (Fig. 10) and 96% mating disruption was achieved over 47 days. Results with yellow borer moths were similar.

CHEMICAL CONTROL

Screening insecticides. The activities of coded and commercial insecticides against the BPH *Nilaparvata lugens*, WBPH *Sogatella furcifera*, GLH



10. Fertile eggs laid by striped stem borer *Chilo suppressalis* moths released in 2 16-m² field cages. Plants in treated cages were sprayed with a mating disruptant, *C. suppressalis* sex pheromone, at 10 g/ha in a microcapsule formulation. IRRI, 1981 dry season.

Nephotettix virescens, striped stem borer *Chilo suppressalis,* yellow stem borer *Scirpophaga incertulas,* and rice bug *Leptocorisa oratorius* were studied. Insecticides were applied directly with a Potter's spray tower, as foliar sprays, and as granules in paddy water.

Contact toxicity. Contact toxicities to hoppers of insecticides applied in the Potter's spray tower are given in Tables 9-12. Coded compounds effective (> 80% mortality) against the BPH and WBPH (Table 10) were M 9918, M 10604, and UC 27867. NS 8265 (Table 12) was effective against the WBPH and GLH. Carbofuran (standard) was the most toxic to the three hopper species.

Foliar sprays. The results of foliar spray studies are given in Tables 13-19. At 1 day after treatment (DAT) DPX 5188 controlled the 3 hopper species as effectively as carbofuran but its residual activity was less than that of carbofuran (Table 13). Coded compounds U 56295, U 57770, UC 54229, and UC SF 1 and the combination pirimiphos-methyl + carbophenothion controlled the striped stem borer at 1 DAT (Table 15). Only the coded compounds provided residual activity at 7 and 14 DAT.

Many of the commercial insecticides tested controlled the yellow stem borer (Table 16). Phosmet and azinphos ethyl provided the longest residual activity.

M 9918 had the longest residual activity against the rice bug (Table 17). Adult rice bugs are generally less sensitive to insecticides than the nymphs, but monocrotophos was effective against bugs at both stages at 1 DAT (Table 18).

Fungicides have been reported to have antifeedant activity against BPH. None of eight fungicides evaluated had antifeedant activity on the basis of honeydew excretion on filter paper (Table 19).

Granules broadcast in paddy water. Carbofuran, diazinon, and combinations of gamma BHC + carbaryl and MIPC at two rates were evaluated for yellow stem borer control (Table 20). Mortality at 1 DAT was low in all treatments. At 14 DAT, both carbofuran and gamma BHC + carbaryl at 1 kg a.i./ha provided effective control. Gamma BHC + MIPC at 1.5 kg a.i./ha was also effective.

Insecticides with promising results in insectary studies were further evaluated in the field at IRRI. Commercially available insecticides, many of them currently recommended for stem borer control, were evaluated at the Maligaya Rice Research and Training Center, a yellow stem borer hot spot, December-January.

Foliar sprays at IRRI. Coded and new insecticides applied as foliar sprays were evaluated against the whorl maggot *Hydrellia sasakii* and the BPH and its predators (Table 21). Methidathion was most effective against the whorl maggot. No

Table 9. Contact toxicity of insecticides against the brown planthopper *Nilaparvata lugens* treated in the Potter's spray tower. IRRI insectary, 1981.

Insecticide[a]	Mortality[b] (%)			
	1 HT	4 HT	24 HT	48 HT
Acephate 40 EC	93.3 a (a)	100.0 a (a)	100.0 a (a)	100.0 a (a)
Azinphos ethyl 40 EC	25.0 de (c)	73.3 cd (b)	100.0 a (a)	100.0 a (a)
BPMC 50 EC	100.00 a (a)	100.0 a (a)	100.0 a (a)	100.0 a (a)
Carbofuran 12 F	93.3 a (a)	93.3 a (a)	93.3 ab (a)	95.0 ab (a)
Carbophenothion 40 EC	38.3 c (d)	58.3 ef (c)	68.3 def (b)	83.3 cd (a)
Chlorpyrifos 40 EC	6.7 fghi (c)	28.3 j (b)	91.7 ab (a)	93.3 abc (a)
Cypermethrin 5.0 EC	21.7 de (c)	40.0 h (b)	65.0 ef (a)	71.7 ef (a)
Decamethrin 2.5 EC	26.7 d (b)	28.3 ij (b)	43.3 hi (a)	46.7 hi (a)
Dioxacarb 50 WP	93.3 a (a)	96.7 a (a)	98.3 a (a)	100.0 a (a)
Dioxathion 96 EC	5.0 ghi (b)	5.0 l (b)	5.0 l (b)	16.6 j (a)
Endosulfan 35 EC	5.0 ghi (c)	13.3 kl (b)	38.3 ij (a)	38.3 i (a)
Ethion 40 EC	18.3 def (c)	36.7 hi (b)	58.3 fg (a)	61.7 fg (a)
Ethylan 45 EC	8.3 fghi (b)	91.7 ab (a)	100.0 a (a)	100.0 a (a)
Fenitrothion 30 EC	16.7 defg (c)	41.7 gh (b)	98.3 a (a)	98.3 a (a)
Fenvalerate 3 EC	8.3 fghi (c)	21.7 jk (b)	28.3 jk (b)	40.0 i (a)
FMC 35001 20 EC	26.7 d (b)	96.7 a (a)	100.0 a (a)	100.0 a (a)
Methyl parathion 50 EC	8.3 fghi (d)	41.7 gh (c)	76.7 cd (b)	86.7 bcd (a)
MIPC 50 WP	15.0 defgh (c)	68.3 de (b)	73.3 de (ab)	78.3 de (a)
Monocrotophos 16.8 EC	13.3 efgh (c)	81.7 bc (b)	100.0 a (a)	100.0 a (a)
MTMC 30 EC	48.3 c (b)	100.0 a (a)	100.0 a (a)	100.0 a (a)
Penncap M 25 EC	6.7 fghi (b)	43.3 gh (a)	51.7 gh (a)	51.7 gh (a)
Permethrin 10 EC	3.3 hi (d)	15.0 kl (c)	23.3 k (b)	46.7 hi (a)
Pirimiphos methyl 25 EC	23.3 de (c)	51.7 fg (b)	86.7 bc (a)	91.7 abc (a)
Propoxur 20 EC	63.3 b (b)	98.3 a (a)	100.0 a (a)	100.0 a (a)
Control	0.0 i (b)	5.0 l (ab)	8.3 l (ab)	10.0 j (a)

[a] Applied at recommended rate in spray solution of 500 liters/ha. [b] Av of 3 replications, each consisting of 2 insects treated and caged on untreated plants. Separation of means in a column and in a row (in parentheses) by Duncan's multiple range test at the 5% level. HT = hours after treatment.

Table 10. Contact toxicity of insecticides against the whitebacked planthopper (WBPH) treated in the Potter's spray tower. IRRI, 1981.

Treatment	WBPH mortality[a] (%)			
	1 HT	4 HT	24 HT	48 HT
M 9918 20 OE	100 a	100 a	100 a	100 a
Dioxacarb 50 WP	98 a	98 ab	99 a	100 a
M 10604 20 OE	79 b	82 c	84 b	89 b
Methidathion 40 EC	43 c	96 b	100 a	100 a
UC 27867 50 WP	41 c	69 d	75 b	88 b
RH 0308 48 EC	0 d	0 e	15 c	30 d
RH 0994 48 EC	1 d	1 e	11 c	41 c
Control	0 d	0 e	4 d	11 e

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

insecticide was effective in reducing BPH populations. UC 27867, RH 0994, and methidathion caused high BPH populations at the last observation, indicating resurgence. Many insecticides were toxic to the predator *C. lividipennis*.

Commercial insecticides at Maligaya. Chlorpyrifos + BPMC, UCX 2001, and triazophos as foliar sprays were most effective against stem borers, as indicated by percentages of deadhearts at 40 and 65 DT (Table 22). Carbofuran was the most effective granular insecticide. None of the insecticides prevented whitehead damage.

Growth regulator. Buprofezin was first evaluated against hoppers at IRRI in 1980. In 1981,

Table 11. Contact toxicity of a combination of pirimicarb + pirimiphos-methyl (JF 8251) and carbofuran against the green leafhopper (GLH) and brown planthopper (BPH) treated in the Potter's spray tower. IRRI, 1981.

Treatment	Rate (kg a.i./ha)	Insect mortality[a] (%)							
		1 HT		4 HT		24 HT		48 HT	
		GLH	BPH	GLH	BPH	GLH	BPH	GLH	BPH
Carbofuran 12 F	0.75	89 a	78 a	95 a	78 a	95 a	80 a	98 a	90 a
Pirimicarb + pirimiphos methyl	0.15 + 0.15	0 b	0 b	1 b	6 b	8 b	10 b	18 b	15 b
Pirimicarb + pirimiphos methyl	0.10 + 0.10	0 b	1 b	6 b	6 b	10 b	9 bc	16 b	15 b
Pirimicarb + pirimiphos methyl	0.075 + 0.075	0 b	1 b	4 b	3 b	4 b	8 bc	14 b	15 b
Control		0 b	0 b	4 b	1 b	6 b	4 c	14 b	10 b

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

Table 12. Contact toxicity of new and coded compounds against the brown planthopper (BPH), green leafhopper (GLH), and whitebacked planthopper (WBPH) treated in the Potter's spray tower. IRRI, 1981.

Treatment[a]	Mortality[b] (%)											
	BPH				GLH				WBPH			
	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT	1 HT	4 HT	24 HT	48 HT
MTI-220 20 EC	7.5 c	7.5 e	43.8 d	48.8 d	0.0 c	0.0 d	0.0 e	6.2 c	2.5 e	3.8 d	26.2 d	55.0 c
MTI-500 20 EC	20.0 ab	46.2 c	87.5 b	91.2 b	11.2 b	28.8 c	57.5 b	57.5 b	12.5 d	30.0 c	67.5 c	71.2 b
Cypermethrin 10 EC	10.0 bc	11.2 e	18.8 e	52.5 d	56.2 a	56.2 b	56.2 b	58.8 b	18.8 d	27.5 c	31.2 d	51.2 c
Phoxim 50 EC	13.8 abc	30.0 d	57.5 cd	61.2 d	2.5 c	3.8 d	22.5 c	63.8 b	68.8 b	93.8 a	100.0 a	100.0 a
NS 8265 75 EC	26.2 a	40.0 cd	62.5 c	70.0 c	61.2 a	82.5 a	86.2 a	87.5 a	42.5 c	80.0 b	81.2 b	82.5 b
DPX 5188 20 EC	20.0 ab	76.2 b	80.0 b	83.8 bc	0.0 c	0.0 d	10.0 d	52.5 b	81.2 ab	96.2 a	97.5 a	97.5 a
Carbofuran 12 F	86.2 a	93.8 a	97.5 a	98.8 a	57.5 a	80.0 a	81.2 a	81.2 a	88.8 a	97.5 a	98.8 a	100.0 a
Control	0.0 d	0.0 f	0.0 f	3.8 f	0.0 c	0.0 d	0.0 e	1.2 d	0.0 e	1.2 d	11.2 e	16.2 d

[a]Applied at 0.75 kg a.i./ha, except the pyrethroids MTI-220, MTI-500, and cypermethrin, which were applied at 0.025 kg a.i./ha. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. HT = hours after treatment.

Table 13. Greenhouse evaluation of new and coded compounds as a foliar spray for brown planthopper (BPH), green leafhopper (GLH), and whitebacked planthopper (WBPH) control. IRRI, 1981.

Treatment[a]	Mortality[b] (%)														
	BPH					GLH					WBPH				
	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
DPX 5188 20 EC	100 a	14 b	6 b	3 a	1 a	91 bc	23 bc	6 b	23 bc	9 b	100 a	39 b	5 b	6 b	4 a
Carbofuran 12 F	82 b	80 a	66 a	5 a	9 a	98 ab	99 a	98 a	84 a	54 a	100 a	100 a	86 a	34 a	5 a
Cypermethrin 10 EC	31 c	9 b	8 b	3 a	4 a	96 ab	94 a	85 a	36 b	35 a	76 b	14 c	9 b	4 b	3 a
Phoxim 50 EC	30 c	9 b	6 b	3 a	3 a	75 c	33 b	8 b	10 c	9 b	60 b	8 c	5 b	5 b	1 a
NS 8265 75 EC	28 c	2 b	18 b	4 a	3 a	100 a	44 b	9 b	23 bc	14 b	68 b	16 c	8 b	4 b	5 a
MTI-220 20 EC	6 d	6 b	8 b	5 a	4 a	18 e	6 c	6 b	23 bc	12 b	14 c	6 c	3 b	5 b	0 a
MTI-500 20 EC	6 d	9 b	9 b	3 a	8 a	39 d	11 c	4 b	18 bc	11 b	16 c	6 c	6 b	9 b	0 a
Control (water)	6 d	10 b	5 b	1 a	0 a	14 e	14 c	3 b	18 bc	4 b	9 c	9 c	1 c	6 b	3 a

[a]All insecticides applied at 0.75 kg a.i./ha, except MTI-220 and MTI-500, which were applied at 0.025 kg a.i./ha, and cypermethrin, applied at 0.075 kg a.i./ha. Spray vol. was 6.25 ml/hill. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after transplanting.

Table 14. Greenhouse evaluation of a combination of pirimicarb + pirimiphos-methyl (JF8251) and carbofuran as a foliar spray for green leafhopper (GLH) and brown planthopper (BPH) control. IRRI, 1981.

Treatment	Rate (kg a.i./ha)	Insect	Mortality[a] (%)				
			1 DAT	5 DAT	10 DAT	15 DAT	20 DAT
Pirimicarb + pirimiphos-methyl	0.15 + 0.15	GLH	35 b	43 c	6 bc	23 b	20 b
		BPH	13 cd	13 def	11 b	9 bc	3 de
Pirimicarb + pirimiphos-methyl	0.10 + 0.10	GLH	25 bc	26 cd	8 bc	21 bc	14 bc
		BPH	10 cd	5 f	15 b	8 bc	3 e
Pirimicarb + pirimiphos-methyl	0.075 + 0.075	GLH	11 cd	21 de	6 bc	16 bc	11 bcd
		BPH	4 d	9 ef	6 bc	6 c	5 de
Carbofuran 12 F	0.75	GLH	100 a	99 a	90 a	95 a	54 a
		BPH	100 a	89 b	86 a	19 bc	5 cde
Control		GLH	6 d	11 def	3 c	15 bc	5 cde
		BPH	6 d	6 f	6 bc	9 bc	5 abc

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

Table 15. Greenhouse evaluation of insecticides applied as foliar sprays against the striped stem borer. IRRI, 1981.

Treatment[a]	Mortality[b]		
	1 DAT	7 DAT	14 DAT
Carbofuran 12 F	100 a	92 a	100 a
U 56295 85 WP	100 a	100 a	100 a
U 57770 85 WP	100 a	100 a	92 a
UC 54229 100 Tech.	100 a	100 a	100 a
UC SF-1 40 F	100 a	98 a	100 a
Pirimiphos-methyl + carbophenothion 20 EC	100 a	30 b	2 b
Buprofezin 50 WP	0 b	0 c	8 b
Control	0 b	0 c	5 b

[a]Applied at 0.75 kg a.i./ha. [b]Av of 4 replications; 10 larvae/treatment. Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 16. Greenhouse evaluation of commercial insecticides applied as foliar sprays against the yellow stem borer *Scirpophaga incertulas*. IRRI, 1981.

Treatment[a]	Mortality[b] (%)		
	1 DAT	7 DAT	14 DAT
Carbofuran 12 F	100 a	100 a	58 bcd
BPMC + chlorpyrifos 31.5 EC	100 a	95 ab	60 bc
Phosmet 50 WP	100 a	95 ab	85 a
Fenitrothion 50 EC	100 a	91 ab	41 cdef
Monocrotophos 16.8 EC	100 a	90 ab	31 cdefg
Azinphos ethyl 40 EC	100 a	79 bc	76 ab
Methomyl 20 EC	100 a	55 cd	25 efg
Dimethoate 40 EC	100 a	41 de	28 fg
Phosphamidon 50 EC	100 a	36 de	25 efg
Diazinon 20 EC	100 a	24 e	32 defg
Fenthion 50 EC	99 abc	42 de	32 defg
Carbophenothion 25 WP	99 abc	91 ab	58 bcd
Endosulfan 35 EC	89 bc	88 b	54 bcde
BPMC 50 EC	49 d	28 de	20 fg
Bacillus thuringiensis	40 d	19 e	15 fg
Control	8 e	14 e	9 g

[a]All insecticides applied at 0.75 kg a.i./ha, except *B. thuringiensis*, which was applied at 0.4 kg formulation (16,000 IU/mg)/ha. [b]Mortality readings taken 2 days after larvae were placed on treated stem pieces. Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 17. Knockdown and residual effect of insecticides applied as sprays on flowering plants against the rice bug *Leptocorisa oratorius*. IRRI greenhouse, 1981.

Treatment[a]	Mortality[b] (%)		
	1 DAT	7 DAT	14 DAT
	Test 1		
UC 54229 100 WP	100 a	100 a	57 b
M 9918 20 OE	100 a	97 ab	77 a
M 10604 20 OE	100 a	87 b	43 bc
Monocrotophos 16.8 EC	100 a	37 c	20 c
Methiocarb 50 WP	100 a	20 cd	3 d
Methidathion 40 EC	93 a	10 de	0 d
UC 27867 50 WP	83 a	0 e	3 d
Cypermethrin 5 EC	57 b	3 e	0 d
Dioxathion 96 EC	3 c	3 e	0 d
US SE-1 40 F	3 c	3 e	0 d
Dioxacarb 50 WP	10 c	0 e	0 d
RP 32861 20 EC	0 c	13 de	0 d
EXP 5494 25 EC	0 c	3 e	0 d
RH 0994 48 EC	0 c	3 e	3 d
RH 0308 48 EC	0 c	0 e	3 d
Control (water)	0 c	3 e	0 d
	Test 2		
Monocrotophos 16.8 EC	100 a	73 a	27 a
NS 8265 57 EC	100 a	3 b	0 b
DPX 5188 20 EC	97 ab	3 b	3 b
Pirimiphos methyl + carbophenothion 20 EC	30 bc	0 b	0 b
Phoxim 50 EC	20 cd	10 b	0 b
UC/MP 19779 48 EC	13 cd	10 b	7 ab

Continued on opposite page

Table 17 continued

Treatment[a]	Mortality[b] (%)		
	1 DAT	7 DAT	14 DAT
MTI 500 20 EC	7 d	3 b	0 b
MTI 220 20 EC	7 d	0 b	0 b
U 57770 85 WP	3 d	7 b	0 b
U 56295 85 WP	3 d	0 b	0 b
Control	10 d	3 b	0 b

[a]All insecticides applied at 0.75 kg a.i./ha, except cypermethrin, MTI-500, and MTI-220, which were applied at 0.060 kg a.i./ha. [b]Av of 3 replications with 10 rice bug adults/replication. Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 18. Knockdown and residual effect of new and coded insecticides against adults and nymphs of the rice bug *Leptocorisa oratorius*. IRRI insectary, 1981.

Treatment[a]	Insect stage	Mortality[b] (%)		
		1 DAT	7 DAT	14 DAT
Monocrotophos 16.8 EC	Nymph	100 a	96 a	40 a
Monocrotophos 16.8 EC	Adult	93 a	62 b	25 ab
Pirimicarb + pirimiphos methyl 10.0 EC	Nymph	90 a	30 c	12 bc
Pirimicarb + pirimiphos methyl 10.0 EC	Adult	0 e	0 d	0 d
BPMC + decamethrin[c]	Nymph	98 a	72 b	38 a
BPMC + decamethrin[c]	Adult	15 bc	2 d	18 ab
BPMC + decamethrin[c] + neem oil	Nymph	92 ab	85 b	18 ab
BPMC + decamethrin[c] + neem oil	Adult	15 cd	2 d	2 cd
Control	Adult	8 cde	0 d	10 bcd
Control	Nymph	2 de	10 cd	5 bcd

[a]Applied at 0.75 kg a.i./ha for monocrotophos, 1 liter formulation/ha for pirimicarb + pirimiphos methyl, and 3 liters formulation/ha for BPMC + decamethrin volume 1000 liters/ha. [b]Mortality was assessed at 48 h after caging. Separation of means in a column by Duncan's multiple range test at the 5% level. Data transformed to Arcsin for analysis. DAT = days after treatment. [c]Formulation = 4.0 + 6 g a.i./liter.

Table 19. Antifeedant activity of fungicides against the brown planthopper *Nilaparvata lugens*.[a] IRRI insectary, 1981.

Fungicide	1 DAT		5 DAT	
	Honeydew area (mm^2)	Mortality (%)	Honeydew area (mm^2)	Mortality (%)
Dithane M-45 80 WP	916 a	0 a	1112 abc	13 a
Apron (CGA 48998) 35 WP	953 a	8 a	1393 ab	20 a
Fuji-One 40 EC	783 a	10 a	1056 bc	8 a
Benomyl 50 WP	806 a	13 a	1005 bc	10 a
GTA 29 EC	821 a	8 a	941 c	5 a
Kitazin 48 EC	819 a	3 a	1009 bc	13 a
Kasugamin 2 EC	991 a	13 a	1467 a	0 a
Hinosan 50 EC	921 a	3 a	1016 bc	3 a
Control	879 a	0 a	996 bc	3 a

[a]Area of honeydew and insect mortality were taken at 48 h after insects were caged at 10 insects/replication on sprayed plants. 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 the plants.

Table 20. Greenhouse evaluation of commercial insecticides broadcast in paddy water for control of the yellow stem borer *Scirpophaga incertulas*. IRRI, 1981.

Insecticide	Rate (kg a.i./ha)	Mortality[a] (%)		
		1 DAT	7 DAT	14 DAT
Carbofuran 3 G[b]	1.0	45 a	88 a	100 a
Carbofuran 3 G[b]	1.0	22 b	85 a	95 abc
Carbofuran 3 G[b]	1.5	29 ab	88 a	99 ab
Diazinon 5 G	1.0	32 ab	44 c	32 e
Diazinon 5 G	1.5	49 a	51 bc	31 e
Gamma-BHC + carbaryl 10 G	1.0	34 ab	50 bc	88 abc
Gamma-BHC + carbaryl 10 G	1.5	39 ab	68 b	84 cd
Gamma-BHC + MIPC 10 G	1.0	20 b	50 bc	72 d
Gamma-BHC + MIPC 10 G	1.5	32 ab	65 bc	91 bc
Control		8 c	11 d	9 f

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment, when larvae were placed on stem pieces. [b]Incorporated into the soil.

Table 21. Activity of insecticides applied as foliar spray in the field (0.75 kg a.i./ha) for whorl maggot and brown planthopper (BPH) control and the effect on associated predators — *Cyrtorhinus lividipennis*, spiders, and *Microvelia atrolineata*.[a] IRRI, 1981.

Insecticide	25 DT	35 DT
	Whorl maggot rating (0-9)	
Dioxacarb	5.98 a	3.18 ab
UC 27867	6.30 a	3.40 ab
RH 0994 (0.75)	6.43 a	3.05 ab
Methidathion	6.33 a	2.90 b
RP 32861	6.13 a	3.48 ab
Methiocarb	6.25 a	3.35 ab
RH 0994 (0.5)	5.40 a	3.08 ab
RH 0994 (0.25)	5.68 a	3.53 ab
Carbofuran	5.98 a	3.63 ab
Control	6.45 a	4.33 a

Insecticide	S_1D_1	S_1D_2	S_2D_1	S_2D_2	S_3D_1	S_3D_2	S_4D_1	S_4D_2
				BPH (no./hill)				
Dioxacarb	15 a	141 a	167 ab	296 a	355 c	820 a	1001 b	5366 bcd
UC 27867	12 a	89 a	152 ab	339 a	651 ab	743 a	1651 ab	14877 a
RH 0994 (0.75)	16 a	99 a	156 ab	388 a	525 abc	570 a	1334 ab	9615 ab
Methidathion	16 a	133 a	201 a	636 a	838 a	801 a	3884 a	17010 a
RP 32861	8 a	78 a	95 b	215 a	460 abc	531 a	1108 b	3984 bcd
Methiocarb	15 a	116 a	122 ab	339 a	452 bc	633 a	2137 ab	7525 abc
RH 0994 (0.5)	15 a	96 a	110 ab	266 a	411 bc	433 a	735 b	2586 d
RH 0994 (0.25)	24 a	134 a	176 ab	408 a	478 bc	566 a	1244 b	8351 bcd
Carbofuran	13 a	113 a	127 ab	409 a	472 abc	532 a	789 b	2206 d
Control	16 a	141 a	119 ab	370 a	434 c	601 a	594 b	3399 cd
				Cyrtorhinus (no./hill)				
Dioxacarb	5 a	4 a	19 ab	7 ab	48 a	0.75 d	34 abc	4 c
UC 27867	3 a	3 a	12 ab	12 ab	41 a	1.00 d	23 bc	66 a
RH 0994 (0.75)	4 a	4 a	19 ab	6 b	45 c	6.00 bc	28 abc	28 ab
Methidathion	4 a	5 a	26 a	6 b	66 a	2.00 cd	36 abc	4 c
RP 32861	2 a	4 a	10 b	11 ab	38 a	1.00 d	47 abc	3 c
Methiocarb	2 a	4 a	16 ab	8 ab	57 a	2.00 cd	18 c	2 c
RH 0994 (0.5)	5 a	4 a	19 ab	8 ab	33 a	11.00 b	32 abc	18 b
RH 0994 (0.25)	6 a	4 a	28 a	23 ab	39 a	14.00 b	68 ab	142 a
Carbofuran	2 a	6 a	22 a	22 ab	48 a	1.00 d	24 bc	6 c
Control	6 a	5 a	16 ab	44 a	70 a	57.00 a	66 a	62 a

Continued on opposite page

Table 21. Continued

Insecticide	S_1D_1	S_1D_2	S_2D_1	S_2D_2	S_3D_1	S_3D_2	S_4D_1	S_4D_2
				Spiders (no./hill)				
Dioxacarb	4 a	8 a	24 a	14 abc	19 a	17 a	21 a	28 abc
UC 27867	2 a	5 a	17 ab	13 bc	13 a	15 a	18 a	52 a
RH 0994 (0.75)	5 a	7 a	21 ab	23 abc	14 a	20 a	20 a	44 ab
Methidathion	6 a	8 a	22 ab	9 c	23 a	3 c	15 a	4 c
RP 32861	3 a	4 a	17 ab	28 ab	15 a	18 a	19 a	20 bc
Methiocarb	2 a	7 a	18 ab	18 abc	13 a	9 b	19 a	30 abc
RH 0994 (0.5)	5 a	7 a	14 b	20 abc	17 a	19 a	18 a	36 abc
RH 0994 (0.25)	3 a	4 a	25 a	29 a	15 a	21 a	15 a	45 ab
Carbofuran	2 a	6 a	18 ab	11 bc	16 a	9 b	11 a	18 c
Control	5 a	10 a	12 b	45 a	16 a	20 a	16 a	36 abc
				Microvelia (no./hill)				
Dioxacarb	1.00 a	0.00 a	4.00 a	1.00 a	9.5 a	15 a	8 ab	20 a
UC 27867	0.00 b	0.00 a	1.00 a	1.00 a	7.8 a	11 ab	5 ab	26 a
RH 0994 (0.75)	0.00 b	0.25 a	0.75 a	2.00 a	7.0 a	4 bc	10 a	14 ab
Methidathion	0.00 b	0.00 a	4.00 a	1.75 a	9.0 a	5 bc	6 ab	4 bc
RP 32861	0.00 b	0.25 a	0.50 a	0.50 a	4.2 a	3 c	3 b	3 c
Methiocarb	0.00 b	0.25 a	1.20 a	1.50 a	5.0 a	8 abc	5 ab	30 a
RH 0994 (0.5)	0.25 ab	0.00 a	0.75 a	1.00 a	9.5 a	6 abc	4 ab	5 bc
RH 0994 (0.25)	0.00 b	0.00 a	1.75 a	2.50 a	6.8 a	10 ab	6 ab	13 ab
Carbofuran	0.25 ab	0.00 a	2.20 a	1.75 a	5.5 a	6 abc	10 a	30 a
Control	0.25 ab	0.00 a	0.25 a	3.20 a	7.5 a	18 a	9 ab	16 ab

[a]Separation of means by Duncan's multiple range test at the 5% level. DT = days after transplanting. S_1, S_2, S_3, and S_4 = first, second, third, and fourth spray application at 20, 35, 50, and 65 DT, respectively. D_1 and D_2 = 1 day before and 2 days after application, respectively.

Table 22. Field evaluation of commercial insecticides for control of the yellow stem borer. Variety IR29. Maligaya Rice Research and Training Center. 1981 dry season.

Treatment[a]	Application method	Deadhearts[b] (%)			Whiteheads[b] (%)
		20 DT	40 DT	65 DT	
Phosphamidon	Spray	25.7 abcde	29.7 abc	14.4 bcd	7.0 abc
Endosulfan	Spray	31.0 abc	25.5 bcde	13.1 cde	7.3 abc
Chlorpyrifos + BPMC	Spray	11.1 g	8.7 fg	9.5 defg	7.5 ab
Monocrotophos	Spray	20.3 abcdefg	31.4 abc	11.9 cdefg	4.4 bcd
Carbaryl XLR	Spray	29.3 abc	38.5 ab	17.0 abc	6.1 abcd
B. thuringiensis[c]	Spray	15.0 efg	32.1 abc	19.6 abc	6.1 abcd
Azinphos ethyl	Spray	17.5 cdefg	17.9 efg	6.9 gh	5.9 abcd
Diazinon	Spray	14.2 efg	24.0 cde	12.4 cdefg	5.8 abcd
BPMC	Spray	32.1 a	28.8 abc	17.3 abc	7.3 ab
UCX 2001	Spray	18.4 bcdefg	9.7 fg	7.2 fgh	4.6 bcd
Triazophos	Spray	12.1 fg	8.4 g	10.0 defg	1.7 d
Propoxur	Spray	29.7 abc	29.9 abc	14.9 bcd	14.7 a
MTMC	Spray	27.8 abcd	31.4 abc	19.0 abc	7.0 abc
Aktrion	Spray	23.8 abcdef	36.2 abc	17.5 abc	7.9 ab
Carbaryl WP	Spray	33.7 a	26.8 bcd	12.2 cdefg	4.8 bcd
MIPC	Spray	29.8 abc	34.3 abc	17.0 abc	7.3 abc
Acephate	Spray	15.5 defg	16.9 def	9.4 defg	3.8 bcd
Carbofuran	Granular broadcast	10.8 fg	0.6 h	3.8 h	1.9 cd
Gamma BHC + carbaryl	Granular broadcast	25.1 abcde	35.1 abc	15.7 bcd	8.3 ab
Gamma BHC	Granular broadcast	27.8 abcde	40.6 a	25.5 a	7.4 ab
Diazinon	Granular broadcast	17.2 cdefg	33.1 abc	12.9 cdef	7.2 ab
Endosulfan	Granular broadcast	30.7 ab	32.8 abc	16.4 bcd	5.4 bcd
Untreated check	Granular broadcast	32.3 a	38.9 a	21.4 ab	7.7 ab

[a]Insecticides were applied 5 times: 10, 25, 45, 60, and 75 days after transplanting (DT). All the insecticides were applied as a foliar spray except the granular formulations, which were broadcast into the paddy water by hand. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. [c]30 billion spores/g.

Table 23. Activity of buprofezin 50 WP against the brown planthopper and the green leafhopper in 3 growth stages treated in the Potter's spray tower. IRRI, 1981.

Treatment[a]	Insect stage	Mortality[b] (%)					
		Brown planthopper			Green leafhopper		
		1 DAT	3 DAT	6 DAT	1 DAT	3 DAT	6 DAT
Buprofezin	3rd instar	6 a	94 a	100 a	1 b	69 a	95 a
Control	3rd instar	1 b	3 c	5 cd	1 b	5 b	5 c
Buprofezin	5th instar	8 a	55 b	91 b	5 ab	65 a	81 b
Control	5th instar	0 b	3 c	3 d	1 b	5 b	6 c
Buprofezin	Adult	5 ab	8 c	10 c	8 a	8 b	9 c
Control	Adult	3 ab	8 c	9 c	4 ab	6 b	9 c

[a]Applied at 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.

Table 24. Activity of buprofezin applied as a foliar spray against the brown planthopper and the green leafhopper in 3 growth stages. IRRI greenhouse, 1981.

Treatment[a]	Insect stage	Mortality[b] (%)					
		Brown planthopper			Green leafhopper		
		2 DAC	4 DAC	6 DAC	2 DAC	4 DAC	6 DAC
Buprofezin 50 WP	3rd instar	45 a	75 a	89 a	18 a	64 a	81 a
Control	3rd instar	8 b	9 b	9 b	0 b	4 b	6 bc
Buprofezin 50 WP	5th instar	40 a	70 a	85 a	13 a	65 a	94 a
Control	5th instar	3 c	6 b	8 c	3 b	8 b	10 bc
Buprofexin 50 WP	Adult	9 b	9 b	20 b	4 b	8 b	13 b
Control	Adult	6 bc	9 b	10 bc	0 b	3 b	4 c

[a]Applied at 0.75 kg a.i./ha. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. DAC = days after caging on treated plant.

several insectary and field tests were conducted against hoppers and other pests and natural enemies.

Toxicity to hoppers. Buprofezin applied to BPH and GLH nymphs and adults in the Potter's spray tower and as a foliar spray was equally effective against the third- and fifth-instar BPH and GLH but had no effect on adults (Table 23, 24). Because buprofezin is a growth regulator, the hopper is killed at molting — 1-3 DAT. In another test, mortality of BPH, GLH, and WBPH treated with 3 rates of buprofezin was equal to that of carbofuran at 6 days after hoppers were caged on treated plants (Table 25). Residual activity of 0.125 kg buprofezin a.i./ha was superior to that of 0.75 kg BPMC commercial insecticide a.i./ha against BPH (Table 26).

Buprofezin was compared with BPMC in a greenhouse and field experiment (Table 27). In both tests, buprofezin was superior to BPMC in residual activity. In another field test, buprofezin and BPMC were applied 3 times and BPH counts were made 5, 10, and 15 days after each application (Table 28). BPH populations at the 0.125 kg a.i./ha rate of BPMC were equal to those at 0.75 kg a.i./ha.

Buprofezin was compared with *Annona* oil and MIPC in field conditions (Table 29). Mortality of caged BPH in the buprofezin treatment was equal to that in the MIPC treatment. Because of the thick canopy, none of the treatments provided effective BPH control at 65 DAT.

Toxicity to striped stem borer and rice bug. In insectary studies, buprofezin had no toxic effect on the striped stem borer (Table 30) and rice bug nymphs and adults (Table 31).

Ovicidal activity. Eggs of the rice bug and leaffolder were dipped in a solution of buprofezin and carbofuran. Carbofuran decreased hatching percentage; buprofezin had no effect (Table 32).

Toxicity to predators. In insectary studies, buprofezin was nontoxic to the natural enemies of

Table 25. Activity of foliar sprays of buprofezin 50 WP and carbofuran 12 F against nymphs of the brown planthopper (BPH), green leafhopper (GLH), and whitebacked planthopper (WBPH). IRRI insectary, 1981.

Insect	Buprofezin 1.0 kg/ha	Buprofezin 0.5 kg/ha	Buprofezin 0.25 kg/ha	Carbofuran 0.75 kg/ha	Control
			Mortality at 2 DAC[a]		
BPH	41.2 a	43.8 a	41.2 ab	100.0 a	2.5 ab
GLH	23.8 b	22.5 b	26.2 b	97.5 a	0.0 b
WBPH	48.8 a	47.5 a	50.0 a	98.9 a	6.2 a
			Mortality at 4 DAC[a]		
BPH	80.0 ab	77.5 b	80.0 b	100.0 a	6.2 ab
GLH	75.0 b	66.2 b	80.0 b	97.5 a	2.5 b
WBPH	88.8 a	88.8 a	92.5 a	100.0 a	12.5 a
			Mortality at 6 DAC[a]		
BPH	95.0 ab	92.5 a	95.0 a	100.0 a	8.8 a
GLH	88.8 b	88.8 a	92.5 a	97.5 a	8.8 a
WBPH	97.5 a	95.0 a	93.8 a	100.0 a	13.8 a

[a]Separation of means in a column, for each test, by Duncan's multiple range test at the 5% level. DAC = days after caging.

Table 26. Residual activity of buprofezin against 3rd-instar brown planthopper (BPH) nymphs placed on foliar-sprayed plants. IRRI insectary, 1981.

Treatment		Mortality[a] (%) of BPH nymphs		
Insecticide	Rate (kg a.i./ha)	1 DAT	7 DAT	13 DAT
Buprofezin 50 WP	0.125	100 a (a)	100 a (a)	59 b (b)
Buprofezin 50 WP	0.250	100 a (a)	99 a (a)	60 b (b)
Buprofezin 50 WP	0.500	99 ab (a)	99 a (a)	59 b (b)
Buprofezin 50 WP	0.750	100 a (a)	100 a (a)	71 a (b)
BPMC 50 WP	0.750	96 b (a)	56 b (b)	21 c (c)
Control		10 c (a)	14 c (a)	11 d (a)

[a]Insects were placed on treated plants at 1, 7, and 13 days after spraying, and mortality readings were taken 6 days after infestation at 7, 13, and 19 days after treatment (DAT). Separation of means in a column and in a row (in parentheses) by Duncan's multiple range test at the 5% level.

hoppers — *L. pseudoannulata, M. douglasi atrolineata,* and *C. lividipennis* (Tables 33-35).

Slow-release formulations. In 1981, the search for compounds that would provide longer residual activity than commercial insecticides continued. A slow-release spray formulation of methyl parathion and lignin-based granular formulations of carbofuran were evaluated.

Microencapsulated methyl parathion. In an insectary study against BPH and GLH, Penncap M provided longer residual activity than the EC formulation of methyl parathion (Table 36). GLH mortality at 15 DAT was 91.3% in the Penncap M treatment, 27.5% in the methyl parathion EC treatment.

Table 27. Residual activity of foliar sprays of buprofezin and BPMC on 3rd-instar brown planthopper nymphs. IRRI, 1981.

Days after treatment	Mortality[a] (%)		
	Buprofezin	BPMC	Control
	Greenhouse		
1	100 a	96 a	10 a
6	100 a	56 b	14 a
12	71 b	21 c	11 a
	Field		
1	100 a	75 a	0 a
5	95 a	1 b	0 a
10	18 b	0 b	0 a

[a]Insects were placed on treated plants at 1, 6, and 12 days after treatment and mortality readings were taken 48 h after infestation. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 28. Effect of 3 applications of buprofezin and BPMC against field populations of the brown planthopper *Nilaparvata lugens*. IRRI, 1981 wet season.

Treatment	Brown planthopper count[a]									
	2 DBFA	1st application			2nd application			3rd application		
		5 DAIA	10 DAIA	15 DAIA	5 DAIA	10 DAIA	15 DAIA	5 DAIA	10 DAIA	15 DAIA
Buprofezin 50 WP										
0.125 kg a.i./ha	30.7	11.0 a	11.5 a	10.5 ab	5.8 c	11.5 ab	5.5 d	3.3 b	2.5 b	2.7 bc
0.250 kg a.i./ha	26.2	10.4 a	11.2 a	9.5 b	6.2 c	11.9 ab	6.09 c	3.31 b	2.7 b	2.3 c
0.500 kg a.i./ha	27.6	10.1 a	11.6 a	10.2 ab	5.0 c	11.8 ab	6.3 c	3.47 b	2.8 b	2.5 bc
BPMC										
0.75 kg a.i./ha	25.6	11.0 a	12.1 a	12.1 a	6.5 b	7.9 b	7.1 b	3.3 b	3.1 b	4.7 b
Control	29.4	11.6 a	12.9 a	11.4 ab	16.4 a	18.5 a	16.0 a	13.7 a	13.2 a	14.7 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DAIA = days after insecticide application. DBFA = days before first application

Table 29. Mortality of the brown planthopper (BPH) when caged in field conditions on plants treated with foliar sprays of a growth regulator (buprofezin), a botanical insecticide, and a commercial insecticide (MIPC).

Treatment	BPH mortality[a] (%)			Grain yield (t/ha)
	1st spray 20 DT	2nd spray 40 DT	3rd spray 65 DT	
Buprofezin				
0.75 kg a.i./ha	87.5 ab	81.2 a	25.0 a	4.2 ab
0.50 kg a.i./ha	95.0 a	83.8 ab	23.5 ab	4.7 a
Annona oil				
0.75 kg a.i./ha	76.2 b	66.2 c	12.5 abc	4.2 ab
0.50 kg a.i./ha	83.8 b	67.5 bc	11.2 bc	4.0 ab
MIPC				
0.75 kg a.i./ha	76.2 b	88.8 a	16.2 abc	4.7 a
0.50 kg a.i./ha	76.2 b	81.2 abc	16.2 abc	3.6 ab
Control	6.2 c	8.8 d	5.0 c	3.3 b

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

Table 30. Activity of buprofezin and carbofuran as foliar spray against the striped stem borer *Chilo suppressalis*. IRRI insectary, 1981.

Treatment[a]	Mortality[b] (%)
Carbofuran 12 F	100 a
Buprofezin 50 WP	4 b
Control	1 b

[a]Applied at 0.75 kg a.i./ha. [b]Twenty larvae per application were placed on plants 1 day after spraying. Mortality was recorded 6 days after infestation. Separation of means in a column by Duncan's multiple range test at the 5% level.

Slow-release formulations of carbofuran. In a dry- and wet-season field study, lignin-based formulations of carbofuran were evaluated. In the wet season, residual activity of the slow-release formulations (CLFG and CLF) against BPH and GLH was similar to that of carbofuran (Table 37). In the dry-season test against GLH, results were similar (Table 38). However, the slow-release formulation of CLF at 0.5 kg a.i./ha controlled tungro virus infestation more effectively than the same rate of carbofuran (Table 39). The CLFG treatment had the lowest whitehead damage.

Application methods. Two methods of applying foliar sprays — the common knapsack sprayer and the spinning-disc ULV sprayer — were compared. In another test, three methods of applying carbofuran into the root zone were compared.

Spinning-disc ULV sprayer. Control of the whorl maggot, BPH, and GLH with the knapsack sprayer was similar to that with the spinning-disc

Table 31. Evaluation of monocrotophos 16.8 EC and buprofezin 50 WP as foliar sprays against 3rd-instar nymphs and adults of the rice bug *Leptocorisa oratorius*. IRRI insectary, 1981.

Treatment[a]	Insect stage	Mortality[b] (%)		
		1 DAC	3 DAC	4 DAC
Monocrotophos	3rd instar	100 a	100 a	100 a
Buprofezin	3rd instar	0 b	3 b	10 b
Control	3rd instar	0 b	0 b	3 b
Buprofezin	Adult	0 b	3 b	10 b
Control	Adult	0 b	5 b	10 b

[a]Applied at 0.75 kg a.i./ha. [b]Insects caged on plants 1 day after spraying. Data cumulative over days. Separation of means in a column by Duncan's multiple range test at the 5% level. DAC = days after caging on sprayed plants.

Table 32. Ovicidal activity of carbofuran 12 F and buprofezin 50 WP against the leaffolder *Cnaphalocrocis medinalis* and the rice bug *Leptocorisa oratorius*. IRRI insectary, 1981.

Treatment[a]	Hatched eggs[b] (%)	
	Leaffolder	Rice bug
Carbofuran	63 b	40 b
Buprofezin	97 a	89 a
Control	94 a	89 a

[a]Eggs were dipped in a 0.075% concn of the insecticides for 2 s. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 33. Activity of buprofezin on planthopper and leafhopper predators treated in the Potter's spray tower. IRRI, 1981.

Treatment[a]	Mortality[b] (%)			
	1 HT	4 HT	24 HT	48 HT
	Lycosa pseudoannulata			
Carbofuran	53 a	90 a	90 a	90 a
Buprofezin	0 b	0 b	0 b	0 b
Control	0 b	0 b	0 b	0 b
	M. douglasi atrolineata			
Carbofuran	20 a	23 a	48 a	50 a
Buprofezin	0 a	2 ab	8 b	22 ab
Control	0 a	0 b	5 b	5 b
	Cyrtorhinus lividipennis			
Carbofuran	78 a	80 a	85 a	100 a
Buprofezin	0 b	0 b	5 b	15 b
Control	0 b	0 b	0 b	2 b

[a]Insecticide applied at 0.75 kg a.i./ha. [b]Separation of means in a column by Duncan's multiple range test at the 5% level. HT = hours after treatment.

sprayer (Table 40). Only 6 liters/ha of spray volume are required with the spinning-disc sprayer; 300 liters or more are required with the knapsack.

Root-zone application. Three methods of applying carbofuran to the soil — injection with a row-marker injector, broadcast of granules and incorporation into the soil with a tiller, and application of granules to seedlings planted with a manual transplanter — were compared (Table 41). At the 0.5 kg a.i./ha rate of carbofuran, all of the application methods tested effectively controlled tungro virus. At 0.25 kg a.i./ha, tungro virus was highest in the soil incorporation treatment.

Seed treatment for rainfed dry-seeded bunded rice. Ants were suspected to have caused the stand reduction of the 1980 direct-seeded rice crop in the rainfed wetland Cagayan Province site in northern Luzon. With their perennial refuges in rice bunds,

Table 34. Contact toxicity of carbofuran 12 F and buprofezin 50 WP against nymphs of the predaceous spider *Lycosa pseudoannulata* treated in the Potter's spray tower. IRRI, 1981.

Treatment[a]	Mortality and molting[b] (%)							
	1 DAT		3 DAT		6 DAT		9 DAT	
	Mortality	Molting	Mortality	Molting	Mortality	Molting	Mortality	Molting
Carbofuran	93 a	0	93 a	0	93 a	3	93 a	7
Buprofezin	0 b	0	0 b	7	0 b	47	0 b	100
Control	0 b	13	0 b	20	0 b	43	0 b	100

[a]Applied at 0.75 kg a.i./ha. [b]Data cumulative over days. Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 35. Contact toxicity of carbofuran 12 F and buprofezin against the predators *Cyrtorhinus lividipennis* and *M. douglasi atrolineata* treated in the Potter's spray tower. IRRI insectary, 1981.

Treatment[a]	Insect stage	Mortality[b] (%)			
		C. lividipennis		*M. douglasi atrolineata*	
		1 DAT	6 DAT	1 DAT	6 DAT
Carbofuran	Nymph	99 a	99 a	14 a	34 a
Buprofezin	Nymph	0 b	10 b	1 b	10 b
Control	Nymph	1 b	9 b	1 b	9 b
Buprofezin	Adult	1 b	9 b	1 b	4 bc
Control	Adult	1 b	8 b	0 b	3 c

[a]Applied at 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.

Table 36. Residual activity of foliar sprays of Penncap M and methyl parathion EC against the brown planthopper and the green leafhopper. IRRI, 1981.

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 F	100.0 a	86.3 a	95.0 a	90.0 a	26.3 a	32.5 a	100.0 a	100.0 a	100.0 a	100.0 a	68.8 a	62.5 a
Penncap M[c]	100.0 a	76.3 a	60.0 b	31.3 b	12.5 a	21.3 ab	100.0 a	92.5 a	97.5 a	91.3 a	40.0 b	36.3 b
Methyl parathion EC	83.8 b	31.3 b	11.0 c	16.3 bc	11.3 a	15.0 ab	100.0 a	71.3 b	20.0 b	27.5 b	6.3 c	11.3 b
Control	10.0 c	10.0 b	2.5 c	6.3 c	10.0 a	10.0 b	8.8 b	11.3 c	7.5 b	10.0 b	8.8 c	8.8 b

[a]Applied at 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. [c]A microencapsulated formulation of methyl parathion.

Table 37. Field evaluation of Kraft lignin slow-release formulations of carbofuran. Variety IR22. IRRI, 1981 wet season.

Treatment	Rate (kg a.i./ha)	Mortality[a]									
		Brown planthopper					Green leafhopper					
		2 DAT	7 DAT	12 DAT	17 DAT	22 DAT	2 DAT	7 DAT	12 DAT	17 DAT	22 DAT	27 DAT
CLFG 15	0.75	15 abc	35 bc	5 a	20 ab	33 a	65 b	50 bc	50 abc	80 a	78 a	0 a
CLFG 15	0.50	25 ab	20 c	23 a	10 ab	5 b	65 ab	50 bc	33 c	50 ab	15 c	0 a
CLF 45	0.75	25 ab	20 c	30 a	25 a	5 b	50 b	35 bc	50 abc	53 ab	15 c	10 a
CLF 45	0.50	10 bc	13 c	8 a	20 ab	18 ab	35 b	28 bc	53 abc	48 ab	43 abc	13 a
Carbofuran 3 G	0.75	30 ab	55 ab	5 a	8 ab	8 ab	75 ab	68 ab	43 bc	73 ab	35 abc	0 a
Carbofuran 3 G	0.50	13 bc	8 c	8 a	20 ab	10 ab	68 ab	50 bc	85 ab	65 ab	40 abc	3 a
Carbofuran 3 G + Polymer	0.75	45 a	73 a	30 a	5 a	5 b	100 a	90 a	63 abc	30 b	60 ab	5 a
Carbofuran 3 G + Polymer	0.50	23 ab	8 c	15 a	28 c	28 ab	75 ab	45 bc	90 a	50 ab	45 abc	3 a
Control		0 c	30 bc	3 a	0 b	25 ab	0 c	10 c	0 d	0 c	28 bc	17 a

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

Table 38. Mortality of field-caged green leafhopper on IR22 plants treated with carbofuran F and slow-release formulations of carbofuran. IRRI, 1981 dry season.

Treatment[a]	Formulation (% a.i.)	Rate (kg a.i./ha)	Mortality[b] (%)						
			3 DAT	8 DAT	13 DAT	18 DAT	24 DAT	34 DAT	44 DAT
CLF	45	1.5	78.1 a	74.7 a	69.1 a	92.5 a	60.0 a	37.5 ab	22.5 a
CLF	45	0.5	83.3 a	75.0 a	75.0 a	70.0 a	35.0 a	17.5 bc	5.0 ab
CLFG	15	1.5	37.5 a	39.2 a	92.5 a	74.4 a	67.5 a	57.5 a	17.5 ab
Carbofuran F	10	1.5	91.6 a	70.0 a	88.8 a	69.1 a	35.0 a	30.0 ab	17.5 ab
Carbofuran F	10	0.5	63.5 a	35.3 a	45.3 a	48.0 a	40.0 a	10.0 c	0.0 b

[a] All treatments were spot injected 2-5 cm deep near the base of the plant with a row-marker injector, except plots receiving treatments with CLFG formulation where the insecticide on cardboard strips was inserted manually close to the plant base. [b] All values shown were corrected by Abbott's formula to compensate for observed mortalities in the untreated control. Separation of means in a column by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 39. Field evaluation of lignin-based slow-release carbofuran formulations.[a] Variety IR22, IRRI, 1981 dry season.

Treatment[b]	Rate (kg a.i./ha)	Whorl maggot damage 30 DT	Tillers (no./hill) 30 DT	Deadhearts (%) 48 DT	Tungro virus (%) 91 DT	Productive tillers (no./hill) 91 DT	Whiteheads (%)	Grain yield (t/ha)
CLF 45	1.5	3.4 b	12.1 b	0.36 ab	1.09 c	21.3 b	2.31 a	5.99 a
CLF 45	0.5	3.1 b	14.7 a	0.10 b	1.10 c	20.5 bc	3.31 a	5.50 a
CLFG 15	1.5	3.9 b	14.1 ab	0.00 b	0.00 c	26.1 a	0.69 b	6.18 a
Carbofuran 10 F	1.5	1.5 c	16.5 a	0.25 ab	0.62 c	20.2 bc	2.68 a	5.75 a
Carbofuran 10 F	0.5	4.0 b	15.1 a	1.01 a	23.00 b	17.2 c	2.46 a	3.56 b
Control	0.0	7.8 a	9.7 c	0.62 ab	65.82 a	18.4 bc	3.77 a	2.21 c

[a] Separation of means in a column by Duncan's multiple range test at the 5% level. [b] All lignin-based formulations were injected into the root zone area with a row-marker injector 1 day before transplanting (DT).

Table 40. Effectiveness of foliar spray application method by growth stage. IRRI, 1981 wet season.

Treatment[a]	Whorl maggot damage[b]	Mortality[c] (%)			
		Brown planthopper		Green leafhopper	
		15 DT	45 DT	15 DT	45 DT
Knapsack sprayer	3.4 ab	34 a	6 a	93 a	81 a
ULV (spinning disc)	2.4 b	36 a	28 a	74 a	66 a
Control	3.9 a	6 a	6 a	10 b	8 b

[a]Monocrotophos applied at 0.75 kg a.i./ha. [b]Based on rating of 0-9: 0 = no damage, 9 = > 50% leaves damaged and some leaves broken. [c]Separation of means in a column by Duncan's multiple range test at the 5% level. DT = days after transplanting, when plants were sprayed.

ants could have built up populations in the fields during the 5-month dry fallow preceding wetland rice culture. IR52 rice seeds were treated with insecticides at 10 g a.i./kg dry seed. Insecticide and rice seeds were shaken in a plastic bag with no water or sticker. Treated seeds were hand sown in open plow furrows. One pass of a harrow covered the rows. Aldrin WP, bendiocarb WP, and diazinon dust gave significant stand increases over untreated control (Table 42).

Botanical insecticides. *Neem oil.* Neem oil's repellency, feeding and oviposition deterrency, and morphogenetic effects against the BPH and leaffolder have been reported earlier (Annual report for 1979, 1980). Topical application of neem oil on the early fifth-instar larvae ($\geq$ 62.5 μg/larva) of the rice ear-cutting caterpillar *Mythimna separata* produced pronounced developmental abnormalities during pupation and eclosion (Table 43). In the control, pupation was normal and healthy moths emerged. Hatchability was totally impaired when freshly laid ear-cutting caterpillar eggs were dipped once in neem oil formulations (Table 44). It also was reduced when eggs were treated with higher concentrations of corn oil, but dipping eggs in 1.66% detergent or in water had no effect.

Azadirachtin. Azadirachtin, a tetracyclic triterpenoid, is the active principle of neem oil. In insect pests, it produces such adverse biological effects as reduced feeding, abnormal growth and development, and poor survival, reproduction, and oviposition. The effect of azadirachtin on BPH, WBPH, and GLH was examined. When nymphs were caged on TN1 rice plants sprayed with azadirachtin, growth and development of the first instar BPH, WBPH, and GLH nymphs were significantly reduced (Table 45). When nymphs were caged on TN1 plants grown in soil incorporated with $\geq$ 1 μg azadirachtin/pot, growth and development of nymphs were also significantly reduced indicating a valuable systemic effect (Table 46). The systemic effect lasted more than a month. Even when infested repeatedly, nymphs failed to reach the adult stage. Development proceeded normally in control.

Chinaberry, custard-apple, and neem seed oil. Chinaberry *Melia azedarach* and custard-apple Annona sp., widely grown in a number of rice-growing countries, are known to possess antifeedant and insecticidal properties. Chinaberry and custard-apple and neem seed oil were evaluated for effectiveness against BPH, WBPH, and GLH. After being sprayed with seed oil formulations of chinaberry, custard-apple, and neem, females of all three test species ingested less food (Table 47). The effective oil concentration for BPH was $\geq$ 5 mg/plant; for WBPH and GLH, $\geq$ 10 mg/plant. At these concentrations, ingestion of food by the insects was significantly reduced to about one-half that in the control. Chinaberry seed oil was as effective as custard-apple seed oil in reducing food intake (Table 48). These two oils were better feeding deterrents than neem oil.

Pure fractions of an indigenous plant extract. The biological effects of selected pure fractions of an indigenous plant extract were tested against the BPH (biotype 1). Differences in the mortality rate of BPH females treated with different doses of the extract fractions were significant (Table 49). Mortality rate increased with dosage. Fraction 3 was as effective as fraction 5. At 50 μg, both fractions killed 97.5% of the treated insects. The mortality

rate was twice as high with these two fractions as with the highest dose of fraction 6 (43.9%).

BIOLOGICAL CONTROL

Insect parasitic on planthopper nymphs and adults. A simple method of rearing the dryinid *Pseudogonatopus flavifemur,* a common parasite of planthoppers, on BPH nymphs was developed. Three cages with plants were used, one for parasitizing hosts, one for rearing parasitized hosts and collecting parasite pupae, and one for collecting emerging adult parasites. About 10 days were needed for egg and larval development and another 10 for pupal development. In greenhouse cages, each female parasite was found to feed on about 50 hoppers and to lay eggs in another 400, killing more than 400 hoppers in a 12-day life span. In equal-choice experiments the parasite preferred BPH to WBPH, larger to smaller BPH nymphs, and nongravid to gravid BPH females for oviposition.

Parasites that increase their killing activity when more pests are present are especially beneficial to pest control. When caged with an increasing number of BPH nymphs, *P. flavifemur* females increased their parasitization activity (Fig. 11).

Parasites were reared in the laboratory and female adults were released in a field infested with BPH. Parasitization of BPH increased, but the BPH population declined only slightly.

Insect diseases. *Fungal pathogens of hoppers.* Control of hoppers with fungi was investigated in collaboration with the Boyce Thompson Institute for Plant Research and the USDA-SEA Insect Pathology Research Unit, Ithaca, New York, USA.

Diseased hoppers were collected in China, Indonesia, and the Philippines. The fungi *Erynia delphacis* and *Hirsutella citriformis* were cultured for bioassay against rice hoppers. Several imported strains showed moderate virulence against rice hoppers at IRRI.

Imported *Beauveria bassiana* was sprayed twice at 10^{13} spores/ha in a field heavily infested with BPH. Up to 50% disease infection developed, but plots still suffered varying degrees of hopperburn.

Greenhouse cultures of the zigzag leafhopper *Recilia dorsalis* are often killed by the green mus-

Table 41. Comparison of methods of applying carbofuran for effective pest control.[a] Victoria, Laguna, Philippines, 1981 wet season.

Application method[b]	Rate (kg a.i./ha)	Whorl maggot damage		*N. virescens* (no./10 sweeps)		Deadhearts (%)		*N. lugens* (no./20 hills)		Rice bugs (no./m²)	Tungro virus (%)	Grain yield (t/ha)
		17 DT	41 DT	41 DT	48 DT	55 DT	41 DT	66 DT	41 DT	62 DT	72 DT	93 DT	
Row-marker injector	0.50	2 c	1 d	5 a	44 a	54 a	2 a	4 a	12 b	8 ab	12 a	1 b	3.57 a
	0.25	3 b	2 bc	7 a	35 a	32 a	0 a	1 b	13 b	6 b	11 a	7 ab	3.01 ab
Soil incorporation	0.50	3 bc	1 d	8 a	61 a	53 a	0 a	2 ab	18 ab	4 b	16 a	2 ab	3.37 a
	0.25	3 b	2 c	18 a	85 a	70 a	0 a	1 ab	19 ab	5 b	8 a	32 a	2.56 b
Manual transplanter	0.50	3 b	3 abc	6 a	60 a	61 a	1 a	2 ab	20 ab	17 a	11 a	1 b	3.19 ab
	0.25	3 b	3 ab	24 a	116 a	82 a	1 a	1 ab	35 a	10 ab	10 a	9 ab	3.29 ab
Control		6 a	4 a	23 a	128 a	117 a	0 a	1 b	21 ab	10 ab	12 a	9 ab	2.82 ab

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. [b]All treatments were applied once. A flowable formulation of the insecticide was suspended in 125 liters water/ha and injected into the root-zone area with a row-marker injector 1 day before transplanting (DT). The granular formulation of the insecticide was either broadcast into the top soil and soil incorporated 1 DT or evenly distributed on top of the seedbed and transplanted the following day with a manual rice transplanter. [c]Based on rating of 0-9: 0 = no damage, 9 = > 50% leaves damaged and some leaves broken.

Table 42. Comparison of insecticides as seed treatments on rainfed dry-seeded bunded IR52 rice.[a] Solana, Cagayan, June 1981.

Insecticide[b]	Plant stand[c] 15 DE[d] (no. plants/50-m row)
Aldrin 40 WP	1948 a
Bendiocarb 80 WP	1680 a
Diazinon 10 Dust	1559 a
BPMC 40 WP	1439 ab
Carbaryl 80 WP	1395 ab
Control	1043 b

[a]Replicated twice within each of 2 fields. [b]4 g a.i./kg seed. Seeding rate = 100 kg/ha. Diazinon (Basudin), BPMC (Shellcarb), carbaryl (Sevin). [c]Ten random samples of 5-m row/replication. Separation of means in a column by Duncan's multiple range test at the 5% level. Ants suspected as seed pests before seedling emergence. [d]Days after emergence.

Table 43. Developmental abnormality caused in 5th-instar rice ear-cutting caterpillars topically treated with neem oil. IRRI, 1981.

Dose (μg/larva)	Abnormal or dead adults[a] (%)
0 (control[b])	9 c
62.5	43 b
125	88 a
250	84 a
500	100 a

[a]Separation of means by Duncan's multiple range test at the 5% level. Av of 4 replications, 10 larvae/replicate. [b]Treated with acetone.

Table 44. Effect of various dip treatments on hatching of ear-cutting caterpillars. IRRI, 1981.

Treatment	Eggs hatched[a] (%)
1.66% Teepol (control)	100 a
Water (control)	86 a
6% corn oil	39 b
12% corn oil	10 c
25% corn oil	10 c
50% corn oil	5 c
6% neem oil	0 c
12% neem oil	0 c
25% neem oil	0 c
50% neem oil	0 c

[a]Separation of means by Duncan's multiple range test at the 5% level. Av of 4 replications; 8-140 eggs/egg mass per replicate.

cardine fungus *Metarhizium anisopliae*. Spraying rice plants with a fungicide before using them as food for hoppers could remedy this problem. When added to spores of *M. anisopliae*, the fungicides manzeb, benomyl, and thiophanate-methyl completely prevented spore germination.

Table 45. Growth and development of 1st-instar brown planthopper (BPH) (biotype 2), whitebacked planthopper (WBPH), and green leafhopper (GLH) nymphs caged on TN1 rice plants sprayed with azadirachtin. IRRI, 1981.

Dosage (mg/5 tillers per pot)	Nymphs becoming adults[a] (%)		
	BPH	WBPH	GLH
0 (control[b])	95	83 a	93
1	5	45 b	18
2	0	13 cd	5
3	3	20 c	3
4	0	3 de	3
5	0	0 e	0

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Av of 4 replications, 10 1st-instar nymphs/replicate. Statistical analysis not performed for BPH and GLH nymphs because of the negligible percentage of nymphs reaching adult stage. [b]Sprayed with 3 ml acetone/pot.

Microbial control with Bacillus thuringiensis. Three commercial formulations of *Bacillus thuringiensis* were tested for toxicity to the ear-cutting caterpillar *Mythimna separata*. Dipel and Bactospeine gave good control of the larvae in 3 days.

Hopper predators. *Bugs. Cyrtorhinus lividipennis* feeds on the eggs of many rice hoppers. When given a choice among BPH, WBPH, and GLH eggs, it slightly but significantly preferred BPH eggs.

A small predacious water strider, *Microvelia douglasi atrolineata,* is an important predator of BPH (Annual report for 1980). When given a choice of attacking several different instars or adults of BPH, *Microvelia* clearly preferred to attack first-instar nymphs. It attacked larger BPH as well. To a limited extent, *Microvelia* attacked more prey if more were available. Successful attacks became more frequent if more predators were present, indicating that group hunting occurred.

Microvelia attacks hoppers that land on the water surface. Under normal conditions in the field and even in the greenhouse, BPH frequently fall off the plant and land on water.

Microvelia was also found to kill WBPH and GLH nymphs.

Microvelia aggregate in corners. This behavioral tendency was used in designing a special trap to catch *Microvelia* in flooded rice fields. The trap has a central cylinder from which a series of triangular vertical metal sheets radiate. *Microvelia* enter the cylinder through small slits adjacent to the metal

Table 46. Growth and development of 1st-instar brown planthopper (BPH) (biotype 2), whitebacked planthopper (WBPH), and green leafhopper (GLH) nymphs caged on TN1 rice plants grown in soil incorporated with azadirachtin. IRRI, 1981.

Dosage[b] (mg/5 tillers)	Nymphs becoming adults[a] (%)				
	BPH		WBPH		GLH
	1st infestation (26 Oct-13 Nov)	2nd infestation (14-Nov-4 Dec)	1st infestation (26 Oct-13 Nov)	2nd infestation (14 Nov-3 Dec)	One infestation (26 Oct-19 Nov)
0 (control[c])	85 a	90 a	80 a	93 a	85 a
1	25 b	87 a	45 b	73 ab	73 a
2	0 c	58 a	45 b	65 b	33 b
3	3 c	20 b	30 bc	75 ab	30 bc
4	6 bc	23 b	15 bc	50 bc	13 c
5	3 c	5 b	10 c	28 c	0 d

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Av of 4 replications, 10 1st-instar nymphs per replicate. [b]30- to 40-day-old TN1 rice plants grown in 9-cm-diam. plastic pots. [c]Treated with 1 ml acetone/pot.

Table 47. Quantity of food ingested by newly emerged brown planthopper (BPH) (biotype 1), whitebacked planthopper (WBPH), and green leafhopper (GLH) females caged on TN1 rice plants sprayed with seed oil of chinaberry, custard-apple, and neem. IRRI, 1981.

Insect	Dosage (mg/plant)	Quantity of food ingested daily[a] (mg/female)		
		Chinaberry oil	Custard-apple oil	Neem oil
BPH	0 (control[b])	27.63 a	33.82 a	30.23 a
	1	24.46 a	27.42 a	28.56 a
	5	14.72 b	13.97 b	21.52 b
	10	14.01 b	8.11 b	21.19 b
WBPH	0 (control[b])	12.54 a	12.76 a	18.04 a
	1	13.02 a	10.55 ab	16.51 a
	5	8.36 ab	5.91 b	14.93 a
	10	3.77 b	5.85 b	9.02 b
GLH	0 (control[b])	26.12 a	30.97 a	30.30 a
	1	23.81 ab	20.94 b	29.14 a
	5	17.23 bc	16.66 b	27.76 ab
	10	12.34 c	15.24 b	19.55 b

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Av of 7 replications, 5 females/replicate. [b]Sprayed with acetone.

sheets. One day's catch in the trap was much greater than the equivalent area density of *Microvelia* in the field, showing that the trap accumulated bugs. The trap provided a quick method of collecting and measuring the relative density of *Microvelia*.

Spiders. A common but small spider in rice fields, *Callitrichia formosana* attacks BPH at a low predation rate (Annual report for 1980). Its predation of second- and third-instar GLH nymphs is even lower. One GLH nymph was killed in 4-10 days. Nevertheless, *Callitrichia* may reach a field density of 10/hill, much higher than the population level of the larger and more voracious predator *Lycosa pseudoannulata*.

Lycosa has a high predation rate in greenhouse tests but it does not appear to suppress field hopper populations as much as is theoretically possible. *Lycosa* may feed on nonpest insects in the field. When given a choice, *Lycosa* slightly preferred to kill chironomid midge adults to BPH, but killed both midges and BPH.

General hopper predation. A physical exclusion trial showed the impact of predation on GLH nymphs. 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 15 days was 62% in closed

Table 48. Comparison of antifeedant effect of seed oils of chinaberry, custard-apple, and neem on food intake by newly emerged brown planthopper (BPH) (biotype 1), white-backed planthopper (WBPH), and green leafhopper (GLH) females caged on treated TN1 rice plants. IRRI, 1981.

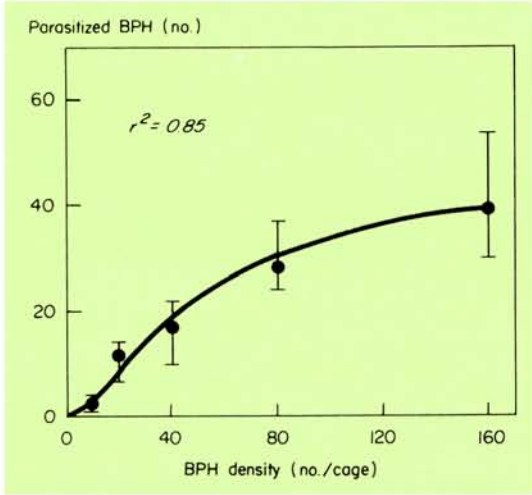
Insect	Dosage (mg/plant)	Quantity of food ingested daily[a] (mg/female)		
		Chinaberry oil	Custard-apple oil	Neem oil
BPH	0 (control[b])	27.63 a	38.82 a	30.23 a
	1	24.46 a	27.42 a	28.56 a
	5	14.72 ab	13.97 b	21.52 a
	10	14.01 b	8.11	21.19 a
WBPH	0 (control[b])	12.54 b	12.76 b	18.04 a
	1	13.02 ab	10.55 b	16.51 a
	5	8.36 b	5.91 b	14.93
	10	3.77 b	5.85 ab	9.02 a
GLH	0 (control[b])	26.12 a	30.97 a	30.30 a
	1	23.81 a	20.94 a	29.14 a
	5	17.23 b	16.66 b	27.76 a
	10	12.34 a	15.24 a	19.55 a

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. Av of 7 replications, 5 females/replicate. [b]Sprayed with acetone.

Table 49. Mortality of newly emerged brachypterous brown planthopper females (biotype 1) topically treated with different doses of selected fractions of the extract of an indigenous plant. IRRI, 1981.

Dose (μ/insect)	Mortality 24 h after treatment[a] (%)		
	Fraction 3	Fraction 5	Fraction 6
0 (control[b])	0 d (a)	0 c (a)	0 c (a)
1	38 c (a)	46 b (a)	13 b (a)
5	62 b (a)	57 a (a)	19 b (a)
10	92 a (a)	89 a (a)	19 b (a)
20	94 a (a)	95 a (a)	24 ab (a)
50	97 a (a)	97 a (a)	44 a (a)

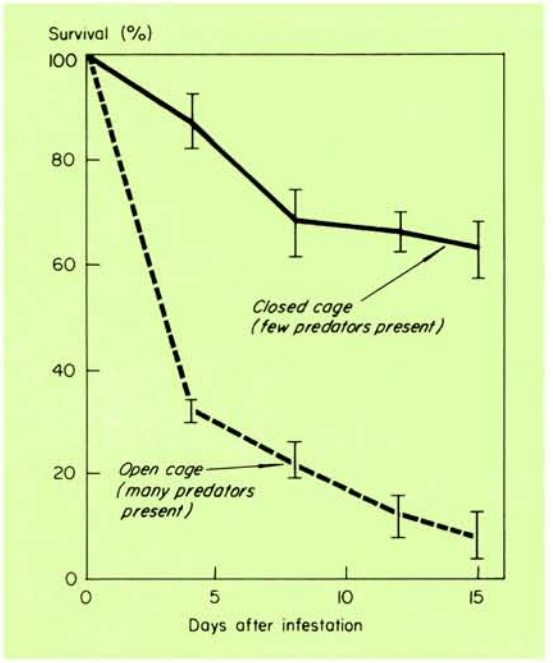
[a]Separation of means in a column and in a row (in parentheses) by Duncan's multiple range test at the 5% level. Av of 4 replications, 10 females per replicate. [b]Treated with acetone.



11. Relationship between density of 3d-instar brown planthopper (BPH) nymphs and parasitization in 24 h by a female wasp *Pseudogonatopus flavifemur* in a greenhouse cage.

cages, 8% in open cages (Fig. 12). Evidently the predators, which were much more abundant in the open than in the closed cages, were primarily responsible for the low GLH nymph survival.

Because natural predators are so useful in reducing pest populations, ways of conserving predators in rice fields were investigated. Predator densities are low after land preparation, when the rice habitat is virtually destroyed (Annual report for 1979). In a test of the effect of zero tillage on predator density, predators were more numerous for several



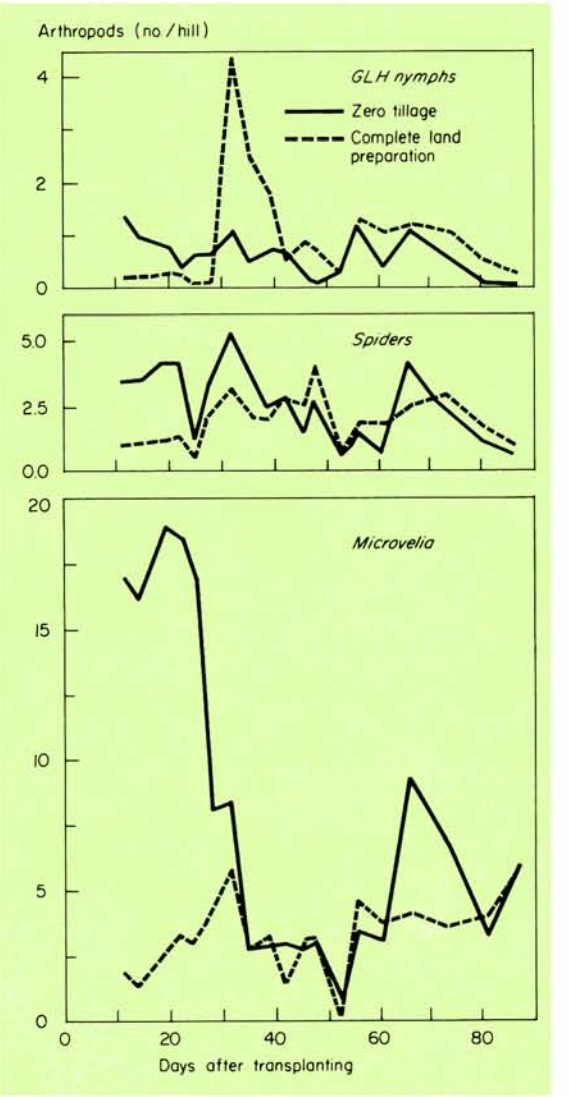
12. Survival of green leafhopper nymphs in closed or open (bottom edges lifted) 4-hill cages initially infested with 40 2d-instar nymphs in wetland fields. Vertical lines show ± S.E. of the mean. IRRI, 1981 dry season.

weeks in zero-tillage plots than in plots that had been prepared for transplanting (Fig. 13). Zero tillage can potentially be a predator conservation technique and can prevent hoppers, especially GLH (Fig. 13), from becoming abundant during the early crop period when there is danger of virus transmission by hoppers.

CULTURAL CONTROL

Synchronous planting. Asynchrony of planting time in irrigated rice fields increases with rice intensification. With irrigation, the timing of farm operations is no longer tied to the rainfall that tends to synchronize cultivation over a wide area. Within a large gravity irrigation system, factors such as head-end to tail-end variation in water delivery, structural design faults, excess water caused by inadequate drainage, and inefficient distribution at various levels of a system enforce staggering cultivation, as do difficulties in obtaining timely credit and shortages of transplanting labor or of power sources for land preparation.

Asynchrony between fields leads to a greater



13. Abundance of green leafhopper (GLH) nymphs and predacious spiders and *Microvelia* bugs in wetland IR42 rice plots with zero tillage or complete land preparation. IRRI, 1981 dry season.

potential for mobile pest buildups: populations developing in early planted fields, upon harvest, can disperse to fields planted later. Within a region, pests that at an early stage of population development are not regulated by the carrying capacity of the rice field habitat, such as those for which there is no significant host plant resistance, and those that are most effectively controlled by natural enemies are likely to be most affected by asynchrony.



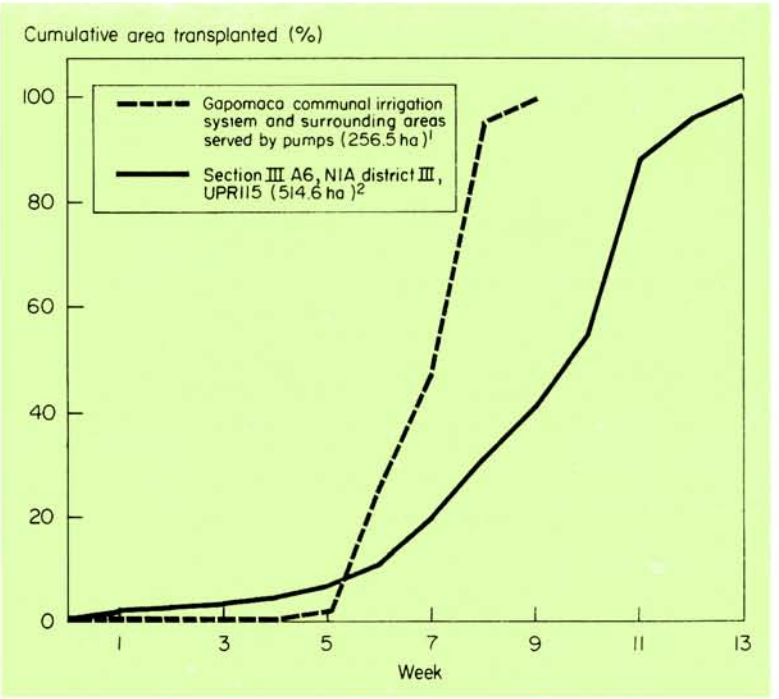
14. Area map of Nueva Ecija, Philippines, showing transects.

A major objective is to estimate the spatial and temporal dimensions of asynchrony. Each pest species differs in dispersal ability and potential for population increase over time. Parameters of space and time are crucial in evaluating the potential of synchronization as a community-level cultural pest control tactic.

The study area consisted of approximately 20,000 ha, mostly within District III of the Upper Pampanga River Integrated Irrigation System in Nueva Ecija, Philippines (Fig. 14). Double-cropped rice, mostly IR36 and IR42, is the predominant cropping pattern. A complete census of farmers' planting dates, farm areas, varieties, harvest dates, and yields was provided by the National Irrigation Administration (NIA).

Three transects of kerosene light traps have been set up, comprising 23 sites with 2 traps at each site. The traps are lit nightly by farmer-cooperators and the catch is collected in labeled bottles for later sorting and counting.

The transects traverse areas suffering from major



15. Cumulative area planted in 2 irrigation systems 7 km apart, illustrating the extremes of synchrony (section III A6) and asynchrony (Gapomaca) found in the project area. Variability of planting dates in a region can be expressed as a variance and the Gapomaca system would have the higher variance.
[1]Data courtesy of Ministry of Agriculture and cooperatives, Zaragoza, Nueva Ecija, Philippines.
[2]Data courtesy of National Irrigation Administration (NIA), Cabanatuan, Nueva Ecija, Philippines.

irrigation or drainage problems, at which a juxtaposition of early- and late-planted fields has been created, and are localized sources of asynchrony.

Figure 15 illustrates two extreme examples of local cropping patterns. Section IIIA6 is situated near an irrigation main canal and receives early and dependable irrigation, which, particularly in the dry season, ensures relatively synchronous cultivation. In Gapomaca Communal Irrigation System on the edge of the study area 7 km to the west, the lateral canals and control structures had not been completed by the 1981 dry season (January-April) and cultivation was delayed in the fields distant from the main canal.

Planting date variance is the major component of asynchronous cultivation where variation in time to maturity due to varietal differences is relatively unimportant.

The correlations between asynchrony at radii of 400 m and 1 km from the midpoint of each pair of light traps and the seasonal totals of 4 major pests from the 20 double-cropped sites where light traps were operating in the 1981 dry season are given in Table 50. The light traps on transect III were set up too late to monitor populations of rice green semilooper *Naranga aenescens*, caseworm *Nymphula depunctalis*, and *N. fluctuosalis*, which attack rice at early vegetation. No correlations with asynchrony are reported from these sites for these species. Yellow stem borer *Scirpophaga incertulas*, brown planthopper *Nilaparvata lugens*, and *N. bakeri* populations were starting to increase when the traps began operating.

Significant correlations were obtained for all four species. *Naranga aenescens* appeared to respond to the pattern of cultivation within 400 m but was unaffected by asynchrony over 1 km, indicating very local dispersal. For the other species, seasonal totals were more closely related to the pattern over 1 km. The high correlation between *Nilaparvata* spp. numbers and asynchrony on Transect 1 may be misleading, since the most asynchronous site, Batitang, was also the only one where substantial areas of traditional susceptible varieties were grown, which raised the local carrying capacity of the species. Removing this site from the analysis reduces the correlation to an insignificant level. On Transect 3, the correlation was negative, with no hint of a positive relationship.

In contrast, yellow stem borer totals are positively, but not significantly, correlated with asynchrony on Transect III. Over all 20 sites, there is a

Table 50. Correlation between asynchrony of cultivation, measured by the variance of planting dates within 400 m and 1000 m radii from paired kerosene light traps, and seasonal totals of 4 common insect pest genera. Nueva Ecija, 1981 dry season.

Insect	Correlation coefficient[a]					
	Transect 1[b]		Transect 3[c]		All sites[d]	
	Radius 0-400 m	Radius 0-1000 m	Radius 0-400 m	Radius 0-1000 m	Radius 0-400 m	Radius 0-1000 m
Naranga aenescens	0.885*	0.046	–	–	–	–
Nymphula depunctalis and *N. fluctuosalis*	0.615	0.760*	–	–	–	–
Scirpophaga incertulas	0.547	0.864**	0.148	0.579	0.130	0.476*
Nilaparvata lugens and *N. bakeri*	0.748*	0.920**	0.562	-0.515	0.287	-0.073

[a]Total insects collected correlated with variance of planting date. [b]9 sites. [c]7 sites. [d]20 sites.

positive and significant relationship. The primary varieties grown are resistant to current populations of BPH, but only moderately resistant to stem borers.

Figure 16 shows the detailed pattern of light trap totals over a 7-km segment of Transect 1, including Valeriana, a rainfed site not included in the first analysis. The two major sources of asynchrony in this region are a 35-ha estate in Santa Rita (Hacienda Ragudo), where 3 rice crops/year are planted in a deliberately staggered pattern, and Batitang, at the end of the NIA service area, where there is diversity of hydrological regimes over a short distance.

Around each of these areas, numbers of *Naranga aenescens*, *Nymphula* spp., and *Scirpophaga incertulas* rose sharply. At Manaol, a relatively synchronous area just a few hundred meters from the hacienda and about 1 km from Batitang, light trap catches of these three species were among the lowest recorded for any site. Monitoring of *Nephotettix virescens*, *N. nigropictus*, and *N. malayanus* began late, but in the fallow period after the dry-season crop, the pattern was similar, as was the trend of tungro infection in farmers' fields during the wet season.

The behavior of *Nilaparvata* spp. was quite different: no peak was observed near the hacienda, and the numbers from Batitang to the rainfed site at Valeriana rose. At both of these sites, insect-susceptible rice, mostly BE3, are grown.

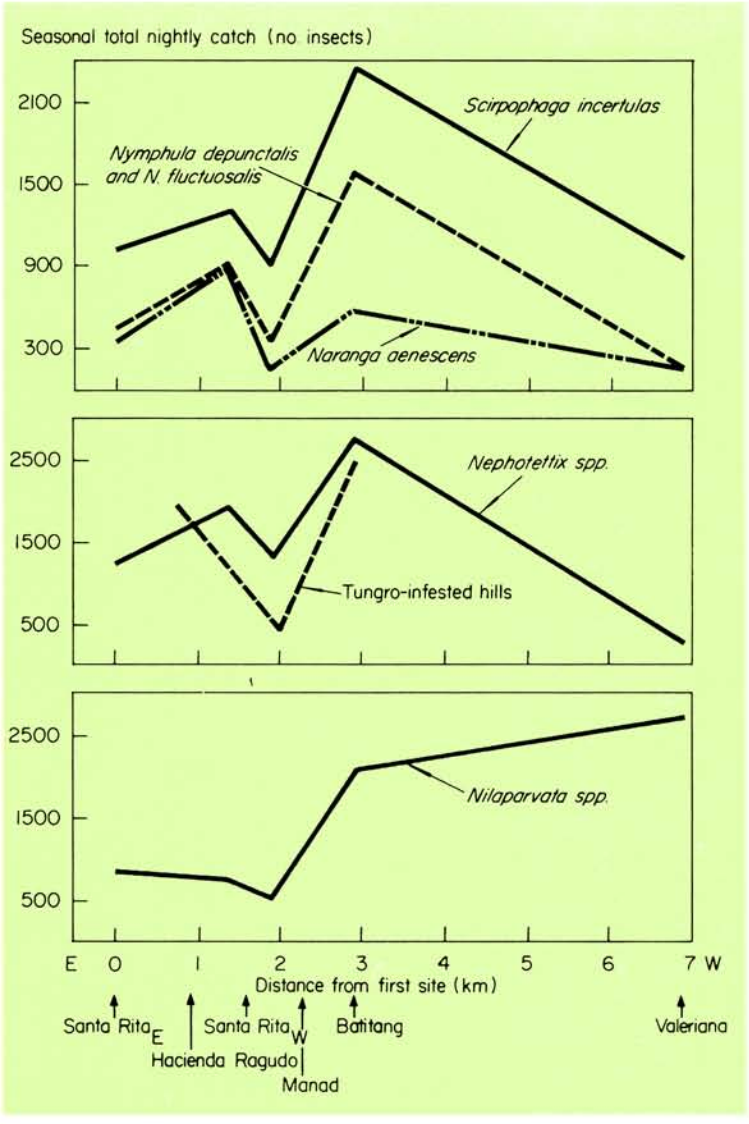
Short-duration variety for BPH control. Studies that began in 1980 indicated that early-maturing rices could escape BPH damage if they were harvested before the damaging third generation occurred. In 1981, two BPH-susceptible cultivars, intermediate-duration variety IR20 and very early-maturing line IR19735-30-3-3-2, were compared. To increase the BPH populations, a resurgence-inducing insecticide was sprayed as one treatment. BPH and its predators were counted (Table 51). With the resurgence-inducing insecticide, BPH populations in IR20 reached 2,986/5 hills at 88 DT, and 55% of the plots were hopperburned. In IR19735, populations were only 250/5 hills and no hopperburn occurred. In IR20, yields were higher in unsprayed plots than in those sprayed. IR19735 yields were similar in both treatments. Natural enemy populations were similar in all treatments except the spraying of IR20 at 73 DT, in which *C. lividipennis* increased because of the high BPH population.

INTEGRATED PEST MANAGEMENT

Insecticides with selective toxicity to natural enemies. Insecticides that will provide effective control of BPH with a low level of toxicity to hopper predators are being evaluated. Commercially available insecticides were applied as a foliar spray in the Potter's spray tower (Table 52). Based on LC_{50} data in the foliar spray test, the synthetic pyrethroids, cypermethrin, and decamethrin and the carbamates FMC35001 (carbosulfan) were the most toxic. In the Potter's spray tower test, carbofuran, cypermethrin, decamethrin, and propoxur were the most toxic.

Decamethrin was highly toxic to the three BPH predators tested (Table 53). All insecticides were toxic to *C. lividipennis*.

To determine the effect of the insecticides on BPH caged with predators *C. lividipennis* and *M.*



16. Pest abundance measured along a 7-km east-west transect of paired kerosene light traps (Transect 1). Hacienda Ragudo and Batitang are areas of extreme local (1 km) asynchrony. Substantial areas of BPH-susceptible traditional varieties are planted at the end of the dry season in Batitang and Valeriana; most fields in Valeriana are fallow through the dry season. Nueva Ecija, Philippines, 1981.

douglasi atrolineata, plants were sprayed with the median lethal concentration for BPH. High BPH mortality indicated either insecticide's high toxicity to the BPH or its low toxicity to the predator. Mortality of the BPH 1 DAT indicated that carbofuran and FMC35001 were selectively toxic to BPH. Cypermethrin had low toxicity to BPH caged with *C. lividipennis* and *M. douglasi atrolineata* (Table 54) caged with the spider *L. pseudoannulata*. Decamethrin was selectively more toxic to the spider than were the other insecticides (Table 55).

Compatibility of resistant varieties and insecticides. Three moderately resistant (MR) and one resistant (R) variety were compared with BPH-susceptible TN1 (Table 56). BPH reared on the five rice varieties were sprayed in the Potter's spray tower and placed on susceptible TN1 seedlings. BPH reared on resistant and moderately resistant varieties were more sensitive to the three insecticides than those reared on susceptible TN1.

Economics of insect control. Dry- and wet-season studies were conducted in farmers' fields in Laguna and Nueva Ecija provinces, Philippines.

Table 51. Brown planthopper (BPH) and predator populations in a BPH-susceptible, intermediate-duration variety IR20, and a susceptible, very early-maturing IR19735-30-3-3-2, with and without sprays of BPH resurgence-inducing insecticide. Victoria, Laguna, 1981 dry season.

Treatment[b]	Population of insects (no./5 hills) sampled at												
	17 DT	23 DT	27 DT	31 DT	36 DT	45 DT	58 DT	62 DT	66 DT	73 DT	88 DT	Hopper-burn	Yield (t/ha)
						BPH[a]							
IR20 with spray	0 a	3 a	8 a	12 a	40 a	79 a	555 a	492 a	443 a	3513 a	2986 a	55 a	1.66 c
IR20 without spray	0 a	2 a	7 a	14 a	26 ab	60 a	569 a	444 a	570 a	2532 a	751 b	7 b	3.48 b
IR19735-30-3-3-2 with spray	0 a	1 a	5 a	3 b	8 b	17 b	73 b	85 c	35 b	152 b	250 c	0 b	5.81 a
IR19735-30-3-3-2 without spray	0 a	1 a	11 a	7 ab	11 b	17 b	87 b	124 b	59 b	261 b	177 d	0 b	5.79 a
						Cyrtorhinus lividipennis							
IR20 with spray	0 a	0 a	1 a	4 a	4 a	8 a	3 ab	9 a	3 bc	21 bc	290 b		
IR20 without spray	1 a	0 a	2 a	4 a	7 a	8 a	11 a	6 a	19 a	67 a	436 a		
IR19735-30-3-3-2 with spray	0 a	0 a	1 a	1 a	2 a	2 b	1 b	4 a	2 c	10 c	93 c		
IR19735-30-3-3-2 without spray	1 a	0 a	2 a	2 a	1 a	3 b	2 b	5 a	6 ab	24 b	53 d		
						Spiders							
IR20 with spray	0 a	0 a	1 a	1 a	1 a	2 a	4 a	6 a	2 b	4 b	12 a		
IR20 without spray	1 a	1 a	0 a	1 a	1 a	4 a	2 a	8 a	11 a	10 a	19 a		
IR19735-30-3-3-2 with spray	0 a	0 a	1 a	1 a	2 a	7 a	1 a	10 a	8 b	25 a	9 a		
IR19735-30-3-3-2 without spray	1 a	1 a	0 a	1 a	1 a	2 a	2 a	5 a	5 ab	14 a	8 a		
						Microvelia douglasi atrolineata							
IR20 with spray	0 a	0 a	0 a	1 a	7 a	3 a	3 a	5 ab	3 ab	3 a	6 a		
IR20 without spray	2 a	0 a	1 a	1 a	4 a	3 a	4 a	13 a	4 a	9 a	22 a		
IR19735-30-3-3-2 with spray	1 a	0 b	0 a	1 a	3 a	1 a	2 a	3 b	1 b	2 a	7 a		
IR19735-30-3-3-2 without spray	3 a	0 a	1 a	3 a	6 a	1 a	3 a	6 ab	5 ab	6 a	15 a		

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. DT = days after transplanting. [b]Population of hoppers was resurged by foliar spray of 30 g decamethrin a.i./ha in 300 liters water starting at 20 days after treatment and repeated 4 times at 15-day intervals. Insects were sampled with a FARMCOP suction machine at indicated DT.

Table 52. The median lethal concentration (LC_{50}) of selected insecticides applied to the brown planthopper *N. lugens*. IRRI insectary, 1981.

Insecticide[a]	LC_{50}[b] (kg a.i./ha)	
	Foliar spray	Potter's spray
Acephate 40 EC	0.20 bcd	0.19 abc
Azinphos ethyl 40 EC	0.20 bcd	0.28 ab
BPMC 50 EC	0.58 a	0.15 bc
Carbofuran 12 F	0.11 cd	0.09 c
Carbophenothion 40 EC	0.14 cd	0.31 ab
Cypermethrin 5 EC	0.02 e	0.02 d
Decamethrin 2.5 EC	0.08 d	0.11 c
Endosulfan 35 EC	0.24 abc	0.40 a
Ethylan 45 EC	0.12 cd	0.21 abc
FMC 35001 20 EC	0.09 d	0.17 abc
Monocrotophos 16.8 EC	0.16 cd	0.28 ab
Propoxur 20 EC	0.48 ab	0.09 c

[a]EC = emulsifiable concentrate, F = flowable; applied in spray solution of 500 liters/ha. [b]Based on av % mortality of *N. lugens* of 5 dosages (below and above the recommended rate), consisting of 3 replications and 20 insects/replication. Separation of LC_{50} values in a column by Duncan's multiple range test at the 5% level.

Seedbed, vegetative, reproductive, and ripening crop stages were protected to determine the stage at which yield losses to insects occurred.

In the dry-season test in Laguna, the insect- and virus-susceptible variety IR22 was compared with the resistant variety IR50. GLH populations were highest in IR22, and tungro infection was high in the treatments unprotected during the vegetative stage (Table 57). GLH populations >5/10 sweeps resulted in high levels of tungro infection. Treatments having GLH populations of 2/10 sweeps had insignificant tungro-infected plants. IR50 had low insect populations and no tungro virus.

Insect damage and tungro virus affected IR22 yield components, especially the number of productive tillers per hill, grain weight per hill, and percentage of filled grains (Table 58). IR22 unprotected at the vegetative stage yielded 2.11 t/ha less than the maximum protection treatment (Table 59). Net gain and gain from insecticide and cost-benefit ratio for insecticide were highest in the treatment with maximum protection at all stages except seedbed, and lowest in the treatment with no protection in the vegetative stage.

In IR50, only the treatment without protection in the vegetative stage had a significant yield reduction (0.84 t/ha). Gain from insecticide was negative in all but the carbofuran soil-incorporated treat-

Table 53. Comparative toxicity of the median lethal concentration (LC_{50}) of foliar sprays of selected insecticides to brown planthopper predators placed on treated plants 1, 3, 5, and 10 days after treatment (DAT). IRRI insectary, 1981.

Insecticide	Mortality[a] (%)											
	1 DAT			3 DAT			5 DAT			10 DAT		
	L. pseudo-annulata	*C. lividi-pennis*	*M. atro-lineata*	*L. pseudo-annulata*	*C. lividi-pennis*	*M. atro-lineata*	*L. pseudo annulata*	*C. lividi-pennis*	*M. atro-lineata*	*L. pseudo-annulata*	*C. lividi-pennis*	*M. atro-lineata*
Acephate 40 EC	0.0 b	80.0 a	0.0 b	0.0 b	40.0 a	0.0 b	0.0 b	36.7 a	0.0 b	0.0 b	30.0 a	0.0 b
Azinphos ethyl 40 EC	6.7 b	86.7 a	6.7 b	3.4 b	60.0 a	0.0 b	0.0 b	56.7 a	0.0 b	0.0 b	40.0 a	0.0 b
BPMC 50 EC	0.0 b	40.0 a	0.0 b	0.0 a	30.0 a	0.0 b	0.0 a	13.3 a	0.0 a	0.0 a	3.4 a	0.0 a
Carbofuran 12 F	13.3 b	86.7 a	0.0 c	0.0 b	56.7 a	0.0 b	0.0 b	53.3 a	0.0 b	0.0 b	26.7 a	0.0 b
Carbophenothion 40 EC	0.0 b	66.7 a	0.0 b	0.0 b	36.7 a	6.7 b	0.0 b	33.3 a	0.0 b	0.0 a	6.7 a	0.0 a
Cypermethrin 5 EC	3.4 c	50.0 a	20.0 b	0.0 b	40.0 a	0.0 b	0.0 b	36.7 a	0.0 b	0.0 b	20.0 a	0.0 b
Decamethrin 2.5 EC	93.3 a	93.3 a	88.7 a	80.0 ab	83.3 a	53.3 b	63.3 b	83.3 a	53.3 b	46.7 b	73.3 a	53.3 b
Endosulfan 35 EC	6.7 b	53.3 a	10.0 b	0.0 b	36.7 a	3.4 b	0.0 b	23.3 a	3.4 b	0.0 b	23.3 a	0.0 b
Ethylan 45 EC	3.4 b	73.3 a	10.0 b	0.0 b	26.7 a	0.0 b	0.0 b	16.7 a	0.0 a	0.0 a	6.7 a	0.0 a
FMC 35001 20 EC	16.7 b	83.3 a	6.7 c	3.4 b	66.7 a	3.4 b	0.0 b	53.3 a	0.0 b	0.0 b	26.7 a	0.0 b
Monocrotophos 16.8 EC	6.7 b	80.0 a	3.4 b	0.0 b	70.0 a	3.4 b	0.0 b	66.7 a	0.0 b	0.0 a	13.3 a	0.0 a
Propoxur 20 EC	0.0 c	90.0 a	20.0 b	0.0 b	73.3 a	0.0 b	0.0 b	63.3 a	0.0 b	0.0 b	23.3 a	0.0 b
Control	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Av of 3 replications, each consisting of 10 adult predators caged individually. Fresh predators were placed on treated plants at 1, 3, 5, and 10 days after insecticide treatment. Mortality readings were taken 48 h after infestation of treated plants.

Table 54. Comparative toxicity of the median lethal concentration of foliar sprays of selected insecticides to the brown planthopper (BPH) when caged with the predators *C. lividipennis* and *M. douglasi atrolineata*. IRRI insectary, 1981.

Insecticide	Mortality[a] (%)							
	BPH caged with *C. lividipennis*				BPH caged with *M. atrolineata*			
	1 DAT	3 DAT	5 DAT	10 DAT	1 DAT	3 DAT	5 DAT	10 DAT
Acephate 40 EC	47.3 abc (a)	17.7 cd (b)	8.7 cd (c)	5.3 bcde (c)	42.7 cd (a)	14.7 d (b)	9.7 cd (bc)	5.7 bc (c)
Azinphos ethyl 40 EC	47.7 abc (d)	33.3 a (b)	25.0 a (b)	12.7 a (c)	46.0 abc (a)	33.3 a (b)	25.0 a (b)	10.7 a (c)
BPMC 50 EC	31.3 e (a)	11.0 e (b)	6.7 d (b)	6.3 bcd (c)	28.7 e (a)	14.3 e (a)	7.7 d (c)	5.3 bc (c)
Carbofuran 12 F	55.7 a (a)	16.0 cde (b)	11.0 bcd (b)	5.7 bcd (c)	52.7 a (a)	16.0 d (b)	12.7 bcd (b)	5.7 bc (c)
Carbophenothion 40 EC	41.0 cd (a)	15.0 de (b)	8.7 cd (b)	3.3 de (c)	39.7 cd (a)	12.7 d (b)	8.7 cd (b)	2.7 c (c)
Cypermethrin 5 EC	28.0 e (a)	15.0 de (b)	9.0 cd (b)	4.7 bcde (c)	27.7 e (a)	16.3 d (b)	9.0 cd (c)	4.7 bc (d)
Decamethrin 2.5 EC	34.7 de (a)	21.0 cd (b)	13.3 bc (c)	7.7 bc (d)	34.3 de (a)	18.7 cd (b)	17.0 b (b)	7.3 ab (c)
Endosulfan 35 EC	49.3 abc (a)	21.7 cd (b)	11.0 bcd (c)	6.3 bcd (c)	47.3 abc (a)	16.0 d (b)	12.7 bcd (b)	5.3 bc (c)
Ethylan 45 EC	48.3 abc (a)	16.7 cde (b)	9.7 cd (c)	4.0 cde (d)	43.3 bc (a)	14.3 d (b)	9.7 cd (bc)	5.3 bc (c)
FMC 35001 20 EC	52.0 ab (a)	29.0 ab (b)	16.0 b (c)	7.7 b (d)	51.7 ab (a)	26.0 ab (b)	16.3 b (c)	7.0 ab (d)
Monocrotophos 16.8 EC	45.7 bc (a)	18.3 cd (b)	10.7 bcd (c)	5.3 bcd (d)	40.0 cd (a)	16.7 cd (b)	10.3 cd (bc)	5.3 bc (c)
Propoxur 20 EC	32.7 e (a)	22.3 bc (b)	11.7 bcd (c)	6.3 bcd (d)	31.0 e (a)	23.7 bc (a)	14.3 bc (b)	4.3 bc (c)
Control	4.3 f (a)	4.0 f (a)	2.7 e (a)	2.7 e (a)	4.7 f (a)	3.7 e (a)	2.7 e (a)	3.0 e (a)

[a]Separation of means in a column and in a row (in parentheses) by Duncan's multiple range test at the 5% level. DAT = days after treatment.

Table 55. Comparative toxicity of median lethal concentration of foliar sprays of selected insecticides to the brown planthopper (BPH) caged with or without the predator *L. pseudo-annulata*. IRRI insectary, 1981.

Insecticide	BPH mortality[a] (%)											
	1 DAT			3 DAT			5 DAT			10 DAT		
	With predator	Without predator	Difference	With predator	Without predator	Difference	With predator	Without predator	Difference	With predator	Without predator	Difference
Acephate 40 EC	98.0 a	46.7 a	51.3**	89.3 b	16.7 b	72.6**	98.7 a	10.0 b	88.7**	97.3 ab	4.0 ab	93.3**
Azinphos ethyl 40 EC	97.3 a	42.7 ab	54.6**	94.0 ab	36.7 a	57.3**	98.7 a	27.3 a	71.4**	98.0 ab	10.0 a	88.0**
BPMC 50 EC	99.3 a	32.7 bc	66.6**	94.0 a	12.7 bc	81.3**	95.3 ab	7.3 bc	88.0**	98.0 a	6.0 a	92.0**
Carbofuran 12 F	98.0 a	55.3 a	42.7**	92.0 b	16.7 b	75.3**	95.3 ab	11.3 b	84.0**	99.3 a	4.7 a	94.6**
Carbophenothion 40 EC	97.3 a	44.7 a	52.6**	94.0 ab	15.3 b	78.7**	95.3 ab	7.3 bc	88.0**	99.3 a	2.0 b	97.3**
Cypermethrin 5 EC	89.3 b	27.3 c	62.0**	77.3 c	14.7 b	62.6**	83.3 c	8.7 bc	74.6**	90.0 c	3.3 b	86.7**
Decamethrin 2.5 EC	54.7 c	34.7 bc	20.0**	56.0 d	20.7 b	35.3**	51.3 d	16.7 ab	34.6**	70.0 d	4.0 ab	66.0**
Endosulfan 35 EC	100.0 a	46.7 a	53.3**	96.0 a	18.7 b	77.3**	95.3 ab	11.3 b	84.0**	95.3 abc	6.0 a	89.3**
Ethylan 45 EC	88.7 b	46.7 a	42.0**	90.0 b	16.7 b	73.3**	94.7 ab	9.3 bc	85.4**	100.0 a	4.0 ab	96.0**
FMC 35001 20 EC	91.3 b	48.0 a	43.3**	90.7 b	26.0 a	64.7**	96.0 ab	14.7 b	81.3**	96.7 ab	5.3 a	91.4**
Monocrotophos 16.8 EC	98.7 a	38.7 bc	60.0**	90.0 b	17.3 b	72.7**	90.0 bc	10.0 b	80.0**	92.7 bc	4.0 ab	88.7**
Propoxur 20 EC	97.3 a	28.7 bc	68.6**	86.0 bc	18.0 b	68.0**	96.7 a	12.0 b	84.7**	100.0 a	4.0 ab	96.0**
Control	99.2 a	3.3 d	96.0**	96.0 a	3.3 d	92.7**	98.0 a	2.7 c	95.3**	100.0 a	0.7 b	99.3**

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

Table 56. Effect of levels of varietal resistance on susceptibility to insecticides of brown planthopper (BPH) biotype 2 adult females treated in the Potter's spray tower. IRRI greenhouse, 1981.

Treatment[a]	Mortality of BPH[b] (%) reared on				
	TN1 (S)	Triveni (MR)	Pao-Hsun (MR)	ASD7 (MR)	Sinna Sivappu (R)
			At 1 HT		
Carbofuran 12 F	37.5 c	95.0 ab	85.0 b	88.8 b	100.0 a
FMC 3501 20 EC	10.0 c	22.5 b	20.0 b	41.3 a	50.0 a
BPMC 50 EC	46.3 c	78.8 a	56.3 bc	68.8 ab	77.5 a
Control	0.0 b	0.0 b	0.0 b	7.5 a	10.0 a
			At 4 HT		
Carbofuran 12 F	50.0 b	87.5 a	88.8 a	86.3 a	95.0 a
FMC 35001 20 EC	53.8 b	68.8 b	68.8 b	88.8 a	87.5 a
BPMC 50 EC	40.0 c	76.3 ab	57.5 bc	80.0 a	87.5 a
Control	0.0 b	0.0 b	1.3 ab	5.0 ab	10.0 a
			At 24 HT		
Carbofuran 12 F	63.8 c	85.0 ab	85.0 b	93.6 ab	95.0 a
FMC 35001 20 EC	66.3 c	82.5 bc	78.8 c	93.8 ab	97.5 a
BPMC 50 EC	46.3 c	73.8 b	67.5 b	80.0 b	92.5 a
Control	0.0 b	1.3 b	3.8 b	17.5 a	22.5 a
			At 48 HT		
Carbofuran 12 F	80.0 b	95.0 a	98.8 a	96.3 ab	100.0 a
FMC 35001 20 EC	75.0 c	87.5 bc	85.0 bc	93.8 ab	95.0 a
BPMC 50 EC	67.5 c	85.0 ab	73.8 bc	86.3 ab	90.0 a
Control	7.5 b	5.0 b	10.0 b	30.0 a	35.0 a

[a] Insects were reared on the test varieties and placed on susceptible TN1 after treatment at 0.75 kg a.i./ha. Mortality was recorded at 1, 4, 24, and 48 h after treatment (HT). [b] S = susceptible, MR = moderately resistant, R = resistant to the BPH biotype 2. Separation of means in a row, under the same insecticide treatment, by Duncan's multiple range test at the 5% level.

Table 57. Insect and virus populations or damage at different days after transplanting (DT) in rice varieties IR22 and IR50 treated with insecticides at various growth stages.[a] Victoria, Laguna, 1981 dry season.

Treatment[b]	Whorl maggot damage[c]		*N. virescens* (no./10 sweeps)			*N. lugens* (no./20 hills)					Deadhearts (%)		Tungro virus (%)
	18 DT	30 DT	24 DT	31 DT	38 DT	36 DT	44 DT	50 DT	57 DT	64 DT	30 DT	60 DT	100 DT
						IR22[d]							
Maximum protection	1 c	1 b	1 a	1 c	2 b	0 c	101 a	154 a	18 b	19 bc	0 b	3 a	1 c
Maximum protection except seedbed	1 c	1 b	1 a	1 c	1 b	0 c	81 a	81 a	10 b	8 c	0 b	2 ab	0 c
Maximum protection except vegetative stage	3 b	5 a	1 a	9 a	17 a	15 a	116 a	142 a	19 b	41 ab	5 a	2 ab	56 a
Maximum protection except reproductive stage	2 c	1 b	1 a	2 bc	1 b	0 c	108 a	147 a	160 a	50 ab	0 b	2 ab	2 c
Maximum protection except ripening stage	1 c	1 b	0 a	2 c	2 b	0 c	98 a	140 a	17 b	12 c	0 b	1 b	0 c
Carbofuran soil incorporated	0 d	1 b	1 a	7 ab	3 b	4 b	108 a	164 a	213 a	78 a	0 b	2 ab	22 b
Control	4 a	5 a	1 a	7 a	10 a	9 ab	111 a	169 a	236 a	84 a	5 a	3 ab	48 a
						IR50[e]							
Maximum protection	1 b	1 b	2 a	2 a	1 ab	0 b	5 bc	0 c	2 d	0 c	0 c	3 ab	0 a
Maximum protection except seedbed	1 b	1 b	1 a	2 a	2 ab	0 b	3 cd	1 c	2 cd	0 c	0 c	3 ab	0 a
Maximum protection except vegetative stage	4 a	5 a	2 a	2 a	2 ab	12 a	23 a	1 c	6 b	1 bc	9 a	2 ab	0 a
Maximum protection except reproductive stage	1 b	1 b	3 a	2 a	1 ab	0 b	1 d	9 b	4 bc	4 ab	0 c	4 ab	0 a
Maximum protection except ripening stage	1 b	1 b	2 a	1 a	2 ab	0 b	1 d	0 c	2 cd	0 c	0 c	2 ab	0 a
Carbofuran soil incor-	1 b	1 b	1 a	3 a	1 b	8 a	7 bc	9 b	8 b	8 ab	1 b	2 b	0 a
Control	4 a	6 a	2 a	2 a	4 a	12 a	14 ab	19 a	79 a	11 a	8 a	4 a	0 a

[a]All observations were done on a per-plot basis. Separation of means in a column within a particular variety by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. [b]Maximum protection = seedbed protection: foliar spray of monocrotophos (0.75 kg a.i./ha) 5 days before transplanting; vegetative stage protection; foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 DT and BPMC (1.0 kg a.i./ha) at 35 DT; reproductive stage protection: foliar sprays of Brodan (chlorpyrifos + BPMC) (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. Carbofuran incorporated into soil at 0.5 kg a.i./ha before transplanting. [c]Based on a scale of 1-9: 1 = 1-2 leaves/hill damaged, 9 = >50 leaves damaged. [d]Susceptible to insects and viruses. [e]Resistant to *Nephotettix virescens, Nilaparvata lugens,* and tungro virus.

Table 58. Yield components[a] of rice varieties IR22 and IR50 at different days after transplanting (DT) as affected by the application of insecticides at various plant growth stages. Victoria, Laguna, 1981 dry season.

Treatment[b]	Tillers (no./hill)			Productive tillers (no./hill)	Plant ht (cm)		Grain wt (g/5 hills)	Filled grains (no./5 hills)	Unfilled grains (no./5 hills)	Filled grains (%)	Grain wt (g/1000)
	28 DT	42 DT	56 DT	100 DT	36 DT	63 DT					
					IR22						
Maximum protection	9 a	18 a	23 a	17 a	38 a	60 ab	6,743	5,400 a	1,343 a	80	21 b
Maximum protection except seedbed	13 a	22 a	26 a	18 a	36 ab	65 a	7,762	6,281 a	1,481 a	81	22 a
Maximum protection except vegetative stage	10 a	16 a	22 a	12 bc	31 c	55 b	4,248	2,293 b	1,955 a	54	20 c
Maximum protection except reproductive stage	10 a	19 a	25 a	15 ab	38 a	62 a	6,143	4,539 a	1,604 a	74	21 b
Maximum protection except ripening stage	12 a	22 a	25 a	19 a	39 a	62 a	3,839	5,570 a	2,269 a	71	22 b
Carbofuran soil incorporated	11 a	20 a	24 a	10 c	39 a	65 a	4,375	2,332 b	2,043 a	53	20 c
Control	9 a	17 a	24 a	11 bc	31 bc	54 b	4,636	2,560 b	2,076 a	55	18 d
					IR50						
Maximum protection	13 a	33 a	37 a	22 a	40 a	71 a	9,312	6,214 a	3,098 a	67	21 a
Maximum protection except seedbed	12 a	30 a	37 a	24 a	39 a	69 ab	10,203	6,298 a	3,905 a	62	21 ab
Maximum protection except vegetative stage	11 a	22 b	36 a	23 a	33 b	65 bc	8,779	5,778 a	3,001 a	66	21 ab
Maximum protection except reproductive stage	13 a	33 a	36 a	22 a	40 a	70 ab	9,545	6,527 a	3,018 a	68	21 ab
Maximum protection except ripening stage	13 a	34 a	38 a	25 a	40 a	70 ab	10,544	6,408 a	4,136 a	61	21 ab
Carbofuran soil incorporated	14 a	32 a	39 a	24 a	40 a	72 a	10,128	6,509 a	3,619 a	64	21 ab
Control	12 a	28 ab	42 a	26 a	33 b	62 c	9,365	5,651 a	3,714 a	60	20 b

[a]Observations based on 5 randomly selected hills/replicate. Separation of means in a column for each variety by Duncan's multiple range test at the 5% level. [b]Maximum protection = seedbed protection: foliar sprays of monocrotophos at 6 and 11 days after sowing; vegetative stage protection: foliar sprays of monocrotophos at 5, 15, and 25 DT and BPMC at 35 DT; reproductive stage protection: foliar sprays of Brodan (chlorpyrifos + BPMC) and BPMC at panicle initiation and flowering stage, respectively; ripening stage protection: foliar spray of monocrotophos at the soft-dough stage. All foliar sprays applied at 0.75 kg a.i./ha. Integrated pest management = soil incorporation of carbofuran G at 0.75 kg a.i./ha before transplanting followed by application of insecticides on the basis of economic thresholds. The leaffolder threshold was reached and BPMC was applied at 0.75 kg a.i./ha at 56 and 88 DT.

Table 59. Comparison of yields and economics of rice insect control in rice varieties IR22 and IR50 protected with insecticides at various growth stages. Victoria, Laguna, 1981 dry season.

Treatment[a]	Yield[b] (t/ha)	Yield loss[c] (t/ha)	Yield contribution[d]	Gross profit[e] ($/ha)	Cost of insecticide[f] application (US$/ha)	Net gain[g] (US$/ha)	Gain from insecticide[h] (US$/ha)	Benefit: cost[i]
			IR22[j]					
Maximum protection	5.59 b	–	2.95	1062	203	859	357	2.8
Maximum protection except seedbed	6.44 a	0.00	3.80	1224	201	1023	521	3.6
Maximum protection except vegetative stage	3.48 d	2.11	0.84	661	82	579	77	1.9
Maximum protection except reproductive stage	4.86 c	0.73	2.22	923	146	777	275	2.9
Maximum protection except ripening stage	5.45 bc	0.14	2.81	1036	180	856	354	3.0
Carbofuran soil incorporated	3.74 d	1.85	1.10	711	24	687	185	8.7
Control	2.64 e	2.95	–	502	0	502	–	–
			IR50[k]					
Maximum protection	6.46 a	–	0.99	1227	203	1024	-15	0.9
Maximum protection except seedbed	6.30 a	0.16	0.83	1197	201	996	-43	0.8
Maximum protection except vegetative stage	5.57 b	0.89	0.10	1058	82	976	-63	0.2
Maximum protection except reproductive stage	6.00 ab	0.46	0.53	1140	146	994	-45	0.7
Maximum protection except ripening stage	6.36 a	0.10	0.89	1208	180	1028	-11	0.9
Carbofuran soil incorporated	6.24 a	0.22	0.77	1186	24	1162	123	6.1
Control	5.47 b	0.99	–	1039	0	1039	–	–

[a]Maximum protection = seedbed protection: foliar spray of monocrotophos (0.75 kg a.i./ha) 5 days before transplanting; vegetative stage protection: foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 days after transplanting (DT) and BPMC (1.0 kg a.i./ha) at 35 DT; reproductive stage protection: foliar sprays of Brodan (chlorpyrifos + BPMC) (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. Carbofuran soil incorporated at 0.5 kg a.i./ha before transplanting. [b]Separation of means in a column for each variety by Duncan's multiple range test at the 5% level. [c]Yield in maximum protection – yield of treatment. [d]Yield of treatment – yield of control. [e]Yield in kg/ha at 14% moisture x 0.19. [f]Seedbed protection = $0.50 labor + $1.50 for insecticide; vegetative stage protection = $12.50 labor + $108.50 for insecticide; reproductive stage protection = $6.25 labor + $50.75 for insecticide; ripening stage protection = $3.13 labor + $19.87 for insecticide; carbofuran soil incorporated = $1.75 labor + $22.25 for insecticide. [g]Gross profit – cost of insecticide application. [h]Net gain of treatment – net gain of control. [i](Gross profit of treatment – gross profit of control) ÷ cost of insecticide application. [j]Susceptible to insects and viruses. [k]Resistant to the green leafhopper and brown planthopper and viruses and susceptible to the whorl maggot.

Table 60. Insect flight activity in a farmer's field, based on kerosene light trap catches. Talavera, Nueva Ecija, 1981 dry season.

Wk after transplanting	Insects (no./trap per wk)							
	Nephotettix spp.	*R. dorsalis*	*N. lugens*	*S. furcifera*	*N. depunctalis*	*C. medinalis*	*R.* nr. *atimeta*	Stem borers
1st	55	1	29	29	2	0	16	14
2nd	11	0	15	9	16	2	82	45
3rd	15	0	22	47	24	8	24	70
4th	15	0	29	50	6	17	36	1
5th	20	0	17	35	23	27	450	39
6th	21	3	12	6	7	17	220	21
7th	16	4	9	7	10	21	49	17
8th	22	2	22	10	2	14	13	11
9th	56	3	14	7	7	5	9	8
10th	52	0	27	0	1	0	5	21
Total	283	13	196	100	98	111	904	247

Table 61. Insect populations and insect damage[a] at different days after transplanting (DT) in rice[b] plots receiving insecticide applications at various growth stages. Talavera, Nueva Ecija, 1981 dry season.

Treatment[c]	Whorl maggot damage[d] 25 DT	*N. virescens* (no./10 sweeps)			*N. lugens* (no./hill)			Stem borer damage			Leaffolder (% of leaves damaged) 59 DT	Leaves damaged by defoliators[e] (%)	
		10 DT	25 DT	41 DT	20 DT	59 DT	66 DT	Deadhearts (%) 17 DT	Deadhearts (%) 31 DT	Whiteheads (%) 100 DT		18 DT	26 DT
Maximum protection	1.3 b	0 a	0.5 c	0.3 b	1.3 a	1.2 c	1.8 c	5.3 b	2.3 c	0.9 d	0.7 c	4.5 cd	1.2 b
Maximum protection except vegetative stage	1.5 b	0 a	1.8 ab	0.3 b	1.1 a	1.7 bc	2.3 bc	4.8 b	3.8 b	1.9 c	0.9 c	11.2 b	3.7 a
Maximum protection except reproductive stage	1.5 b	0 a	1.8 ab	0.3 b	0.9 a	2.1 bc	2.4 b	4.8 b	3.4 b	3.6 b	2.6 b	4.3 d	1.2 b
Maximum protection except ripening stage	1.4 b	0 a	1.5 b	0.8 ab	0.9 a	2.1 bc	2.0 bc	4.1 b	3.5 b	2.0 c	1.1 c	6.6 bcd	1.3 b
Carbofuran broadcast at 10 DT	1.4 b	0 a	2.0 ab	0.3 b	1.2 a	2.3 ab	2.7 ab	4.8 b	3.6 b	5.8 a	2.3 b	8.9 bc	3.3 a
Control	1.8 a	0a	2.8 a	2.0 a	1.0 a	3.1 a	3.4 a	9.2 a	7.7 a	7.2 a	4.8 a	19.5 a	5.0 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Likely a line of IR5853. [c]Maximum protection = seedbed protection: foliar sprays of monocrotophos (0.75 kg a.i./ha) at 7 and 14 days after sowing; vegetative stage protection: foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 DT and chlorpyrifos + BPMC (1.0 kg a.i./ha) at 35 DT; reproductive stage protection: foliar sprays of chlorpyrifos + BPMC (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. [d]Based on a scale of 1-9: 1 = 1-2 leaves damaged hill, 9 = > 5% leaves damaged. [e]*Mythimna separata, Spodoptera* sp., and *Naranga aenescens.*

Table 62. Comparison of yields and economics of rice insect control[a] when insecticides were applied at various growth stages. Talavera, Nueva Ecija, 1981 dry season.

Treatment[b]	Yield (t/ha)[c]	Gross profit[d] (US$/ha)	Cost of insecticide application[e] (US$/ha)	Net gain[f] (US$/ha)	Gain from insecticide[g] (US$/ha)	Benefit: cost[h]
Maximum protection	6.82 a	1296	233.71	1062.69	-35.31	0.84
Maximum protection except vegetative stage	6.30 a	1197	123.96	1073.04	-24.96	0.79
Maximum protection except reproductive stage	6.08 a	1155	180.65	974.35	-123.65	0.31
Maximum protection except ripening stage	6.39 a	1214	165.21	1048.79	-49.21	0.70
Carbofuran broadcast at 10 DT[i]	5.96 a	1132	16.00	1116.00	18.00	2.13
Control	5.78 a	1098	0.00	1098.00	–	–

[a]Likely a line of IR5853. [b]Maximum protection = seedbed protection: foliar sprays of monocrotophos (0.75 kg a.i./ha) at 7 and 14 days after sowing; vegetative stage protection: foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 days after transplanting (DT) and chlorpyrifos + BPMC (1.0 kg a.i./ha) at 35 DT; reproductive stage protection: foliar sprays of chlorpyrifos + BPMC (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. [c]Separation of means in a column by Duncan's multiple range test at the 5% level. [d]Yield in kg/ha at 14% moisture x $0.19. [e]Cost of insecticide + labor ($2.20/ha per application). Cost of seedbed protection = $2.40; vegetative protection = $109.75; reproductive protection = $53.06; and ripening protection = $68.50. [f](Gross profit of treatment – gross profit of control) ÷ cost of insecticide application. [g]Net gain of treatment – net gain of control. [h]Gain from insecticide ÷ cost of insecticide application. [i]0.5 kg a.i./ha.

Table 63. Insect populations or damage at different days after transplanting in rice varieties IR22 and IR54 when treated with insecticides at various plant growth stages.[a] Victoria, Laguna, 1981 wet season.

Treatment[b]	Whorl maggot damage[c] 30 DT	*N. virescens* (no./10 sweeps) 20 DT	30 DT	44 DT	*N. lugens* (no./20 hills) 30 DT	54 DT	86 DT	Leaffolder damaged leaves (%) 54 DT	77 DT	Deadhearts (%) 28 DT	46 DT	Whiteheads (%)
					IR22[d]							
Maximum protection	2 b	1 a	0 e	0 f	0 e	17 de	73 ab	24 bcde	9 e	0 b	2 ab	0 bcd
Maximum protection except seedbed	2 b	0 a	1 e	2 de	1 de	10 e	73 ab	12 defg	6 e	0 b	2 ab	0 bcd
Maximum protection except vegetative stage	5 a	1 a	3 ab	12 a	76 ab	30 de	15 de	31 abc	14 e	7 a	2 ab	0 bcd
Maximum protection except reproductive stage	2 b	0 a	1 e	1	1 de	63 abc	23 cde	24 bcde	98 a	0 b	3 ab	1 abc
Maximum protection except ripening stage	2 b	0 a	1 de	1 ef	3 cd	12 e	44 abcd	6 fg	9 e	0 b	1 b	0 d
Seedbed protection	5 a	0 a	2 abcd	6 bcd	70 ab	138 a	42 abcd	48 a	91 ab	9 a	3 ab	0 bcd
Vegetative stage protection	1 b	1 a	2 abcde	3 cde	1 de	41 bcd	94 a	19 cdef	91 ab	1 b	4 a	1 ab
Reproductive stage protection	5 a	0 a	2 abc	7 bcd	86 a	52 bcd	134 a	20 cdef	10 e	7 a	2 ab	0 cd
Ripening stage protection	5 a	0 a	4 a	3 de	44 ab	145 ab	36 bcde	45 ab	91 ab	7 a	1 ab	0 cd
Integrated pest management	2 b	0 a	1 cde	3 cde	10 cd	86 abc	30 bcde	13 defg	78 bcd	1 b	2 ab	1 abcd
Control	5 a	0 a	4 a	9 ab	55 ab	171 a	139 a	34 abc	89 ab	8 a	2 ab	0 cd
					IR54[e]							
Maximum protection	2 b	1 a	1 ab	0 d	0 b	0 a	2 a	8 efg	26 d	0 b	2 ab	2 a
Maximum protection except seedbed	2 bcde	0 a	1 ab	1 d	0 b	1 a	0 a	3 efg	17 d	0 b	2 b	1 abcd
Maximum protection except vegetative stage	5 a	0 a	1 a	2 ab	24 a	1 a	0 a	12 cdefg	25 d	10 a	2 ab	1 cde
Maximum protection except reproductive stage	3 b	0 a	1 ab	0 d	0 b	1 a	0 a	16 bcde	90 a	0 b	3 ab	1 bcde
Maximum protection except ripening stage	2 bcd	1 a	2 a	0 cd	1 b	0 a	1 a	8 defg	15 d	0 b	3 ab	2 ab
Seedbed protection	5 a	0 a	2 a	1 bcd	18 a	3 a	1 a	26 abc	92 ab	10 a	2 ab	1 cde
Vegetative stage protection	2 bcd	0 a	1 ab	0 d	0 b	1 a	0 a	14 bcdef	97 a	0 b	5 a	1 abcde
Reproductive stage protection	5 a	0 a	2 a	2 abcd	26 a	0 a	0 a	15 bcde	25 d	11 a	2 b	1 abc
Ripening stage protection	5 a	0 a	1 ab	2 abcd	24 a	2 a	2 a	31 ab	95 ab	10 a	3 ab	0 e
Integrated pest management	1 cdef	0 a	0 b	1 bcd	1 b	1 a	1 a	4 efg	86 bc	0 b	3 ab	1 abcd
Control	5 a	0 a	1 ab	2 a	27 a	2 a	0 a	24 abcd	91 ab	10 a	3 ab	0 de

[a] Separation of means in a column for each variety by Duncan's multiple range test at the 5% level. Identical numbers may be followed by different letters because of rounding. [b] Maximum protection = seedbed protection: foliar sprays of monocrotophos at 6 and 11 days after sowing; vegetative stage protection: foliar sprays of monocrotophos at 5, 15, and 25 DT and BPMC at 35 DT; reproductive stage protection: foliar sprays of Brodan (chlorpyrifos + BPMC) and BPMC at panicle initiation and flowering stage, respectively; ripening stage protection: foliar spray of monocrotophos at soft-dough stage. All foliar sprays applied at 0.75 kg a.i./ha. Integrated pest management = soil incorporation of carbofuran G at 0.75 kg a.i./ha before transplanting followed by application of insecticides on the basis of economic thresholds. The leaffolder threshold was reached and BPMC was applied at 0.75 kg a.i./ha at 56 and 78 DT. [c] Based on a scale of 1-9; 1 = 1-2 damaged leaves/hill, 9 = >50% of leaves damaged. [d] Susceptible to insects. [e] Resistant to *Nephotettix virescens* and *Nilaparvata lugens*.

Table 64. Comparison of yields and economics of insect control in rice varieties IR22 and IR54 when protected with insecticides of various growth stages. Victoria, Laguna, 1981 wet season.

Treatment[a]	Yield[b] (t/ha)	Yield loss[c] (t/ha)	Yield contribution[d] (t/ha)	Gross profit[e] (US$/ha)	Cost of insecticide application[f] (US$/ha)	Net gain[g] (US$/ha)	Gain from insecticide[h] (US$/ha)	Benefit: cost[i]
			IR22[j]					
Maximum protection	4.84 ab	–	1.15	920	186	734	33	1.2
Maximum protection except seedbed	5.10 a	0.00	1.41	969	182	787	86	1.5
Maximum protection except vegetative stage	4.84 ab	0.00	1.15	920	79	841	140	2.8
Maximum protection except reproductive stage	4.31 bc	0.53	0.62	819	142	677	-24	0.8
Maximum protection except ripening stage	4.80 ab	0.04	1.11	912	156	756	55	1.4
Seedbed protection	3.90 c	0.94	0.21	741	4	737	36	10.0
Vegetative stage protection	3.99 c	0.85	0.30	758	107	651	-50	0.5
Reproductive stage protection	4.35 bc	0.49	0.66	827	44	783	82	2.9
Ripening stage protection	4.01 c	0.83	0.32	762	30	732	31	2.0
Integrated pest management	4.18 bc	0.66	0.49	794	68	726	25	1.4
Control	3.69 c	1.15	–	701	0	701	–	–
			IR54[k]					
Maximum protection	4.27 abcd	–	0.61	811	186	625	-70	0.6
Maximum protection except seedbed	4.55 a	0.00	0.89	865	182	683	-12	0.9
Maximum protection except vegetative stage	4.17 abcde	0.10	0.51	792	79	713	18	1.2
Maximum protection except reproductive stage	3.42 f	0.85	0.00	650	142	508	-187	0.0
Maximum protection except ripening stage	4.34 abc	0.00	0.68	825	156	669	-26	0.8
Seedbed protection	3.69 def	0.58	0.03	701	4	697	2	1.5
Vegetative stage protection	3.18 f	1.09	0.00	604	107	497	-198	0.0
Reproductive stage protection	4.47 ab	0.00	0.81	849	44	805	110	3.5
Ripening stage protection	3.62 def	0.65	0.00	688	30	658	-37	0.0
Integrated pest management	3.84 bcdef	0.43	0.18	730	68	662	-33	0.5
Control	3.66 def	0.61	–	695	0	695	–	–

[a]Maximum protection = seedbed protection: foliar sprays of monocrotophos at 6 and 11 days after sowing; vegetative stage protection: foliar sprays of monocrotophos at 5, 15, and 25 days after transplanting (DT) and BPMC at 35 DT; reproductive stage protection: foliar sprays of Brodan (chlorpyrifos + BPMC) and BPMC at panicle initiation and flowering stage, respectively; ripening stage protection: foliar spray of monocrotophos at the soft-dough stage. All foliar sprays applied at 0.75 kg a.i./ha. Integrated pest management = soil incorporation of carbofuran G at 0.75 kg a.i./ha before transplanting followed by application of insecticides as based on economic thresholds. The leaffolder threshold was reached and BPMC was applied at 0.75 kg a.i./ha at 56 and 88 DT. [b]Separation of means in a column, for each variety, by Duncan's multiple range test at the 5% level. [c]Yield in maximum protection – yield of the treatment. [d]Yield of the treatment – yield of the control. [e]Yield in kg/ha at $14 moisture x $0.19. [f]Seedbed protection = $0.50 for labor + $3.50 for insecticides; vegetative stage protection = $12.00 for labor + $95.00 for insecticides; reproductive stage protection = $6.00 for labor + $38.00 for insecticides; ripening stage protection = $3.00 for labor + $27.00 for insecticides; IPM = $8.00 for labor + $60.00 for insecticides. [g]Gross proft – cost of insecticide application. [h]Net gain of treatment – net gain of control. [i](Gross profit of treatment – gross profit of control) ÷ cost of insecticide application. [j]Susceptible to insects. [k]Resistant to the green leafhopper and brown planthopper.

Table 65. Insect populations and insect damage[a] at different days after transplanting (DT) in plots of rice variety IR54 receiving insecticide applications at various growth stages. Talavera, Nueva Ecija, 1981 wet season.

Treatment[b]	Whorl maggot damage[c] 30 DT	*N. lugens* (no./hill) 70 DT	*N. virescens* (no./10 sweeps) 51 DT	Leaffolders (% damaged leaves) 58 DT	Leaffolders (% damaged leaves) 74 DT	Defoliators (% damaged leaves) 30 DT	Stem borers: Deadhearts (%) 32 DT	Stem borers: Deadhearts (%) 53 DT	Stem borers: Whiteheads (%) 90 DT
Maximum protection	2.8 a	1.10 ef	4.0 ab	3.4 b	10.3 de	3.0 abc	2.6 bc	1.6 d	2.5 a
Maximum protection except seedbed	2.8 a	0.96 f	3.3 b	1.2 b	9.9 e	2.7 bcd	1.8 c	1.9 d	2.5 a
Maximum protection except vegetative stage	2.9 a	1.11 cdef	5.8 a	12.3 a	18.4 bc	3.6 ab	2.6 bc	2.5 cd	1.7 a
Maximum protection except reproductive stage	2.8 a	1.05 def	2.5 b	3.6 b	14.6 cd	2.7 d	2.3 bc	1.7 d	4.3 a
Maximum protection except ripening stage	2.9 a	1.09 def	3.5 ab	1.5 b	6.4 e	2.7 bcd	2.5 bc	1.9 d	4.3 a
Seedbed protection	2.6 a	1.71 ab	5.3 ab	13.0 a	23.3 abc	4.6 a	3.5 ab	5.1 ab	4.9 a
Vegetative stage protection	2.7 a	1.31 cde	4.0 ab	2.5 b	14.4 cd	3.0 abc	2.6 bc	2.1 cd	3.8 a
Reproductive stage protection	3.0 a	1.44 bc	4.5 ab	12.2 a	17.8 bc	3.5 ab	2.7 ab	4.9 ab	4.0 a
Ripening stage protection	3.0 a	1.01 ef	4.8 ab	15.5 a	23.3 ab	3.9 a	4.2 a	5.2 ab	5.1 a
Carbofuran soil incorporated[d]	2.3 a	1.38 cde	5.0 ab	17.6 a	27.4 a	3.4 abc	2.0 c	3.9 abc	3.1 a
Control	2.6 a	1.75 a	5.3 ab	12.3 a	19.8 bc	3.9 a	4.7 a	6.2 a	2.7 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Maximum protection = seedbed protection: foliar sprays of monocrotophos (0.75 kg a.i./ha) at 7 and 14 days after sowing; vegetative stage protection: foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 DT; reproductive stage protection: foliar sprays of chlorpyrifos + BPMC (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. [c]Based on a scale of 1-9: 1 = 1-2 damaged leaves/hill, 9 = > 50% leaves damaged. [d]Applied before planting at 0.75 kg a.i./ha.

Table 66. Comparison of yields and economics of rice insect control when insecticides were applied at various growth stages of rice variety IR54. Talavera, Nueva Ecija, 1981 wet season.

Treatment[a]	Yield[b] (t/ha)	Gross profit[c] (US$/ha)	Cost of insecticide application[d] (US$/ha)	Net gain[e] (US$/ha)	Gain from insecticide[f] (US$/ha)	Benefit: cost[g]
Maximum protection	5.53 ab	1,051	234.00	817.00	-133.00	0.4
Maximum protection except seedbed	5.52 ab	1,049	231.60	817.40	-132.60	0.4
Maximum protection except vegetative stage	5.01 ab	952	123.69	828.04	-121.96	0.0
Maximum protection except reproductive stage	5.34 ab	1,015	180.65	834.35	-115.65	0.4
Maximum protection except ripening stage	5.60 ab	1,064	165.21	898.79	- 51.21	0.7
Seedbed protection	4.82 ab	916	2.40	913.60	- 36.40	0.0
Vegetative stage protection	5.66 a	1,076	109.75	965.25	15.25	1.1
Reproductive stage protection	5.12 ab	973	53.06	919.94	- 30.06	0.4
Ripening stage protection	4.78 b	908	68.50	838.50	-110.50	0.0
Carbofuran soil incorporated	5.00 ab	942	32.00	910.00	- 40.00	0.0
Control	5.00 ab	950	0.00	950.00	–	–

[a]Maximum protection = seedbed protection: foliar sprays of monocrotophos (0.75 kg a.i./ha) at 7 and 14 days after sowing; vegetative stage protection: foliar sprays of monocrotophos (1.0 kg a.i./ha) at 5, 15, and 25 days after transplanting; reproductive stage protection: foliar sprays of chlorpyrifos + BPMC (1.0 kg a.i./ha) at panicle initiation and flowering; ripening stage protection: foliar spray of carbaryl (1.5 kg a.i./ha) at the soft-dough stage. [b]Separation of means within a column by Duncan's multiple range test at the 5% level. [c]Yield in kg/ha at 14% moisture x $0.19. [d]Cost of insecticide + labor ($2.20/ha per application). Cost of seedbed protection = $2.40; vegetative protection = $109.75; reproductive protection = $53.06; and ripening protection = $68.50. [e]Gross profit – cost of insecticide application. [f]Net gain of treatment – net gain of control. [g](Gross profit of treatment – gross profit of control) ÷ cost of insecticide application.

ment, which had the highest net gain and the only favorable cost-benefit ratio for insecticides.

Insects were monitored with a light trap in the Nueva Ecija dry-season test (Table 60). Moths of the green hairy caterpillar *R. near. atimeta,* a defoliator, were the most abundant. Insect populations in the field were low, with defoliation causing the most damage (Table 61). Yields in all treatments were similar (Table 62), resulting in uneconomical insecticide applications.

Susceptible IR22 and resistant IR54 were compared in a wet-season test in Laguna. Leaffolder was the most serious pest; both varieties had a high percentage of damaged leaves (Table 63). Neither has resistance to this pest. Tungro virus did not occur. Weekly monitoring for leaffolder damage was not effective as damage increased so rapidly, that percentage of folded leaves surpassed the economic injury level between sampling dates.

Application of BPMC at 56 DT did not prevent leaffolder damage from increasing by 77 DT. Yield losses occurred in both varieties (Table 64); they were highest in treatments receiving no protection at the reproductive stage, when leaffolder infestations were most severe. Gain from insecticide was high in the treatment receiving sprays only at the reproductive stage for both varieties.

In the wet-season test in Nueva Ecija, insect populations and damage were low in resistant IR54 (Table 65). Application of insecticide was not profitable and gain from insecticide was negative in all but one treatment (Table 66).

Control and management of rice pests

Weeds

Agronomy Department

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Research to identify herbicides that would complement other methods of weed control in rice continued at IRRI; at the Maligaya, Bicol, and Visayas research stations of the Philippine Bureau of Plant Industry (BPI); and in farmers' fields in Cagayan Province. All screening trials and studies on the control of specific weeds were conducted at IRRI; advanced trials were carried out inside and outside IRRI.

Echinochloa crus-galli ssp. *hispidula, Echinochloa glabrescens, Monochoria vaginalis,* and *Cyperus difformis* were common in irrigated wetlands. Weed species in rainfed and dryland fields were diverse.

Irrigated transplanted rice. *Preliminary screening.* Grain yield increase was not significant because weed infestation was low (Table 1). However, a few chemicals that were completely safe on rice gave slightly higher yields than the thiobencarb - 2,4-D check.

Secondary screening. All herbicide treatments gave significantly higher yields than the untreated check (Table 2). Heavy weed infestation resulted in no yield from the untreated plots. Perfluidone - molinate and perfluidone - bifenox caused little or no injury to the crop and gave yields similar to yields with hand weeding.

Advanced trials, IRRI and BPI. At Maligaya, all the herbicide treatments except naproanilide - thiobencarb, piperophos - 2,4-D, oxyfluorfen, and

Table 1. Effect of herbicides on weed control, crop tolerance, and yield of irrigated transplanted IR42. IRRI, 1981 wet season.

Herbicide treatment[a]	Application		Weed wt[d] (g/m²)			Visual toxicity rating[e]	Yield[d] (t/ha)
	Rate (kg a.i.[b]/ha)	Time (DT[c])	Broadleaf weeds	Grasses	Sedges		
Chlornitrofen – 2,4-D IPE G	1.75-0.5	3	12 a	2 a	9 a	0	5.2 a
Hand-weeded check	Twice	15 & 30	8 a	1 a	4 a	0	5.1 a
EPTC – 2,4-D G	2.0 -0.5	3	9 a	1 a	6 a	2	5.1 a
Fluridone EC	0.3	3	23 ab	4 a	13 a	1	5.0 a
Molinate – 2,4-D G	2.3 -0.5	3	10 a	3 a	8 a	0	5.0 a
Chlornitrofen – 2,4-D IPE G	1.25-0.5	3	12 a	2 a	10 a	0	4.8 a
Thiobencarb – 2,4-D IPE G check	1.0 -0.5	3	14 ab	1 a	10 a	3	4.7 a
PPG-844 EC	1.0	3	38 b	5 a	9 a	0	4.6 a
Untreated check	–	–	21 ab	6 a	9 a	0	4.5 a

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. IPE = isopropyl ester. G = granules. EC = emulsifiable concentrate. [b]Active ingredient. [c]Days after transplanting. [d]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [e]Rated 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

Table 2. Effects of herbicides applied before weed emergence[a] on weed control, crop tolerance, and yield of IR36 rice. IRRI, 1981 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Weed wt[c] (g/m²)	Visual toxicity rating[d]	Yield[c] (t/ha)
Perfluidone – molinate G	1.1 -2.75	113 b	2	3.2 a
Hand-weeded check	–	15 a	0	3.0 a
Perfluidone – bifenox G	0.3 -2.7	179 bcd	0	2.9 a
Bifenox F	2.0	148 b	5	2.3 ab
Perfluidone – molinate G	0.55-0.38	172 bcd	0	2.2 ab
Perfluidone – bifenox G	0.15-1.35	244 bcde	0	1.8 ab
Anilofos EC	0.6	232 bcde	3	1.3 b
Tiocarbazil – 2,4-D IBE G	1.0 -0.5	201 bcd	0	1.2 b
Tiocarbazil – 2,4-D IBE G	1.5 -0.75	190 bc	2	1.0 b
Untreated check	–	441 e	0	0.0 c

[a]4 days after transplanting (DT). A spaced dash (–) means 2 herbicides were formulated on the same carrier and applied as a single treatment. G = granules. Hand-weeded check = weeded at 15 and 35 DT. F = flowable. EC = emulsifiable concentrate. IBE = isobutyl ester. [b]Active ingredient. [c]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [d]Rated 1 week after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

2,4-D, yielded significantly more than the untreated check (Table 3). At IRRI and Bicol, several herbicide-treated plots yielded significantly less than the hand-weeded check.

In the wet season, all herbicide-treated plots at IRRI and Bicol, except the oxyfluorfen plots, yielded significantly more than the untreated check (Table 4). The herbicide-treated plots at Bicol yielded significantly less than the hand-weeded check.

Advanced trials, farmers' field. Advanced trials were conducted in Alcala-Amulung, Cagayan Province, Philippines, to determine appropriate methods of weed control in irrigated transplanted rice. The most important weed was *M. vaginalis.* Other weed species present were *Scirpus supinus, Marsilea minuta,* and *C. difformis.*

Most of the plots with single herbicides or herbicide combinations had significantly lower weed weights than the unweeded check. In general, weed control with granular formulations was inferior because of a lack of water 1 week after herbicide application.

All the herbicide treatments except thiobencarb

Table 3. Effect of granular herbicides applied before weed emergence[a] on yields of IR36. IRRI, and the Maligaya Rice Research and Training Center and the Bicol Rice and Corn Experiment Station of the Philippine Bureau of Plant Industry, 1981 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	IRRI	Yield[c] (t/ha)	
			Maligaya	Bicol
Hand-weeded check	–	2.8 ab	4.5 ab	5.4 a
Molinate – simetryn – MCPB	1.8 -0.1-0.1	2.9 a	4.6 a	4.7 abc
Bifenox – 2,4-D EE	2.0 -0.66	2.9 a	4.8 a	4.4 bc
Chlomethoxynil – 2,4-D IPE	2.1 -0.75	2.8 ab	4.8 a	4.3 bc
Naproanilide – thiobencarb	1.0 -0.7	2.4 abcd	4.5 ab	4.8 ab
Piperophos – 2,4-D IPE	0.33-0.17	2.3 bcd	4.5 ab	4.1 bcd
Pendimethalin	0.75	2.5 abc	4.6 a	3.4 de
2,4-D IPE	0.8	1.9 d	4.1 ab	4.0 cd
Oxyfluorfen	0.15	2.0 cd	4.2 ab	3.1 e
Untreated check	–	1.0 e	3.8 b	1.2 f

[a]4 days after transplanting (DT). 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.

Table 4. Effect of granular herbicides applied before weed emergence[a] on yields of IR36. IRRI, Maligaya Rice Research and Training Center, Bicol Rice and Corn Experiment Station, and Visayas Rice Experiment Station of the Philippine Bureau of Plant Industry, 1981 wet season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
Hand-weeded check	–	3.0 a	4.5 a	6.6 a	4.1 a
Naproanilide – thiobencarb	1.0 -0.7	2.9 a	4.6 a	5.2 bc	3.7 ab
2,4-D	0.8	2.7 a	4.2 a	5.3 bc	3.8 ab
Molinate – simetryn – MCPB	1.8 -0.1-0.1	2.6 a	4.1 a	5.4 b	3.8 ab
Chlomethoxynil – 2,4-D IPE	2.1 -0.75	2.5 a	4.3 a	5.1 bc	3.7 ab
Bifenox – 2,4-D EE	2.0 -0.66	2.2 a	4.5 a	4.5 c	4.2 a
Piperophos – 2,4-D IPE	0.33-0.17	2.6 a	4.4 a	4.7 bc	3.6 ab
Pendimethalin	0.75	2.4 a	4.2 a	5.2 bc	3.1 b
Oxyfluorfen	0.15	2.9 a	4.3 a	3.1 d	3.5 ab
Untreated check	–	0.6 b	4.2 a	2.8 d	3.3 ab

[a]4 days after transplanting (DT). 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. 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.

- 2,4-D at a combined rate of 0.75 kg/ha yielded significantly higher than the unweeded check (Table 5). Only plots treated with thiobencarb - 2,4-D and granular butachlor at 0.5 kg/ha had yields significantly different from the hand-weeded check.

Returns to weeding from all weed control treatments ranged from $41 for thiobencarb - 2,4-D at 0.75 kg/ha to $234 for butachlor - 2,4-D (Table 5). Benefit-cost ratios ranged from 3 for 2,4-D followed by rotary weeding to 37 for 2,4-D applied 21 days after transplanting.

Applying herbicides by sprinkling. The effects on weed control of undiluted herbicides applied by sprinkling were studied during the wet season. Formulations of herbicides other than oxadiazon normally should be diluted with water and applied by knapsack sprayer. In this trial, 7 days after transplanting, herbicides were sprinkled from a bottle with a perforated cap directly onto plots flooded 3-5 cm deep.

All herbicides except thiobencarb and dinitramine, gave significantly higher yields than the untreated control (Table 6). However, yields did not significantly differ between herbicide treatments and were comparable to the yields with the hand-weeded and butachlor checks. These results suggest that the herbicides can be applied with or without dilution.

Weed control and seedling age. The effects of rice variety and seedling age on weed control were examined during the dry season. One-, 10-, 21- and 45-day-old seedlings of IR36 and IR42 were planted in weeded and unweeded plots. One-day-old seedlings were direct-seeded onto puddled soil at 90 kg dry seed/ha. The same day, 10-, 21-, and 45-day-old seedlings were transplanted 20 cm apart.

Weed infestations did not differ significantly with seedling age in both treatments. However, unweeded direct-seeded plots had fewer weeds than unweeded transplanted plots, regardless of variety (Table 7). Apparently the direct-seeded plots had significantly more rice plants than transplanted plots.

IR36 consistently yielded more when seedlings were transplanted younger than 45 days. However, 45-day-old seedlings planted in a weedy field yielded significantly less than younger seedlings. Direct-seeded IR42 lodged at maturity, and yielded significantly less than transplanted IR42.

Direct-seeded flooded rice. *Preliminary screening.* The performance of some herbicides varied with type of weed (Table 8). For example, molinate

Table 5. Effect of weed control treatments on grain yield, return to weeding, and benefit-cost ratios of irrigated transplanted IR50 rice.[a] Alcala-Amulung, 1981 wet season.

Treatment[b]	Herbicide rate[c] (kg a.i./ha)	Time of application[d]	Grain yield[e] (t/ha)	Return to weeding ($)	Benefit-cost ratio
Hand weeded twice	–	21 fb 35 DT	5.9 a	220	4
Butachlor EC + 2,4-D EC	0.5 + 0.25	PE	5.7 ab	234	25
Butachlor EC	0.75	PE	5.6 ab	216	20
Butachlor EC fb 2,4-D EC	0.5 fb 0.4	PE fb 21 DT	5.6 ab	216	19
2,4-D EC	0.5	21 DT	5.4 ab	190	37
Butachlor G	0.75	PE	5.4 ab	183	16
2,4-D EC fb rotary weeding	0.25	15 fb 25 DT	5.3 ab	126	3
Thiobencarb EC	1.0	PE	5.3 ab	161	10
Thiobencarb EC	0.75	PE	5.3 ab	165	12
Butachlor EC	0.5	PE	5.2 abc	155	21
Butachlor G	0.5	PE	5.1 bc	138	17
Thiobencarb – 2,4-D G	1.0	PE	5.0 bc	120	13
Thiobencarb – 2,4-D G	0.75	PE	4.5 cd	41	6
Unweeded check	–	–	4.2 d	–	–

[a]Av of 3 replications. [b]EC = emulsifiable concentrate; G = granules; + = tank-mixed; fb = followed by (applied sequentially). A spaced dash (–) indicates that 2 herbicides were formulated on the same carrier and applied as a single treatment. [c]a.i. = active ingredient. [d]DT = days after transplanting; PE = preemergence. [e]Separation of means by Duncan's multiple range test at the 5% level.

Table 6. Effect of early postemergence[a] application of herbicides with a sprinkler bottle on weed control and yield of irrigated transplanted IR42. IRRI, 1981 wet season.

Treatment[a]	Application rate (kg a.i.[b]/ha)	Weed wt[c] (g/m²)			Yield[c]
		Broadleaf weeds	Grasses	Sedges[d]	
Oxadiazon	0.75	14 ab	4 ab	41 bc	3.3 a
Butachlor	1.0	38 ab	0 a	77 bc	2.7 a
Butralin	2.0	50 ab	45 abc	176 c	2.7 a
Hand-weeded check	Twice	2 a	4 ab	0 a	2.6 a
Pendimethalin	0.75	64 b	14 ab	95 bc	2.4 a
Thiobencarb	2.0	36 ab	0 a	48 bc	2.2 ab
Dinitramine	1.0	29 ab	63 abc	137 c	1.9 ab
Butachlor check	1.0	16 ab	0 a	96 bc	2.9 a
Untreated check	–	30 ab	338 c	59 bc	0.9 b

[a]7 days after transplanting (DT). Hand-weeded check = weeded 15 and 30 DT. Butachlor check = diluted and applied with knapsack sprayer. [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]Mainly *Scirpus maritimus*.

Table 7. Effect of cultivar and seedling age on grain yield, panicle number, and weed control.[a] IRRI, 1981 dry season.

Seedling age[b] (days)	Grain yield (t/ha)		Panicle (no./m²)		Weed wt (g/m²)	
	IR36	IR42	IR36	IR42	IR36	IR42
			Weeded			
1	3.0 b	1.8 c	779 a	704 a	34 a	71 a
10	3.5 ab	3.1 b	485 b	357 b	23 a	28 a
21	4.1 a	3.3 b	348 c	254 c	32 a	40 a
45	2.9 b	4.5 a	286 c	347 bc	38 a	32 a
			Unweeded			
1	3.1 a	1.5 b	609 a	575 a	43 b	72 a
10	2.5 ab	1.1 b	385 b	293 b	171 a	147 a
21	3.4 a	1.6 b	348 b	248 b	104 a	133 a
45	1.8 b	2.7 a	325 c	280 b	122 a	124 a

[a]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]1-day-old seedlings direct-seeded onto puddled soil; 10-, 21-, and 45-day-old seedlings transplanted.

Table 8. Effect of herbicide on weed control, crop tolerance, and yield of wet-seeded flooded IR42 rice. IRRI, 1981 wet season.

Herbicide treatment[a]	Application		Weed wt[d] (g/m²)			Visual toxicity rating[e]	Yield[d] (t/ha)
	Rate (kg a.i.[b]/ha)	Time (DS[c])	Broadleaf weeds	Grasses	Sedges		
Thiobencarb – 2,4-D IPE G check	1.0 -0.5	5	29 b	0 a	0 a	4	3.6 a
Molinate – 2,4-D G	2.3 -0.5	10	6 ab	0 a	0 a	6	3.0 a
EPTC – 2,4-D G	2.0 -0.5	10	8 ab	8 a	3 a	7	2.9 a
Chlornitrofen – 2,4-D IPE G	1.25-0.5	5	0 a	205 d	1 a	7	2.8 a
Molinate – R-24216 G	2.0 -1.0	12	3 ab	2 ab	40 b	6	2.8 a
PPG-844 EC	2.0	5	71 b	104 bcd	1 a	9	2.5 a
PPG-844 G	1.0	5	92 b	73 bcd	0 a	1	2.4 a
Chlornitrofen – 2,4-D G	1.75-0.5	5	0 a	137 cd	0 a	5	2.3 a
Fluridone EC	0.15	10	40 b	63 cd	1 a	2	2.1 a
Untreated check	–	–	37 b	173 d	0 a	0	1.9 a

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. IPE = isopropyl ester. G = granules. EC = emulsifiable concentrate. [b]Active ingredient. [c]Days after seeding. [d]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [e]Rated 2 weeks after herbicide application on a scale of 0-10 where 0 = no toxicity and 10 = complete kill.

- 2,4-D and EPTC - 2,4-D provided very good to excellent control of broadleaves, grasses, and sedges. Plots treated with those herbicides yielded about 1 t/ha higher than the untreated check. Chlornitrofen - 2,4-D also gave excellent control of broadleaves and sedges, but poor control of grasses.

On the other hand, molinate - R-24216 gave very good control of broadleaves and grasses but poor control of sedges.

The liquid form of PPG 844 was most toxic to the rice crop; others were slightly to moderately toxic. The crop recovered completely from all herbicide injury.

Secondary screening. All treated plots except those treated with anilofos had significantly fewer weeds and significantly higher yields than the untreated check (Table 9). However, almost all the chemicals caused slight to severe initial crop injury. Perfluidone - bifenox appeared safest in wet-seeded rice. Tiocarbazil - 2,4-D, bifenox, and the lower dosage of perfluidone - molinate also showed promising yield and selectivity.

Advanced trials. In the dry season, at all sites, plots treated with thiobencarb - 2,4-D, naproanilide - thiobencarb, and bifenox - 2,4-D gave significantly higher yields than the untreated control (Table 10). All herbicide treatments at Maligaya yielded significantly more than the untreated check. Plots treated with butachlor + 2,4-D and chlomethoxynil - 2,4-D at Bicol yielded significantly less than the untreated plots.

In the wet season at all sites, all herbicide-treated plots gave significantly higher yields than the untreated control (Table 11). Piperophos - 2,4-D performed best at Maligaya and butachlor + 2,4-D at Bicol.

Rainfed transplanted rice. *Preliminary screening.* Yields did not vary significantly between herbicide treatments and the untreated check because the weed population was very low (Table 12). All chemicals were slightly toxic to rice.

Rainfed wet-seeded rice. *Preliminary screening.* Treatment with molinate - 2,4-D provided about 80% control of grasses, caused very slight toxicity, and yielded 2.3 t/ha more than did the untreated control (Table 13). Molinate - R-24216 also gave very good control of the grasses, but it was 60% toxic to rice.

Dry-seeded bunded rice. *Advanced trials.* At IRRI, the major weeds, in decreasing order of importance, were *E. glabrescens, Melochia concatenata, Echinochloa colona,* and *Eclipta prostrata.* Treatments with pendimethalin alone or in combination with oxadiazon gave excellent weed control (Table 14). They resulted in weed weights equivalent to those from the plot hand weeded twice and significantly lower than those of the

Table 9. Effect of early postemergence[a] application of promising herbicides on weed control, crop tolerance, and yield of wet-seeded, flooded IR36 rice. IRRI, 1981 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Weed wt[c] (g/m^2)	Visual toxicity rating[d]	Yield[c] (t/ha)
Tiocarbazil – 2,4-D IBE	1.5 -0.75	69 bcd	3	4.0 a
Perfluidone – bifenox G	0.3 -2.7	50 abc	2	3.5 a
Perfluidone – molinate G	0.55-0.38	27 a	4	3.3 ab
Perfluidone – molinate G	1.1 -2.75	27 a	8	3.2 ab
Bifenox F	2.0	46 ab	3	3.1 ab
Tiocarbazil – 2,4-D IBE G	1.0 -0.5	58 abc	3	3.0 ab
Perfluidone – bifenox G	0.15-1.35	33 ab	0	3.0 ab
Anilofos EC	0.6	170 de	6	3.0 ab
Thiobencarb – 2,4-D IPE check G	1.0 -0.5	62 abcd	4	2.8 ab
MC 10108 EC	0.5	67 bcd	9	2.6 b
Untreated check	–	195 e	0	0.4 c

[a] 6 days after seeding. A spaced dash (–) means 2 herbicides were formulated on the same carrier and applied as a single treatment. IBE = isobutyl ester. G = granules. F = flowable. EC = emulsifiable concentrate. IPE = isopropyl ester. [b] Active ingredient. [c] Av of 3 replications. Separation of means by the Duncan's multiple range test at the 5% level. [d] Rated 1 week after herbicide application on a scale of 0-10, where 0 = no toxicity and 10 = complete kill.

Table 10. Effect of early postemergence[a] application of granular herbicides on yield of direct-seeded, flooded IR36 rice at IRRI and at Maligaya Rice Research and Training Center, and Bicol Rice and Corn Experiment Station of the Philippine Bureau of Plant Industry, 1981 dry season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha)		
		IRRI	Maligaya	Bicol
Piperophos – 2,4-D IPE	0.33-0.17	2.7 bcd	4.9 a	4.8 a
Thiobencarb – 2,4-D IPE	1.0 -0.5	3.6 a	4.3 a	4.5 a
Naproanilide – thiobencarb	1.0 -0.7	3.7 a	4.2 a	4.4 a
Molinate – simetryn – MCPB	1.8 -0.1 -0.1	2.6 d	4.3 a	4.9 a
Pendimethalin	0.75	2.6 d	4.6 a	4.2 a
Bifenox – 2,4-D EE	2.0 -0.66	3.5 a	3.6 a	4.3 a
Oxyfluorfen	0.15	3.4 ab	3.5 a	4.3 a
Butachlor + 2,4-D IPE	0.75 + 0.5	3.7 a	4.2 a	2.2 c
Chlomethoxynil – 2.4-D IPE	2.1 -0.75	3.4 abc	4.9 a	1.8 c
Untreated check	–	2.7 bcd	1.2 b	3.0 b

[a]6 days after seeding. A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. IPE = isopropyl ester, EE = ethyl 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.

Table 11. Effect of early postemergence[a] application of granular herbicides on yield of direct-seeded, flooded IR36 rice at IRRI and at 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, 1981 wet season.

Treatment[a]	Rate (kg a.i.[b]/ha)	Yield[c] (t/ha)			
		IRRI	Maligaya	Bicol	Visayas
Piperophos – 2,4-D IPE	0.33-0.17	2.5 a	6.2 a	2.8 c	3.1 a
Thiobencarb – 2,4-D IPE	1.0 -0.5	2.3 a	5.9 ab	3.4 abc	2.9 a
Bifenox – 2,4-D EE	2.0 -0.66	3.1 a	5.0 bc	3.6 ab	2.7 a
Chlomethoxynil – 2,4-D IPE	2.1 -0.75	3.0 a	5.0 bc	3.4 abc	2.9 a
Molinate – simetryn – MCPB	1.8 -0.1 -0.1	2.8 a	4.8 bc	3.2 abc	3.1 a
Oxyfluorfen	0.15	2.5 a	5.1 bc	3.2 abc	2.9 a
Butachlor + 2,4-D IPE	0.75 + 0.5	2.4 a	4.6 c	3.9 a	2.7 a
Naproanilide – thiobencarb	1.0 -0.7	2.1 a	5.4 abc	3.1 bc	2.7 a
Pendimethalin	0.75	2.4 a	4.8 bc	3.0 bc	2.9 a
Untreated check	–	1.1 b	3.5 d	1.8 d	1.9 b

[a]6 days after seeding. A spaced dash (–) means that 2 or more herbicides were formulated on the same carrier and applied as a single treatment. IPE = isopropyl ester. EE = ethyl 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.

Table 12. Effect of herbicides on weed control, crop tolerance, and yield of rainfed transplanted IR42. IRRI, 1981 wet season.

Herbicide treatment[a]	Application		Weed wt[d] (g/m²)			Visual toxicity rating[e]	Yield[d] (t/ha)
	Rate (kg a.i.[b]/ha)	Time (DT[c])	Broadleaf weeds	Grasses	Sedges		
PPG-844 G	2.0	8	3 a	11 b	4 a	1	4.1 a
EPTC – 2,4-D G	2.0 -0.5	8	0 a	6 ab	2 a	1	3.6 a
Fluridone EC	0.15	8	0 a	14 b	1 a	1	3.6 a
Chlornitrofen – 2,4-D IPE G	1.75-0.5	3	0 a	10 ab	3 a	1	3.6 a
Molinate – 2,4-D G	2.3 -0.5	3	0 a	9 ab	3 a	3	3.6 a
Chlornitrofen – 2,4-D IPE G	1.25-0.5	3	1 a	7 ab	5 a	3	3.5 a
Untreated control	–	–	1 a	8 ab	12 a	0	3.5 a
Thiobencarb – 2,4-D IPE G check	1.0 -0.5	3	0 a	5 ab	4 a	3	3.3 a
Hand-weeded check	Twice	15 & 30	1 a	2 a	9 a	0	3.2 a

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. G = granules. EC = emulsifiable concentrate. IPE = isopropyl ester. [b]Active ingredient. [c]Days after transplanting. [d]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [e]Rated 2 weeks after herbicide application on a scale of 0-10, where 0 = no toxicity and 10 = complete kill.

Table 13. Effect of herbicides on weed control, crop tolerance, and yield of rainfed wet-seeded IR42. IRRI, 1981 wet season.

Herbicide treatment[a]	Application		Weed wt[d] (g/m²)			Visual toxicity rating[e]	Yield[d] (t/ha)
	Rate (kg a.i.[b]/ha)	Time (DS[c])	Broadleaf weeds	Grasses	Sedges		
Molinate – 2,4-D G	2.3 -0.5	10	0 a	11 a	0 a	3	3.7 a
Thiobencarb – 2,4-D IPE G check	1.0 -0.5	5	0 a	11 a	0 a	2	2.4 a
Chlornitrofen – 2,4-D IPE G	1.25-0.5	10	0 a	17 a	1 a	1	2.4 a
PPG-844 EC	1.0	10	6 a	84 a	0 a	3	2.2 a
Molinate – R-24216 G	2.0 -1.0	12	0 a	10 a	6 a	6	2.2 a
EPTC – 2,4-D G	2.0 -0.5	10	1 a	72 a	1 a	3	2.2 a
PPG-844 G	2.0	5	1 a	73 a	0 a	1	2.1 a
Fluridone EC	0.3	5	3 a	26 a	1 a	4	2.1 a
Chlornitrofen – 2,4-D IPE G	1.75-0.5	10	0 a	45 a	0 a	2	2.1 a
Untreated check	–	–	0 a	77 a	13 b	0	1.4 a

[a]A spaced dash (–) means that 2 herbicides were formulated on the same carrier and applied as a single treatment. G = granules. IPE = isopropyl ester. EC = emulsifiable concentrate. [b]Active ingredient. [c]Days after seeding. [d]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [e]Rated 2 weeks after herbicide application on a scale of 0-10, where 0 = no toxicity and 10 = complete kill.

Table 14. Effect of herbicide treatments on weed weight and yield of dry-seeded wetland rice.[a] IRRI, 1981 wet season.

Treatment[b]	Herbicide rate (kg a.i.[c]/ha)	Time of application[d]	Weed wt 40 DE (g/m²)	Grain yield (t/ha)
Weeded twice	–	10 fb 30 DE	4 a	2.5 a
Thiobencarb + oxadiazon	2.0 + 0.25	PE	23 bcd	2.3 ab
Pendimethalin fb 2,4-D	2.0 fb 0.5	PE fb 20 DE	23 bc	2.3 ab
Butachlor fb hand weeding	2.0	PE fb 20 DE	13 ab	2.1 ab
Propanil	3.0	15 DE	121 ef	2.0 ab
Butachlor	2.0	PE	77 de	2.0 abc
Pendimethalin + propanil	1.5 + 1.5	15 DE	123 e	1.6 abc
Oxadiazon	0.75	PE	96 e	1.6 abc
Thiobencarb	3.0	PE	76 e	1.6 abc
Pendimethalin + oxadiazon	1.5 + 0.25	PE	4 a	1.5 abc
Butachlor + oxadiazon	1.5 + 0.25	PE	48 cde	1.4 abc
Thiobencarb + propanil	2.5 + 1.25	15 DE	145 ef	1.2 bcd
Pendimethalin	2.0	PE	4 a	0.8 cde
Butachlor + propanil	1.5 + 1.5	15 DE	146 ef	0.2 de
Unweeded	–	–	286 f	0 e

[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]Active ingredient. [d]DE = days after emergence; PE = preemergence.

other herbicide-treatments, except butachlor followed by hand weeding.

Other herbicide combinations applied before preemergence and pendimethalin followed by 2,4-D also gave good weed control. Propanil and combinations of residual herbicides with propanil applied 15 days after emergence (DE) gave generally poor control. The weeds were too large (5- to 6-leaf stage) at the time of treatments. Application at 7-10 DE, when the weeds were younger, probably would have resulted in better weed control.

The plot that was hand weeded two times had the highest yield (Table 14). The highest yields from herbicide treatments were with thiobencarb + oxadiazon and pendimethalin followed by 2,4-D. All the herbicides tested, except butachlor + propanil and pendimethalin gave higher yields than the unweeded check. Butachlor + propanil controlled weeds poorly, pendimethalin was phytotoxic. The unweeded check gave no yield because of intense weed pressure.

In farmers' fields, the major weed at both sites

(Amulung and Solana, Cagayan Valley) was *E. colona.* Other weeds, in order of importance, were *Cyperus rotundus, Commelina diffusa, Ipomoea aquatica, Ischaemum rugosum,* and *Cynodon dactylon.*

In Solana, preemergence herbicides failed to control weeds adequately because of limited soil moisture after application. In Amulung, control was satisfactory during early crop establishment. At both sites, all plots that received a preemergence herbicide treatment, except butachlor at 2 kg/ha at Solana, were hand weeded 3 weeks after emergence (WE) because the treatments failed to give sustained weed control.

In Amulung, propanil applied alone or in combination with butachlor, thiobencarb, and pendimethalin gave weed control similar to that of the residual herbicides applied before emergence. In Solana, fields were flooded when the herbicides should have been applied. The herbicide combinations performed poorly because application was late. These plots were hand weeded 6 WE.

In both sites, herbicide treatments without a follow-up hand weeding gave the lowest yields. None of the herbicides by themselves gave adequate weed control (Table 15). Preemergence herbicides followed by hand weeding performed consistently well. Yields from those treatments and from two hand weedings were similar. In Amulung, yields from plots hand weeded once at 5 WE were significantly lower than yields from the plots weeded twice. In Solana, differences were not significant. That reflected the greater weed weight in Amulung.

Interrow cultivation. The major weeds in the area, in decreasing order of importance, were *Digitaria* spp. *Eriochloa procera, E. colona, Cyperus iria,* and *Mimosa pudica.* All the weed control practices, except harrowing alone, resulted in significantly lower weed weights than the unweeded check (Table 16).

Harrowing followed by hoe weeding + hand weeding in the rows + herbicide gave the highest yield (Table 16). That yield was significantly higher than yields from harrowing alone and the unweeded check but was not significantly different from yields from cultivation herbicide combinations or cultivation combinations.

Net returns to weeding were highest with the highest yielding treatment and lowest with two hand weedings because of the large amount of labor required for hand weeding (Table 16). The net return to weed control was higher with interrow cultivation than with hoe weeding because of the savings in time with interrow cultivation. In general, net returns from pendimethalin treatments were lower because pendimethalin cost more than the other herbicides used.

Dryland rice. *Advanced trial, interrow cultivation.* Different equipment for interrow cultivation were tested alone and in combination with herbicides and hand weeding in the row. Interrow cultivation was compared with hand weeded,unweeded, and herbicide checks.

Table 15. Effect of weed control practice on yield of dry-seeded wetland IR52 rice.[a] Amulung and Solana, Cagayan Valley, Philippines, 1981 wet season.

Treatment[b]	Herbicide rate (kg a.i.[c]/ha)	Time of application[d]	Grain yield (t/ha)	
			Amulung	Solana
Pendimethalin fb HW	1.5	PE fb 3 WE	4.1 a	2.8 a
Thiobencarb fb HW	2.5	PE fb 3 WE	4.2 a	2.3 abc
Hand weeded twice	–	3 WE fb 5 WE	4.0 ab	2.4 ab
Butachlor fb HW	1.5	PE fb 3 WE	3.2 bcd	2.7 a
Pendimethalin + propanil[e]	1.5 + 1.5	10 DE	2.0 cde	2.3 abc
Thiobencarb + propanil[e]	2.5 + 1.5	10 DE	2.6 def	2.3 abc
Hand weeded once	–	5 WE	1.9 fg	2.2 abc
Butachlor + propanil[e]	1.5 + 1.5	10 DE	1.5 g[f]	2.2 abc
Propanil	2.0	10 DE	2.3 efg	1.4 bc
Butachlor fb 2,4-D	1.5 fb 0.5	PE fb 3 WE	3.7 abc	–
Butachlor	2.0	PE	–	1.2 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; HW = hand weeding; + = tank-mixed. [c] Active ingredient. [d] PE = preemergence; WE = weeks after emergence; DE = days after emergence. [e] Followed by hand weeding 6 WE in Solana. [f] Av of 2 replications.

Table 16. Effect of weed control practice on weed weight, grain yield, and returns to weed control of IR50 dry-seeded wetland rice.[a] IRRI, 1981 wet season.

Weed control practice[b]	Time of application[c]	Weed wt 40 DE (g/m^2)	Grain yield (t/ha)	Net return to weed control ($/ha)
Harrow fb (Hoe + HW) + butachlor (2.0)	1 DE fb 12 DE	47 c	3.1 a	191
Weeded twice	10 fb 30 DE	42 c	2.6 ab	36
Harrow fb (IRC + HW) + butachlor (2.0)	1 DE fb 12 DE	47 c	2.6 ab	145
Pendimethalin (2.0)	PE	47 c	2.5 ab	109
Harrow + butachlor (2.0)	1 DE	87 bc	2.4 abc	114
Harrow fb (Hoe + HW) + pendimethalin (2.0)	1 DE fb 12 DE	46 c	2.4 abc	43
Harrow fb (IRC + HW)	1 DE fb 12 DE	84 bc	2.3 abc	133
Butachlor (2.0)	PE	67 bc	2.3 abc	136
Propanil (3.0)	10 DE	65 bc	2.3 abc	126
Harrow fb (IRC + HW) + pendimethalin (2.0)	1 DE fb 12 DE	35 c	2.2 abc	17
Harrow fb (Hoe + HW)	1 DE fb 12 DE	67 bc	2.2 abc	75
Harrow + pendimethalin (2.0)	1 DE	39 c	2.1 abc	55
Thiobencarb – 2,4-D (2.4 – 1.2)	PE	59 bc	2.0 abc	72
Harrow	1 DE	133 ab	1.6 bc	51
Unweeded	–	218 a	1.2 c	–

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]fb = followed by; Hoe = hoe weeding by Swiss hoe; HW = weeding of old weeds within rows of crop; IRC = Interrow cultivation by *lithao*. Number in parentheses is the rate of herbicide in kilograms of active ingredient per ha. [c]DE = days after emergence; PE = preemergence.

The major weeds in the area were *Rottboellia exalta, Eleusine indica, Digitaria* sp., *C. rotundus, Amaranthus spinosus,* and *Portulaca oleracea.* Sedges dominated at 14 DE but grasses increased with time and were the most important weed group by 42 DE. Sedges decreased in importance with time. The relative dry weights of broadleaf weeds increased up to 42 DE, then decreased.

Weed weight 42 DE (after the second interrow cultivation) was lowest in the plot that had received a hoe weeding plus hand weeding in the rows (Table 17). Hand weeding in the rows accounted for 11% more weed suppression than interrow cultivation alone. Hoe weeding gave 92% lower weed weight than the unweeded check; high-wheel cultivator, 86% lower; and rolling weeder, 15% lower. Weed weight in the herbicide treatment was not significantly lower than that in the unweeded check (Table 17).

Weeding with the rolling weeder required 99% fewer labor hours/ha than 2 handweedings; the high wheel cultivator, 91% fewer, and the hand hoe, 90% fewer. Complete weeding in the rows after the interrow cultivation required 998 labor hours/ha, 39% of the time needed for 2 hand weedings (Table 17).

Grain yields were low because establishment of the crop was late and moisture stress occurred at flowering and grain filling. Interrow cultivation with the hoe or the high wheel cultivator, supplemented with complete hand weeding in the rows, resulted in a yield not significantly different from that of the weed-free plot (Table 17).

The net return to weedings was highest when interrow cultivation equipment was used alone. Complete hand weeding and hand weeding in the rows resulted in a net loss. Using the rolling weeder in the herbicide-treated plot had a net return of $62/ha. The high wheel cultivator and hand hoe gave a negative return because more time was needed than with the rolling weeder.

PERENNIAL WEEDS AND THEIR CONTROL

Long-term effects of reduced tillage. The study on the effects of reduced tillage on weed shift and density in transplanted rice continued on the 15th and 16 crops. IR34, IR40, and IR42 were planted

Table 17. Effect of weed control method on weeding time, weed weight, yield, and return to weeding of dryland IR50 rice.[a] IRRI, 1980 wet season.

Treatment[b]	Weeding time (labor h/ha)	Weed wt (g/m²)	Yield (t/ha)	Net return to weeding ($/ha)
Weed-free check	3528 a	21 efg	1.6 a	-435
Hoe + HWR	1154 c	8 g	1.4 a	11
HWC + HWR	1482 c	34 cdef	1.3 abc	-91
Herbicide fb HWC + HWR	926 d	14 fg	1.1 bcd	-64
Hoe	258 e	41 cdef	0.8 cde	88
Herbicide fb RW	26 e	97 bc	0.8 de	62
HW	2538 b	42 cdef	0.7 de	-386
Herbicide fb RW + HWR	1129 cd	64 cd	0.7 de	-174
Herbicide fb HWC	281 e	47 cde	0.7 de	-4
RW + HWR	1246 c	55 cde	0.7 de	-147
Herbicide fb Hoe + HWR	1174 c	23 defg	0.7 de	-183
HWC	224 e	70 bc	0.6 de	62
Herbicide fb Hoe	315 e	30 cdef	0.6 de	-13
RW	22 e	108 bc	0.5 ef	67
Herbicide	4 e	218 ab	0.1 fg	-48
Unweeded check	–	326 a	0.0 g	–

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]HWR = hand weeding in rows; HWC = high wheel cultivator; fb = followed by; + = applied at the same time; RW = rolling weeder; HW = hand weeding.

in plots prepared by conventional tillage, minimum tillage, and zero tillage. Conventional tillage was one plowing and two harrowings and minimum tillage was one harrowing. For zero tillage, stubble of the previous crop was removed and paraquat was applied.

Annual weeds were *E. glabrescens, E. crus-galli* ssp. *hispidula,* and *M. vaginalis*; perennials were *Paspalum paspalodes* and *Scirpus maritimus.* Butachlor was applied to control annual weeds.

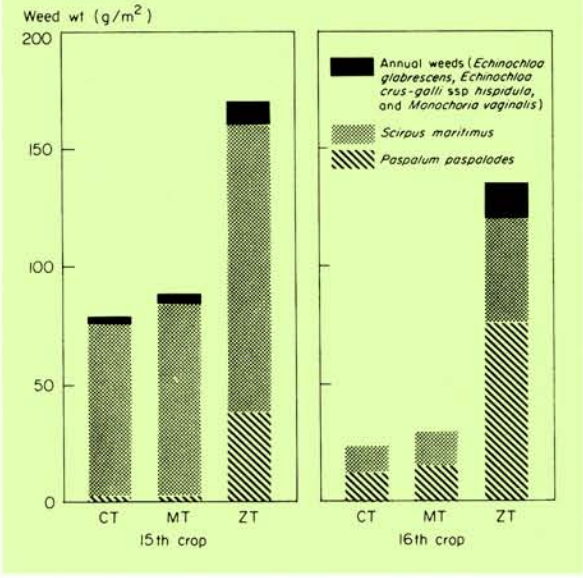
In the 15th crop, the zero-tillage plots were cultivated conventionally to control a severe infestation of *P. paspalodes.* Cultivation drastically reduced this weed but the stand of *S. maritimus* increased (Fig. 1). *S. maritimus* also dominated in the conventional tillage plots. Consequently, yields in the zero-tillage plots were significantly lower than those in the conventional tillage plots, regardless of variety (Table 18).

In the 16th crop, weed dominance shifted back to *P. paspalodes* in the reinstated zero-tillage treatments (Fig. 1). As a result, yields in the zero-tillage plots were again significantly lower than those in the conventional-tillage plots (Table 18).

These results suggest that *P. paspalodes* is more easily controlled by tillage than *S. maritimus.*

Control of *Scirpus maritimus.* Field experiments begun in the 1974 dry season continued in 1981. During the dry season, herbicide-treated and rotary-weeded plots had statistically higher yields than the untreated control (Table 19). A heavy population of *S. maritimus* resulted in very low yields in the untreated check.

When maize was intercropped with soybean,



1. Weed dry weights at harvest as indices of weed control by conventional tillage (CT), minimum tillage (MT), and zero tillage (ZT) (av of 3 cultivars). IRRI, 1981 dry and wet seasons.

Table 18. Effect of tillage on weed control and yield of the 15th and the 16th continuous rice crops. IRRI, 1981 dry and wet seasons.

Treatment	IR34 weed wt[a] (g/m²)			Yield[b] (t/ha)	IR40 weed wt[a] (g/m²)			Yield[b] (t/ha)	IR42 weed wt[a] (g/m²)			Yield[b] (t/ha)
	Annual	Perennial	Total		Annual	Perennial	Total		Annual	Perennial	Total	
15th crop, 1981 dry season												
Conventional tillage	2	62	64	3.3 a	3	71	74	2.7 a	3	93	96	2.9 a
Minimum tillage	2	74	76	3.3 a	4	89	93	2.5 ab	3	100	103	2.8 ab
Zero tillage	16	189	205	2.6 b	10	166	176	2.1 b	5	128	133	2.4 b
16th crop, 1981 wet season												
Conventional tillage	0	13	13	3.0 a	0	15	15	2.9 a	1	42	43	3.8 a
Minimum tillage	0	19	19	2.4 b	0	19	19	2.9 a	0	51	51	3.6 a
Zero tillage	2	87	89	1.9 b	16	167	183	2.1 b	26	111	137	2.7 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 by Duncan's multiple range test at the 5% level.

Table 19. Effect of weeding method and cropping pattern on crop yield and population density of *Scirpus maritimus* and other weeds, IRRI, 1981 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	4.1 a		28	53	101	124	0
Bentazon (2 kg a.i./ha)	4.2 a		44	0	0	59	0
No weeding	0.7 b		24	55	85	473	0
Dryland crops-transplanted rice	Maize (ears)	Soybean (kg)					
Handweeding	41,500 b	500 a	0	0	0	0	0
Butachlor (2 kg a.i./ha) fb bentazon (1 kg a.i./ha)	50,000 a	529 a	91	0	3	3	0
No weeding	54,000 a	68 b	207	7	22	16	0
Dryland crop-dry-seeded, rainfed bunded rice							
Butachlor (2 kg a.i./ha) fb bentazon (1 kg a.i./ha)	40,000 a		52	4	0	0	2
Handweeding	33,500 a		0	0	0	0	0
No weeding	46,000 a		76	63	22	0	4

[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.

weeds did not affect the maize yield very much. Herbicide-treated and hand-weeded soybean plots had significantly higher yields than the untreated control.

When maize was planted alone, yield differences between treatments were not significant, probably because of fewer weeds in all plots.

During the wet season, in continuous transplanted rice, bentazon-treated and rotary-weeded plots had statistically similar yields. However, only the bentazon-treated plots yielded significantly higher than the untreated control (Table 20). A heavy population of *S. maritimus* in the untreated control caused a yield 2.5 t/ha lower than that of the treated plots.

In dryland crop-transplanted rice, treated plots also yielded significantly higher than the untreated control.

In the first crop of dry-seeded rainfed bunded rice following maize, the only yield (3.5 t/ha) was from plots hand weeded twice. Because of a build-up of the broadleaf *Macroptilium lathyroides* (formerly *Phaseolus lathyroides*), butachlor as preemergence treatment and the untreated control gave no yield. Butachlor decreased grass and sedge populations but not the broadleaf weeds that dominated the plots later. Because the soil was unworkable, the second dry-seeded rice crop was not planted.

Control at different growth stages with 2,4-D. 2,4-D was applied at 0.5 kg/ha to *S. maritimus* at 6 growth stages to examine the growth stages susceptible at a minimal control rate. Annual weeds were controlled with butachlor.

2,4-D provided adequate control at all stages, and all treated plots yielded significantly more than the untreated check (Table 21). Its application at the 4-leaf stage provided significantly better weed control than its application at earlier (0- to 4-leaf) or later (5- to 8-leaf) stages. However, yields did not vary significantly between leaf-stage treatments. Yields of plots treated at 0- and 7-leaf stages were significantly lower than those of the hand-weeded check.

Control of *Cyperus rotundus*. The effect of ben-

Table 20. Effect of weeding method and cropping pattern on rice yield and population density of *Scirpus maritimus* and other weeds. IRRI, 1981 wet season.

Cropping pattern, 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)	4.7 a	51	50	38	2	0
Rotary weeding	4.3 ab	5	8	27	206	0
No weeding	1.8 b	30	38	102	452	0
Dryland crops-transplanted rice						
Rotary weeding	5.6 a	8	12	86	98	0
Bentazon (2 kg a.i./ha)	4.9 b	25	3	29	0	0
No weeding	2.6 c	15	43	354	172	0
Dryland crop-dry seeded, rainfed bunded rice						
Handweeding	3.5	12	2	5	0	0
Butachlor (2 kg a.i./ha)	0	340	162	95	3	19
No weeding	0	592	218	181	4	12

[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.

Table 21. Effect of 2,4-D[a] applied at different growth stages of *Scirpus maritimus* on weed control and yield of transplanted IR36. IRRI, 1981 wet season.

Growth stage	Application time[b]	Weed wt[c] (g/m²)	Yield[c] (t/ha)
Hand-weeded check	2 & 5 WT	2 a	3.8 a
5-leaf stage	3 WT	21 c	3.6 ab
6-leaf stage	4 WT	43 cd	3.6 ab
4-leaf stage	2 WT	8 b	3.3 ab
3-leaf stage	1 WT	79 d	3.3 ab
7-leaf stage	5 WT	36 cd	3.2 b
0-leaf stage	PE	65 cd	3.1 b
Untreated check	–	137 e	2.3 c

[a] Applied at 0.5 kg active ingredient/ha. [b] WT = weeks after transplanting. PE = preemergence to the weed. [c] Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 22. Effect of herbicide on control of *Cyperus rotundus* and on stand and yield of IR36 under dryland conditions. IRRI, 1981 wet season.

Treatment[a]	Application		*C. rotundus* dry wt[d] (g/m²)	Rice count[d] (no./m²)	Yield[d] (t/ha)
	Rate (kg a.i.[b]/ha)	Time[c]			
Hand-weeded check	Twice	2 fb 5 WE	10 a	358 a	2.4 a
2,4-D fb bentazon	0.5 fb 1.0	2 fb 4 WE	29 abcde	305 a	2.4 a
Bentazon	1.0	3 WE	35 bcde	337 a	2.4 a
Bentazon fb bentazon	1.0 fb 1.0	2 fb 4 WE	12 ab	285 a	2.3 ab
Bentazon	2.0	3 WE	18 abcd	387 a	2.3 ab
2,4-D	1.0	3 WE	50 cde	369 a	2.2 ab
Bentazon fb 2,4-D	1.0 fb 0.5	2 fb 4 WE	16 abc	363 a	2.2 ab
2,4-D	0.5	3 WE	68 ef	356 a	2.0 ab
NC 20484	–	PE	100 ef	293 a	2.0 ab
2,4-D fb 2,4-D	0.5 fb 0.5	2 fb 4 WE	34 bcde	323 a	1.9 ab
NC 20484	0.5	PE	77 def	282 a	1.8 ab
Untreated check	–	–	164 f	154 b	1.0 c

[a]fb = followed by. [b]Active ingredient. [c]WE = weeks after emergence. PE = preemergence. [d]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

tazon, 2,4-D, and NC 20484 on *C. rotundus* in dryland rice was studied during the wet season. All plots were kept free of other weeds during the experiment. *C. rotundus* was harvested for dry matter yield at its flowering stage. Rice plants were counted at maturity.

All treated plots gave significantly higher yields than the untreated check. The check had significantly fewer rice plants because of the high *C. rotundus* infestation (Table 22). In a few treated plots, weed stand was not significantly different from that in untreated control. Generally, bentazon and hand weeding gave comparable control of *C. rotundus*.

Irrigation water management

Irrigation Water Management and Agricultural Economics Departments

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PREDICTION OF SEEPAGE AND PERCOLATION

Field work to define patterns and develop predictive models for seepage and percolation was concluded in 1981. Seepage and percolation, the land component of total water requirement, is highly variable across locations, whereas evapotranspiration, the crop component of water requirement, can be specifically determined for wide areas of irrigated paddies with a minimum of field observations.

The major factors influencing seepage and percolation are *landscape* — slope, elevation relative to major drainage sink, distance to drainage sink, water surface slope to major drainage sink, and drainage density; *paddy field* — bund width, area, perimeter-to-area ratio, and relative elevation; *soil profile* — bulk density, porosity, texture (maximum percentage of clay in 50-cm profile), penetration resistance (penetrometer), organic matter, minimum saturated hydraulic conductivity, depth of standing water, number of days with an absence of standing water, and water table depth; *stochastic* — season, and rainfall.

In the Lower Talavera River Irrigation System (LTRIS) management intervention research (considered Phase I), seepage and percolation was measured in a grid sample of 60 locations in the 2,500-ha system. Preliminary multiple regression analysis of dry-season data identified the importance of five factors (Table 1, 2).

The most important factor in accounting for 27.5% of the variation in seepage and percolation rate in the wet season, and 26.4% in the dry was the influence of length of the paddy boundary, relative to its size, as the opportunity for water to be lost from the field. Slope and paddy surface elevation relative to the nearest sink explained 17-21% of the seepage and percolation variation, depending on the season. Water adequacy explained 9-11% and highest clay percentage in the top 45 cm of the soil profile accounted for 5-7%.

The regression model accounted for 84% of the variability in seepage and percolation rate in the dry season, for 77% in the wet season.

In Phase I, no data on soil organic matter, aggregate index, vertical hydraulic conductivity in the soil profile, dynamics of the water table, and differences in standing water on adjacent paddies were available. Because measurements were primarily to predict seepage and percolation as a guide for management and to evaluate system efficiency, they were made at widely scattered locations, not on adjacent paddies. The effect of landscape position and drainage density also could not be included.

In Phase II, eight sites were selected so that the influence of the major factors could be incorporated into prediction equations. Sloping (meter stick) gauges, plastic rain gauges, Class A evaporation pans, and a battery of piezometers to a maxi-

Table 1. Multiple regression model[a] relating seepage and percolation (S&P) rates to physical variables and water adequacy. Lower Talavera River Irrigation System, 1978 and 1979 dry seasons.

Physical variable	Estimated regression coefficient	Standard error of estimate	T-statistic	Partitioned R^{2b} (%)
Constant (*a*)	0.500	–	–	–
Perimeter-to-area ratio (*PA*)	0.187**	0.040	21.83	26.4
General land slope (*SL*)	0.664**	0.185	12.87	19.3
Elevation relative to nearest major sink (*EL*)	0.319**	0.073	19.16	20.7
Highest clay percentage in top 45 cm of soil profile (*CL*)	-0.019*	0.011	3.36	6.6
No. of days without paddy standing water (*SD*)	0.319	0.041	5.08	10.8
Coefficient of determination, R^2	86.1%			
F-statistic	56.81**			
N	52			

[a]Regression model: S&P = $a + b\ (PA) + c\ (SL) + d\ (EL) + c\ (CL) + f\ (SD)$. [b]Adjusted for all other factors.

Table 2. Multiple regression model[a] relating seepage and percolation (S&P) rates to physical variables and water adequacy. Lower Talavera River Irrigation System, 1977 and 1978 wet seasons.

Physical variable	Estimated regression coefficient	Standard error of estimate	T-statistic	Partitioned R^{2b} (%)
Constant (*a*)	0.795	–	–	–
Perimeter-to-area ratio (*PA*)	0.199**	0.049	16.55	27.5
General land slope (*SL*)	0.832**	0.225	13.61	18.5
Elevation relative to nearest major sink (*EL*)	0.280**	0.090	9.90	17.7
Highest clay percent in top 45 cm of soil profile (*CL*)	-0.021	0.013	3.02	5.1
No. of days without paddy standing water (*SD*)	0.117*	0.050	5.44	9.3
Coefficient of determination, R^2	77.6%			
F-statistic	46.75**			
N	52			

[a]Regression model: S&P = $a + b\ (PA) + b\ (SL) + d\ (EL) + e\ (CL) + f\ (SD)$. [b]Adjusted for all other factors.

mum depth of 1 meter to monitor hydraulic gradients were installed in 10 to 18 contiguous paddies at each site.

Seepage and percolation in those 84 paddies were significantly different from season to season and for days with and without rain (Table 3). This seasonal difference was similar to that in Phase I, in which wet-season values exceeded dry-season values. This is attributed to differences in standing water depth and to occurrence of rainy and non-rainy days (Table 4).

A stepwise linear regression analysis was used to develop prediction equations. Nineteen variables described soil profile characteristics of individual paddies as well as landscape characteristics of sites. In most cases, season was included as a dummy variable. In one model, season, paddy bund width, elevation of the paddy relative to an adjacent higher paddy, average depth to the true groundwater table, and the highest aggregate index of the top 50 cm of the soil profile accounted for 94.7% of the variability in the predicted result (Table 5). In a second model, season, paddy bund width, general land slope, elevation of the paddy relative to the nearest major drainage sink, minimum hydraulic conductivity measured in the top 50 cm of soil, and total number of days without standing water during irrigation accounted for 96.1% of the variability (Table 6).

These models include a minimum number of laboratory tests and easily observable field parameters as a guide to practical irrigation scheduling. Rice-growing irrigation systems in the region would each require calibration to make predictive models appropriate for each set of site conditions.

SLOPING GAUGE WATER METER

Development of simple low-cost devices for measuring irrigation requirements and periodic depths continued.

In 1981, the sloping (meter stick) gauge (Annual report for 1975) was modified by adding a low-cost plastic or metal rain gauge (Fig. 1). The gauge measures daily water level recession in a paddy with closed bunds including evapotranspiration and net seepage and percolation. When adjusted for the daily rainfall at the site, those two components constitute paddy-level irrigation water requirement. The improved sloping gauge was extensively tested in seepage and percolation research, with more than 6,400 measurements completed in 1980-1981, and is now being tested in practical management application.

IRRIGATION SYSTEM MANAGEMENT

Communal systems. Three studies of communal irrigation systems in northern, central, and southern Luzon, Philippines, were concluded in 1981.

Table 3. Seasonal seepage and percolation (S&P) rate during days with and without rain. Lower Talavera River Irrigation System, Nueva Ecija, 1980 dry and wet seasons.

Season	S&P (mm/day)		T-statistic
	Days with rain	Days without rain	
Dry	10.3	3.0	-3.79**
Wet	7.0	0.7	-10.33**
Weighted mean	7.3	2.4	

Table 4. Paddy standing water during days with and without rain. Lower Talavera River Irrigation System, Nueva Ecija, 1980 dry and wet seasons.

Season	Paddy standing water (cm)		T-statistic
	Days with rain	Days without rain	
Dry	5.7	5.2	-2.29*
Wet	6.1	5.3	-6.55**

Table 5. Regression model[a] of seepage and percolation (S&P) against some physical variables, with season as time parameter. Lower Talavera River Irrigation System, Nueva Ecija, 1980 dry and wet seasons.

Regressor	Parameter estimate	Standard error	F-statistic
Intercept (*a*)	28.407		
Season (dummy): 0-dry; 1-wet (*S*)	0.837*	0.360	5.39
Paddy bund width (cm) (*W*)	-0.351**	0.062	31.59
Elevation relative to upper paddy (cm) (*E*)	-0.092*	0.031	8.88
Groundwater table (m) (*G*)	-4.40**	0.403	119.08
Highest aggregate index in top 50 cm soil layer (*I*)	-0.604**	0.162	13.95
Coefficient of determination, R^2	0.947**		
F-statistic	35.78		
N	16		

[a] $S\&P = a + b\ (S) + c\ (W) + d\ (E) + e\ (G) + f\ (I)$.

Table 6. A 6-variable regression model[a] of seepage and percolation (S&P) against selected physical site characteristics, with season as time determinant. Lower Talavera River Irrigation System, Nueva Ecija, 1980 dry and wet seasons.

Regressor	Parameter estimate	Standard error	F-statistic
Intercept (*a*)	17.116		
Season (dummy): 0-dry; 1-wet (*S*)	1.148**	0.341	11.30
Paddy bund width (cm) (*W*)	-0.294**	0.50	33.46
General landslope (%) (*LS*)	-4.975**	0.421	139.49
Elevation relative to major sink (m) (*ES*)	0.561**	0.112	25.30
Minimum hydraulic conductivity in top 50 cm soil layers (m/day) (*HC*)	-5.920**	1.680	11.42
Total number of days in season without paddy standing water (*WL*)	0.009*	0.002	10.29
Coefficient of determination, R^2	0.961**		
F-statistic	36.66		

[a] $S\&P = a + b\ (S) + c\ (W) + d\ (LS) + e\ (ES) + f\ (HC) + g\ (WL)$.

The analysis used water measurements, interviews, surveys, and participant observation.

In the Bacarra-Vintar area of Ilocos Norte, Philippines, nine federated communals on a single water source were studied. The communals are the Zanjera type unique to northern Luzon. That organizational form pays particular attention to egalitarianism and trust as well as to performing an agrarian land access function for persons who participate in building the irrigation system in return



1. Improved sloping gauge to measure rainfall, evapotranspiration, and seepage and percolation in rice paddies.

for cultivation rights to land. The nine systems, with autonomous organizational structures but with some overlapping membership, irrigate approximately 500 ha of rice lands in the wet season, and a much smaller area in the dry, and serve approximately 1,000 farmers. Dryland crops and garlic are important cash crops.

Even though the egalitarian emphasis on land access to water persists, the federated system has the classical maldistribution of water — tremendous excess at the head, a deficit at the tail. Basically, the system has excessive water throughout the year, with the lowest daily flow available to the gross area equal to 1.5 liters/second.

The problem of deficit at the tail is minimized by checking of creeks and drainageways in the area for reuse downstream (Table 7). The monthly shares of irrigation water received (expressed as % of total discharge available in the main canal at the headworks) provide a mean annual reuse factor of 1.41, ranging from 0.94 in December to 1.95 in February. Individual Zanjeras receive 0-80% of the main canal flow.

These systems demonstrate community self-reliance and an independence from centralized government irrigation assistance. Despite the great maldistribution of water, individual Zanjeras have used the organizations for maintenance activities that require group action. The individuals responsible for water distribution in each system demonstrate the importance of strong leadership and decentralized, community-level responses to water needs.

The Upper Banila Communal Irrigation System of Pangasinan irrigates 1,076 ha and serves 620 farmers in 6 barangays. This large communal system has been assisted by the National Irrigation Administration (NIA). A semipermanent diversion structure was constructed in the late 1970s to accompany a corporate rice production project.

Table 7. Monthly shares of irrigation water received by each Zanjera, 1981.

Month	Share of irrigation water[a] (%)											Reuse factor[b]
	Head					Tail						
	San Jose 4.2%	Cabaroan 6.3%	San Juan 13.7%	Sinigpit 6.0%	Sum, %	Surgui 26.6%	San Pedro 2.8%	Collibeng 3.4%	Santa Rosario 28.7%	Nibinib 8.3%	Sum, %	
January	9	15	63	22	109	32	4	0	24	13	73	1.82
February	13	17	80	23	133	36	6	0	14	6	62	1.95
March	15	16	79	24	134	22	10	0	5	4	41	1.75
April	18	9	72	24	123	16	2	0	0	1	19	1.42
May	15	2	55	23	95	28	4	2	0	1	35	1.30
June	15	5	45	21	86	30	4	1	8	5	48	1.34
July	12	15	33	10	70	28	15	4	7	5	59	1.29
August	11	15	30	13	69	26	15	7	7	4	59	1.28
September	11	17	29	10	67	34	20	10	8	3	75	1.42
October	11	13	30	12	66	32	18	8	6	1	65	1.31
November	7	3	28	12	50	18	19	8	3	2	50	1.00
December	7	9	22	9	47	30	3	0	11	3	47	0.94
Range	7-18	2-17	22-80	9-24		16-36	2-20	0-10	0-24	1-13		

[a]Of the total discharge of the main canal at the headworks. [b]Reuse factor = $\frac{\Sigma \text{ percentages of flow received by each Zanjera}}{100\% \text{ in main canal}}$.

The diversion structure washed away within a year of construction and the farmers, on their own initiative, reconstructed a brush dam to divert water in the traditional manner. The corporate farm project was discontinued after the second year.

The study attempted to determine farmers' responses to discontinuation of the project and the physical and social factors related to access to water in a large system. The system was similar in some characteristics to the Zanjera — the land layout, with long narrow fields and holdings that were oriented perpendicular to the lateral canals, particularly in the head reach of the system, emphasized equal access to water. The farmers, through group maintenance of the brush dam, demonstrated their need to work together for the acquisition of the water.

To explain differential access to water, stress days (defined as the number of days in excess of three in any one sequence over rice vegetative and reproductive growth stages) was used as the dependent variable. Independent variables included position on canal, linear distance from headgate on the lateral canal, elevation difference between canal and paddy, farm size, farmer's years of education and years of membership in the association. Direct access to the canal and use of exchange labor were dummy variables. The regression equation accounted for 62.4% of the differential access variability (Table 8). The most important variables were lateral distance, elevation, years of membership in association, and the dummy variables. A large system modernization project scheduled to start in 1983, using external loan funding without farmer participation, could convert the communal system to a national system under the direct control of the government. The current study will serve as a benchmark for evaluation of that project.

The Aslong Communal Irrigation System (ACIS) irrigates approximately 300 ha and serves 150 farmers in Camarines Sur. It is an example of systems that received government assistance through popular participation. The Republic of the Philippines requires that all assistance to communal irrigation associations be amortized in equal annual payments at no interest over a period of up to 50 years.

The NIA is testing the use of participation to assist communals. Six to nine months before actual

Table 8. Estimated coefficients, means and standard deviation of regression equation using number of stress days as dependent on specified differential access variables. Upper Banila Communal Irrigation System of Pangasinan, Philippines, 1981.

Variable	Regression coefficient[a]	Standard error	Mean	Standard deviation
No. stress days			29.78	50.78
Intercept (days)	14.255			
Canal position (*CP*)	-1.179	0.942		
Lateral distance (100 m) (D_L)	0.001[c]	0.006	10.26	12.49
Elevation (m) (*E*)	-0.069[c]	0.053	16.26	13.38
Land size (ha) (*L*)	0.865	0.713	1.34	0.83
No. years in school (E_d)	0.322	0.235	5.05	2.99
Duration membership in association (yr) (*DM*)	0.343[c]	0.077	19.01	9.68
Accessibility[b] (*A*)	3.295[c]	1.527		
Exchange labor[b] (E_x)	-3.396[c]	1.401		
No. of observations	64,000		64.00	64.00
R^2	0.624**			
F-value	11.44			

[a]Regression model: $SD = a + b\ (CP) + c\ (D_L) + d\ (E) + d\ (E) + e\ (L) + f\ (E_d) + g\ (DM) + h\ (A) + i\ (E_x)$.
[b]Dummy variables. [c]Significant at 10% level of probability.

construction, it fields community organizers, who help existing or new irrigation association leaders learn to manage the construction. These management skills include canvassing materials, checking on the NIA project engineer's work, organizing daily labor, and contracting for portions of the work. Participating farmers pay 10% in cash, kind, or labor. The irrigation association pays direct costs of construction materials. The engineer's and community organizer's time is free.

In 1981, the first year after construction was completed, the system displayed the classic head-to-tail maldistribution of water. The water right is listed as 777 liters/second, but the system extracted an average 815 liters/second from the Aslong River and diverted 777 liters or less/second only 10% of the time. Some portions of the system were flooded during several serious consecutive typhoons in November and December.

With the overappropriation of water, a 2.86 relative water supply by the system and a serious water supply insufficiency at the tail of the system existed simultaneously. Some parts of the system never received water (Table 9). Relative water supply, as the ratio of water supplied to water required, ranged from 2.8 at the head to 1.3 toward the tail.

The major problem is the inability of lateral canals to handle the amount of water conveyed. The conveyance efficiency for system components (59% conveyance efficiency at the head and close to 100% efficiency at the tail) is largely responsible for water maldistribution. So long as the quantity of water is large, careful management of the system to achieve efficient and equitable operations does not appear to be urgent. In the 1981 wet season, yields averaged 1.3 t/ha because of low input use (Table 10) and typhoon damage. Crop cuts and farmer reports agreed. The 1980 study will serve as a benchmark for a follow-up study planned for 1983, to assess socioeconomic costs and benefits of participatory management of communal irrigation.

Irrigation system management research committee. The recognition of major maldistribution problems over the main system led to a memo of agreement between IRRI and NIA to form an Irrigation System Management Research Committee, which plans, implements, evaluates, and reports research. Current research activities include an intensive model (2,500 ha), an intermediate model (13,500 ha), and an extensive model (24,000 ha), of irrigation system management, to minimize drainage problems, farmer participation, and a Barangay school on irrigation water management.

Intensive model. Monitoring in the LTRIS continued. The 1981 water-use efficiencies were among the highest so far (Table 11). Crop yield remains 3 t/ha, largely because of major weather disturbances and the low use of inputs the season after a

Table 9. Irrigated area, irrigable area, and relative water supply by sectors of the Aslong Communal Irrigation System, 1981 wet season.

	Sagup II	Sagup I	Bahay	Aslong	Palangon	Total
Irrigated area (ha)	64.8	64.9	21.3	52.2	95.6	298.8
Irrigable area (ha)	76.3	67.5	33.2	52.2	109.0	337.4
Percent irrigated	84.4%	96.0%	66.0%	100.0%	88.0%	88.6%
Weighted mean RWS[a]	2.86	1.80	1.70	1.61	1.32	
Position	Head	Middle	Tail	Tail	Tail	

[a]Relative water supply = amount of water supplied/amount of water required.

Table 10. Area, yield, inputs, and input cost[a] benchmark survey. Aslong Communal Irrigation System, Camarines Sur, Philippines, 1980.

Season	Respondents (no.)	Av area (ha)	Yield (t/ha)	Fertilizer		Insecticide cost ($/ha)	Herbicide cost ($/ha)	Seasonal cost ($/ha)
				N/ha	$/ha			
Wet	59	1.25	1.4	16.80	13.16	4.77	3.13	21.06
Dry	31	1.37	1.2	9.83	7.08	3.81	2.80	13.69

[a]$1 = ₱7.50.

Table 11. Seasonal water-use efficiencies in the Lower Talavera River Irrigation System for the before, during, and after implementation of intensive management intervention, 1981.

	Year	Water efficiency (%)	
		Dry season	Wet season
Before implementation	1975	–	43
	1976	51	–
During implementation	1977	–	60
	1978	60	50
	1979	73	70
After implementation	1980	69	50
	1981	75	65

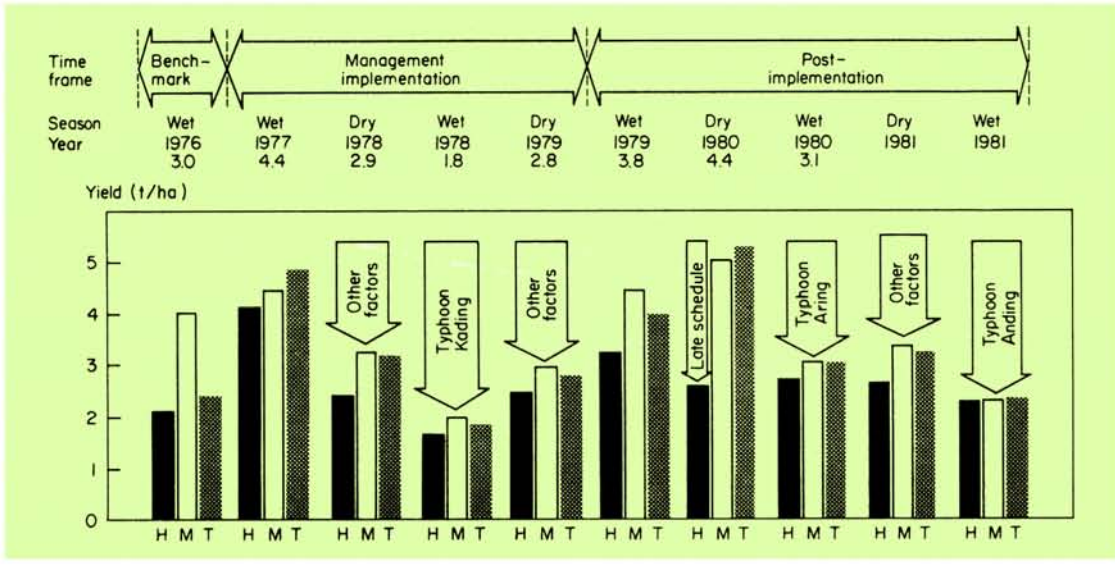
major crop disaster (Fig. 2). Relative head, middle, and tail equity in yield are observed from the 1980 wet season to the present.

Actual farming activities in the LTRIS system indicate a high degree of equity in access to water supply (Fig. 3). The similarity of the cumulative cropped areas for soaking, plowing and harrowing, transplanting, terminal drainage, and harvest, in terms of slope of the curve and duration of the activity from the upper section to the middle section to the tail section, confirms the relative equitable access to the available water supply. One result that appears to have deviated from earlier performance is the lack of agreement between target water flow and measured water flow. These two water flow parameters indicated closer agreement in 1980 than in 1981 (Fig. 4).

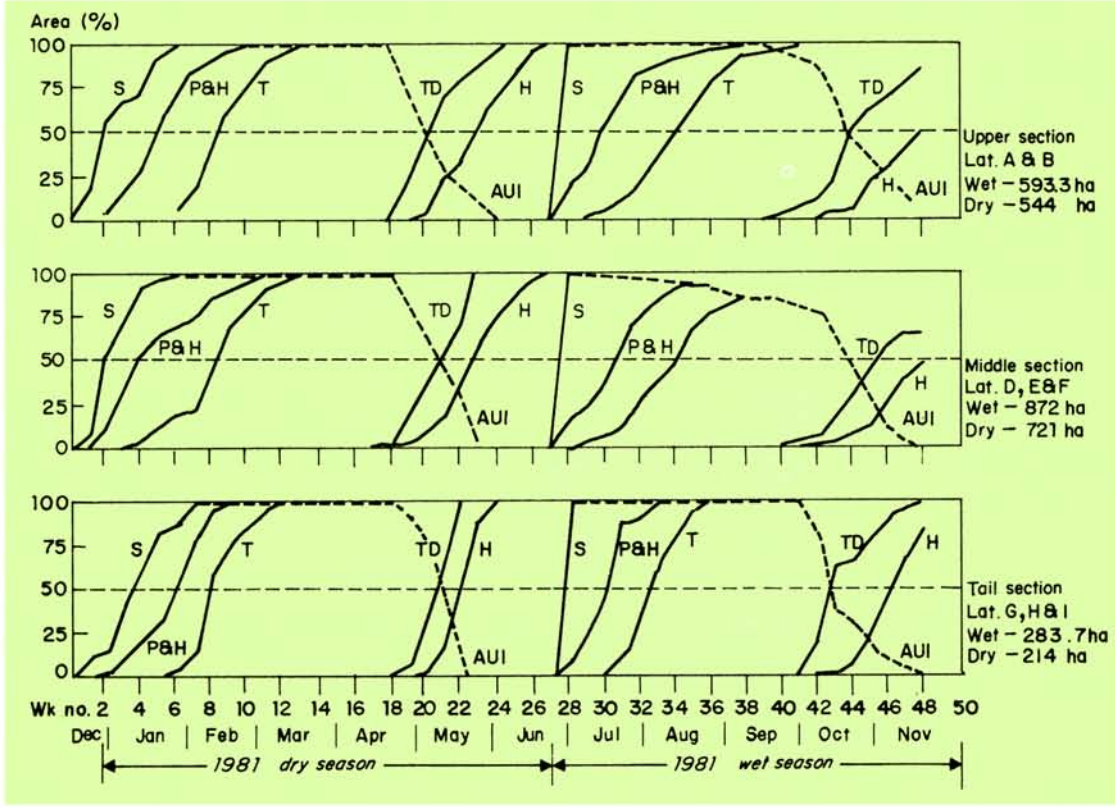
Intermediate model. The intermediate model has less intensive measurement, control, and monitoring than the intensive model. In the Pampanga River Irrigation System (PRIS), where an intermediate system management model will be introduced in the 1982 wet season, the benchmark data indicate dry-season yields (Table 12, 13) far below potential and less than wet-season yields. Yields averaged 3.7 t/ha for the head, 3.4 t/ha for the middle, and 3.3 t/ha for the tail.

In both the wet and dry seasons, yields at the tail of lateral C (2,500 ha) and of the system as a whole (13,500 ha) are lowest.

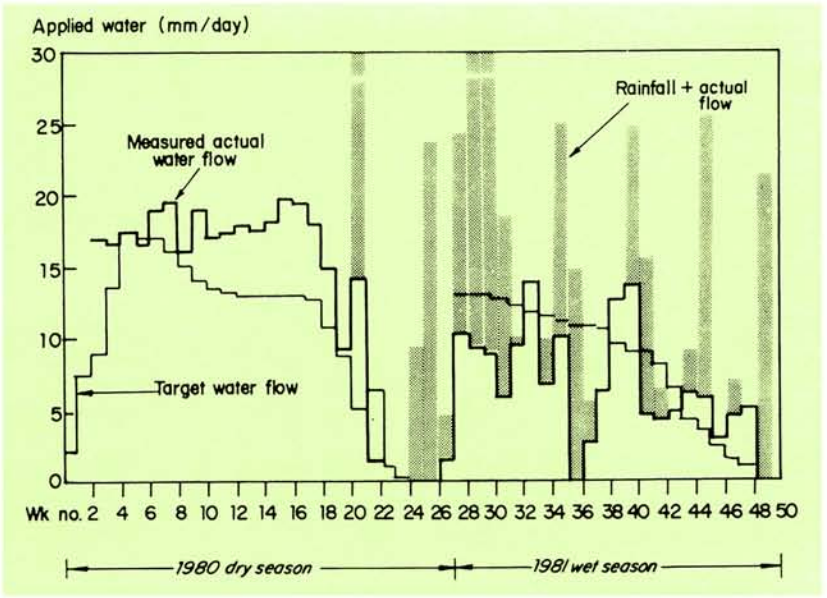
The benchmark data for the PRIS system indicate a major discrepancy between the calculated target discharge based on crop needs and actually measured flows for the dry season (Fig. 5). Another manifestation of water problems is indicated in length of time between the beginning of land soaking in mid-December and completion of transplanting or time for final fields to reach normal irrigation practice. The lateral F component of the PRIS system, the furthest from the source, is more than 20 km long and serves more than 3,000 ha.



2. Mean seasonal yield performance, by position, in Lower Talavera River Irrigation System, 1976-81. H = head, M = middle, T = tail.



3. Actual farming activities in terms of cumulative areas in land soaking (S), plowing and harrowing (P&H), transplanting (T), terminal drainage (TD), and harvesting (H) observed in the Lower Talavera River Irrigation System in the 1981 dry and wet seasons.



4. Average daily target water flow, measured actual flow and rainfall (mm/day), by weekly intervals. Lower Talavera River Irrigation System-District II, Upper Pampanga River Integrated Irrigation System-National Irrigation Administration, Nueva Ecija, 1981 dry season and 1981 wet season.

Table 12. Average yield at 3 laterals of Pampanga River Irrigation System (PRIS), Nueva Ecija, Philippines, 1981 dry season.

Lateral	Av yield[a] (t/ha)		
	Head	Middle	Tail
C	2.62 (9) ab	3.30 (14) a	2.40 (10) b
C-1	1.23 (3) a	2.76 (8) a	2.78 (5) a
F	2.82 (11) a	2.52 (9) a	2.66 (10) a
PRIS system	3.18 (27) a	2.73 (46) a	2.57 (40) a

[a]Numbers in parentheses refer to number of samples. Separation of means in a row by Duncan's multiple range test.

Table 13. Average yield at 3 laterals of Pampanga River Irrigation System (PRIS), Nueva Ecija, Philippines, 1981 wet season.

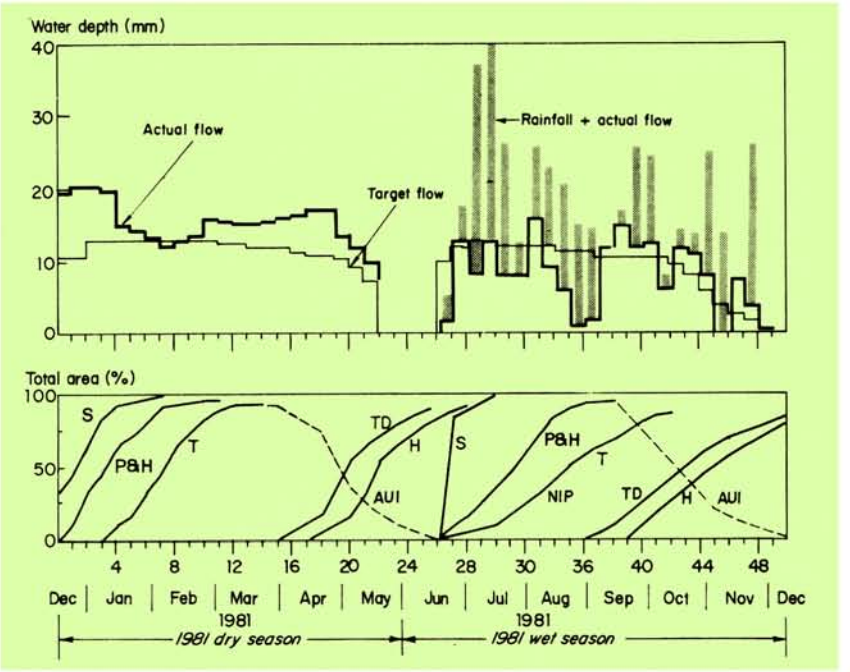
Lateral	Av yield[a]		
	Head	Middle	Tail
C	3.48 (7)	3.22 (14)	3.11 (11)
C-1	2.38 (10)	2.81 (17)	3.06 (13)
F	2.92 (8)	3.24 (10)	3.60 (9)
PRIS system	2.80 (32)	3.16 (47)	3.12 (47)

[a]Note no significant differences by Duncan's multiple range test at 5% probability.

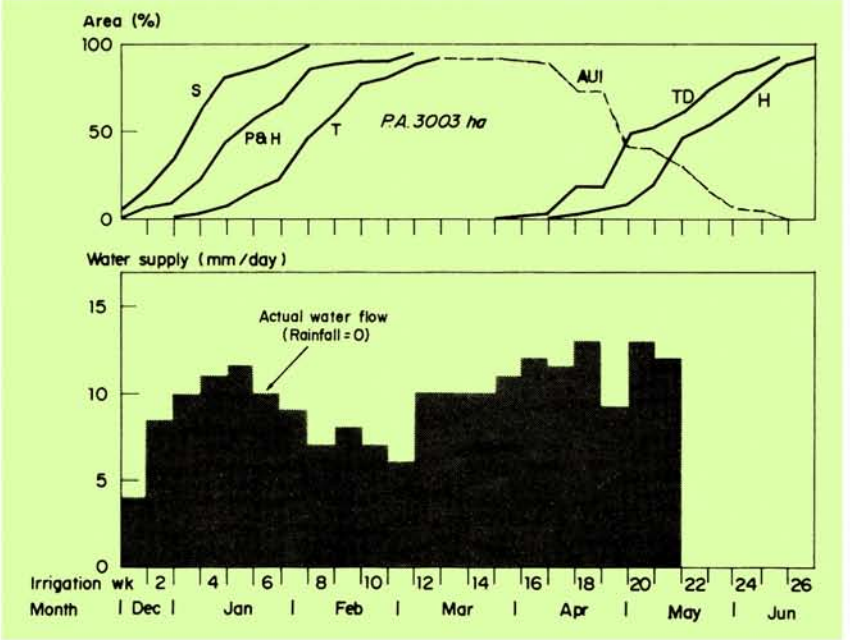
The length of time from first soaking to last transplanting is nearly 3 months (Fig. 6). Reducing this component turnaround-time is another major objective.

Extra turnout problem. Extra turnouts represent a significant problem to the management of an irrigation system, because they lack control and measuring devices. Generally extra turnouts are attributed either to a physical problem of insufficient head or insufficient water supply to cause water to flow by gravity to the fields from the channel or for personal reasons, such as a desire for private access to the canal water or a lack of good relations with the neighbors. The extra turnouts that were permanent in the LTRIS system were fewer in 1981 than in 1978 (Annual report for 1979) (Fig. 7). The area at the head of lateral B had the largest number of extra turnouts, largely to spill extra water back into the lateral canal. This is a positive manifestation of the extra turnout phenomenon.

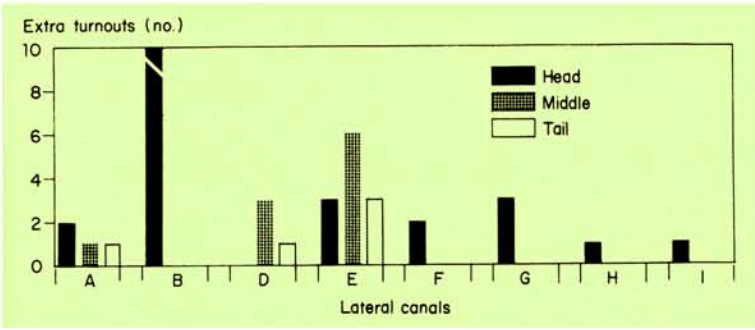
PRIS has large numbers of extra turnouts (Fig. 8). In particular, lateral F, which is very large and very long, has a tendency toward increased use of extra turnouts from the head to the tail of the lateral.



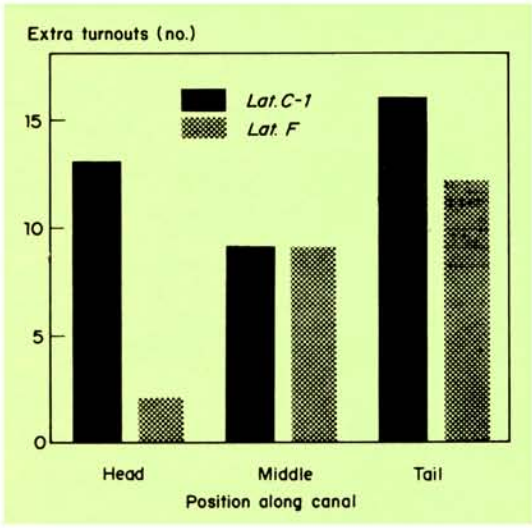
5. Irrigation system performance in terms of the progression of farming activities and the corresponding water supply in the Pampanga River Irrigation System, 1981 dry and wet seasons. S = land soaking, P&H = plowing and harrowing, T = transplanting, TD = terminal drainage, H = harvesting, AUI = area under irrigation, NIP = normal irrigation period.



6. Status of farming activities and water supply at Lat. F, Pampanga River Irrigation System. Nueva Ecija, 1981 dry season. S = land soaking, P&H = plowing and harrowing, AUI = area under irrigation, TD = terminal drainage, H = harvesting.



7. Comparative number of extra turnouts at head, middle, and tail of laterals in Lower Talavera River Irrigation System, after project implementation, 1981 wet season.



8. Comparative number of extra turnouts at laterals C-1 and F, Pampanga River Irrigation System, Nueva Ecija, before the project implementation, 1980 wet season.

EVALUATING MODELS FOR STRUCTURAL UPGRADING

Major efforts have been made in a number of countries in the Asian rice-growing region to upgrade the capacity of old irrigation systems by providing tertiary-level facilities. In 1981, two such upgrading programs were evaluated in collaboration with national irrigation agencies. The overall objective was to analyze the impact of the programs, their relevance to local needs, and farmer acceptance of the facilities provided. The programs are the Jatiluhur Irrigation System in West Java, Indonesia, and the Camiling River Irrigation System in Tarlac, Philippines.

The Jatiluhur system, Indonesia. Jatiluhur, a reservoir-type facility that serves about 340,000 ha of rice land, was upgraded by a tertiary improvement program. Physical irrigation facilities were improved in each 50- to 250-ha area served by a tertiary canal. Changes included an improved canal with a control gate and a device for measuring tertiary flow, new or improved quarternary canals to deliver water to the farms, and drainage canals (Table 14). In each area, a water users association was to be developed to fully utilize the physical facilities provided. Several pilot tertiary units — Petak Tertier Percontohan (PTP) — were established to demonstrate better water and crop management.

The study was conducted during the 1980-81 wet and dry seasons in three categories of tertiary areas, with two replications. The areas were close to one another to keep water flow variations at the source the same and soil and climate similar. The units evaluated were improved PTP, improved non-PTP, and unimproved (but scheduled for improvement). All three were irrigated only from the Jatiluhur reservoir. With minor exceptions, only two irrigated rice crops were grown in each area. Six quarternaries were selected to represent the head, middle, and tail portions of the total service area of each tertiary canal. Water delivery to each tertiary canal and farmer agronomic and water management practices were monitored in 24 selected paddies for each tertiary canal area.

Water supply and rice yield. During the dry season, a shortage of water in the reservoir and insignificant rainfall created water shortages

Table 14. Tertiary units selected for the study. Jatiluhur Irrigation Project, Indonesia, 1980-81.

Tertiary category[a]	Unit name	Service area (ha)	Canal density (m/ha)		Drainage canal density (m/ha)
			Tertiary	Quarternary	
Improved PTP	Brs 1	229	15.5	22.4	20.1
	Ble 5	138	17.0	55.8	53.5
Improved non-PTP	Brs 2	211	8.5	15.5	8.5
	Brs 3	150	14.0	15.3	5.0
Unimproved	Rwg 1	80	20.0	0	8.1
	Rwg 2	60	22.5	0	8.3

[a]PTP = Petak Tertier Percontohan.

Table 15. Average relative water supply (RWS) to the 3 categories at tertiary areas. Jatiluhur Irrigation System, West Java, Indonesia, 1980-81 dry and wet seasons.

Tertiary category[a]	RWS	
	Dry season	Wet season
Improved PTP	1.06	2.73
Improved non-PTP	1.13	1.62
Unimproved	0.72	1.55

[a]PTP = Petak Tertier Percontohan.

Table 16. Average number of days perched water table was below specified depth in the sample paddies during crop's reproductive stage. Jatiluhur Irrigation System, West Java, Indonesia, 1980 dry season.

Tertiary category[a]	Days without standing water	Days perched water table was below		
		5 cm	10 cm	15 cm
Improved PTP	13	1.6	0.3	0.1
Improved non-PTP	13	2.0	0.2	0.0
Unimproved	29	10.9	8.6	5.9

[a]PTP = Petak Tertier Percontohan.

throughout the Jatiluhur system. But the relative water supply (RWS) the ratio of water supplied to water required for crop evapotranspiration and field seepage and percolation — was higher in improved tertiary areas than in unimproved tertiary areas (Table 15). Because rainfall was negligible, the difference reflected a larger water supply delivered through the improved tertiary canals. During the wet season, more rainfall resulted in a larger RWS to all tertiaries, but improved tertiaries received much more than unimproved ones.

RWS represents the seasonal water adequacy condition in aggregate. A detailed analysis of water inadequacy during the dry season is shown in Table 16. The shortage of water during the reproductive period of rice was more severe in the unimproved tertiary areas.

Dry-season yields in the sample tertiaries were only 50-70% of the wet-season yields. The lower yields in the dry season could be attributed to the shortage of water and to less use of nitrogen fertilizer (Table 17). In the dry season, unimproved tertiary areas suffered more water shortage than improved areas — yields were only about 50% of those in the wet. Improved tertiary areas achieved about 70% of the wet-season yield.

This regression model explains 91% of the yield variation for the 2 seasons:

$$Y = 4.950 - 0.030\ W^{**} - 0.147\ D_{\cdot} + 0.040\ N^{**} - 0.956\ D^{**}$$
$$(R^2 = 0.91;\ n = 36;\ F = 60.38^{**})$$

where Y = yield (t/ha)

W = total number of days a sample paddy is without standing water during the reproductive period

$D_{\cdot}$ = relative location of a paddy from the turnout along the tertiary (1 = head, 2 = middle, and 3 = tail)

N = nitrogen used (kg/ha)

D = dummy variable for season (0 = wet season, 1 = dry season)

Dry-season yield could be increased by 0.55 t/ha if, by supplying more water, the value of W (av.

Table 17. Mean amounts of nitrogen used and average yields obtained in the dry and wet seasons. Jatiluhur Irrigation System, West Java, Indonesia, 1980-81.[a]

Tertiary category[b]	Dry season		Wet season		Difference (wet-dry)	
	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)
Improved PTP	4.10 a	43.40 a	5.96 a	60.27 a	1.85**	16.87
Improved non-PTP	4.73 b	56.38 a	6.72 a	70.70 bc	1.99**	14.32
Unimproved	3.50 c	51.47 a	7.08 a	69.92 ac	3.58**	18.45

[a]Separation of means in a column for wet and dry season yields and N by *t*-test at 5% level. [b]PTP = Petak Tertier Percontohan.

18.4 days) could be brought to zero. Similarly, yield could be increased by 0.66 t/ha if mean nitrogen during the dry season was raised to the mean level during the wet season.

Farmer attitude and response. All farmers in the improved-PTP-area samples said they could follow the Jatiluhur irrigation project authority's water delivery schedule; 70% of improved non-PTP area farmers could, and 61% of unimproved-area farmers could (Table 18). Water fee collection also was better in the improved-PTP areas.

All farmers in the unimproved and most of those in the improved areas indicated approval of the tertiary improvement program. However, relatively more farmers in improved areas wanted farmer participation in planning, designing, and implementing upgrading activities of the irrigation agency (Table 18). The reasons farmers in the unimproved areas showed more confidence in the capacity of the irrigation agency to carry out planning, design, and implementation of the tertiary improvement program than did those who had already experienced the process of improvement were not explored.

On the whole, farmers' perceived satisfaction with tertiary facilities, water distribution, gatekeeper's, and water users association performance associated with the tertiary improvement program increased (Table 19).

Camiling River system, Philippines. Camiling is a run-of-the-river system that serves about 8,900 ha of rice land. Intensive upgrading of irrigation facilities was made for approximately each 50 ha served from a common turnout. Facilities provided included a constant head orifice or a gated turnout with a measuring device, a main farm ditch, supplementary farm ditches, division boxes, and drainage ditches designed for a once-in-5-days rotational allocation of water for each 5 units of about 10 ha in a service area.

Use of upgraded facilities. A survey of the system indicated that the upgraded facilities were not meeting farmers' irrigation needs. Most of the facilities were either unused (such as turnout control and measuring devices and division boxes) or removed from the field (such as supplementary farm ditches). Farmers themselves had installed extra turnouts at suitable locations to obtain additional water.

The primary reason for nonuse of the upgraded facilities was that in the dry season, when the river flow is low and available water for irrigation is inadequate for the whole area, water delivery to a turnout only on a scheduled day of the week, not throughout the week, made the designed rotational allocation unworkable. The supplementary farm ditches provided by the upgrading were erased by the farmers because the rotational allocation was not followed at the 10-ha unit level and because more than 90% of the farm strips in the system are perpendicular to the main farm ditches (MFD), which can conveniently serve the farmers' need to irrigate their farms independently of their neighbors.

Effective service area. Two conclusions emerged: First, farmers did not rotate irrigation water within the service area of a turnout. Second, because a turnout effectively serviced a much smaller area than it was originally designed for, numerous extra turnouts were constructed and used by farmers. Two to six extra turnouts were common in the designated service area of the agency-provided turnout. One area had 18 extra turnouts.

The construction of extra turnouts by farmers

Table 18. Farmers' opinion about the process of Tertiary Improvement Program and water schedules[a] Jatiluhur Irrigation System, West Java, Indonesia, 1981.

Item[b]	Unimproved N	Improved PTP[c] N	Improved non-PTP[c] N
Willingness in improving the tertiary			
Willing	33 (100)	17 (85)	88 (97)
Not willing	0	3	3
	33	20	91
$X^2 = 7.486^*$ df = 2			
Who should make planning and design			
POJ	25 (93)	12 (60)	58 (64)
Farmers	2	1 (5)	4 (4)
POJ & farmers	0	7	28
	27	20	90
$X^2 = 11.713^{**}$ df = 4			
Who should implement tertiary improvement program			
POJ	21 (64)	1 (5)	16 (19)
Farmers	1 (3)	9 (45)	30 (36)
POJ & farmers	11	10	43
	33	20	89
$X^2 = 34.589^{**}$ df = 4			
Capability to follow given irrigation schedule			
Unable to follow	13 (29)	0	27 (30)
Able to follow	20	19	64
	33	19	91
$X^2 = 9.617^{**}$ df = 2			
Effect of tertiary improvement in ease of following water schedule			
Positive effect	–	16 (84)	81 (88)
No effect	–	3	11
		19	92
$X^2 = 0.066$ df = 1			

[a]Number in parentheses indicates the percentage figure. [b]POJ = Jatiluhur Project Authority. [c]Petak Tertier Percontohan.

can be considered a manifestation of the deficiencies in the existing irrigation facilities or in the operation of the system, or in both. The irrigation system management cannot be improved without an understanding of the farmers' reasons for the proliferation and use of extra turnouts.

A sample of 23 existing turnout service areas, ranging in size from 2.6 to 54.6 ha and serving 4-55 farmers within lateral A of the Camiling system, was studied in the 1981 dry season. The purpose was to identify the physical parameters that determine the effective size of a service area of a turnout under existing conditions in the system and to identify farmers' reasons for installing extra turnouts. The samples included areas served by agency-constructed turnouts and by farmers' extra turnouts.

In general, farmers used extra turnouts where 1) the main farm ditch (MFD) was very long, negatively sloping, or not well maintained; 2) the lateral or main supply canal was parallel to the MFD; and 3) the water level in the supply canal was higher than that in adjacent irrigated fields.

Table 20 shows the regression relationship

Table 19. Farmers' level of satisfaction from tertiary improvement and related services. Jatiluhur Irrigation System, West Java, Indonesia, 1981.

Item	Before[a]								After[b]							
	Not satisfied		Slightly satisfied		Satisfied		Highly satisfied		Not satisfied		Slightly satisfied		Satisfied		Highly satisfied	
	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Irrigation facilities in tertiary level $X^2 = 81.398^{**}$ df = 3	69	48	68	47	7	5	0	0	4	4	42	39	57	52	6	5
Gatekeeper performance $X^2 = 98.367^{**}$ df = 3	61	42	57	40	26	18	0	0	9	8	38	33	61	53	7	6
Water distribution $X^2 = 102.876^{**}$ df = 3	69	48	68	47	7	5	0	0	4	4	42	39	57	52	6	5
Performance of ulu-ulu in water distribution $X^2 = 49.342^{**}$ df = 3	100	69	32	22	12	9	0	0	25	22	41	38	41	38	2	2

[a] Including all farmers (N = 144) in the interview. [b] Including only those in the improved tertiaries, Petak Tertier Percontohan (PTP) and non-PTP.

Table 20. Estimated coefficients of regression equation relating turnout service area to measured physical variables. Camiling River Irrigation System, Philippines, 1981 dry season.

Physical variable[a]	Regression coefficient[b]	Standard error of estimate	T-value	% of explained variation
Intercept	22.32			
Av rate of flow to turnout, q (liters/sec per ha)	0.33	2.43	0.14	0.08
Av farm size (ha/farm)	2.70	3.94	0.69	1.89
Shape factor, SF	1.08	9.32	0.12	0.05
SF x SF	-1.19	1.18	-1.01	4.11
q x SF	0.96	2.01	0.48	0.91
General land slope (%)	-1.95	4.09	-1.70	11.59
Orientation of MFD, Or	26.93***	8.34	3.23	41.92
% of irrigation period with zero flow in turnout, IZ	0.42**	0.18	2.31	21.38
SF x IZ	-0.20*	0.10	-2.12	18.06
Coefficient of determination, R^2	0.90			
F-statistic	12.67			
N	23			

[a] SF = effective MFD length (m)/av width of service area (m). Or is with respect to the supply canal (lateral or main canal). Or is treated as a dummy variable. Or = 0 if MFD is parallel to the supply canal and Or = 1 when it is perpendicular. [b] *** significant at 1% level, ** significant at 5% level, and * significant at 10% level.

between the measured variables and the service area effectively irrigated from a turnout. The orientation of the MFD to the supply canal (whether the MFD is parallel or perpendicular to the supply canal) was the dominating factor in the regression relationship.

As expected, the optimum area that could be effectively irrigated from a turnout with an MFD orientation perpendicular to the supply canal was more than two times the area with a parallel orientation (Table 21). The MFD orientation played such a critical role in determining the effective size of a turnout service area because parallel orientation provided opportunities for easy access to canal water through an extra turnout or cut in the canal embankment. Because of that, farmers were not

Table 21. Estimated optimal turnout service area, main farm ditch (MFD) length, service area width, and number of farmers for 2 different MFD orientations.[a] Camiling River Irrigation System, Tarlac, Philippines, 1981.

Particulars	MFD orientation	
	Parallel	Perpendicular
Turnout service area (ha)	20	47
MFD length (m)	473	723
Width of service area (m)	427	652
Number of farmers	23	54

[a]Computation based on av values of q = 1.5 liter/sec per ha; general land slope = 0.87%; farm size = 0.87 ha/farm.

interested in maintaining the MFD. When the MFD is perpendicular to the supply canal, such opportunities are not available because of the great distances between the canal and the farms. The longer the MFD maintenance problem, the more involved farmers were in it and the more aggravated it became.

Farmer response. To assess farmers' viewpoints toward water-sharing problems within the turnout service area and their use of extra turnouts to meet their water needs, 70 farmers who used extra turnouts from lateral A of the system were interviewed. The reasons cited most frequently for water shortages on their farms and their consequent construction of extra turnouts to alleviate the shortage were: 1) fragmented farms (average number of parcels per farm is 2.4 and parcels are usually far apart); a farmer's preference to irrigate a parcel at the time he visits it; 2) a "take-more-water" attitude of the MFD head-end farmers (leaving little or no water for the tail-end farmers), 3) unmaintained MFD (restricting the water flow down the MFD), 4) negative MFD bed slope (requiring more time for water to move in the MFD), 5) short duration of the irrigation water schedule in the supply canal (making water delivery to the MFD inadequate for all), and 6) preference for morning irrigation (because it is harder to work in the hot afternoons, which are more suitable for family and recreational activities).

Notwithstanding the importance of the factors behind the use of extra turnouts by farmers, which make most of the irrigation facilities below the system-provided turnout useless, the factor that made construction of extra turnouts physically possible was easy access to the water in the supply canal. Only 37% of the farmers in the sample recognized this overriding factor, but 21% mentioned that system personnel knew about their use of extra turnouts.

A further study of the service area of 89 agency-provided turnouts in the Camiling system determined the orientation of MFDs; 55% had MFDs parallel to and 40% had MFD's perpendicular to the supply canals.

In the run-of-the-river type system at Camiling, where fluctuating river flow necessitates rotational allocation of water, section by section, in the lateral canal, the elaborate irrigation facilities required for water rotation within the service area of a turnout were not relevant.

BENEFITS FROM 12 TYPES OF IRRIGATION SYSTEMS

A 1980 study of the investment and operation and maintenance (O&M) costs of various types of irrigation systems in Central Luzon showed that gravity diversion systems are the least costly, surface pump systems intermediate, and deepwell pumps the most costly (Annual report for 1980). The benefits or returns from 12 such systems were estimated and compared to obtain information that would assist policy makers, planners, and financiers in evaluating and comparing the relative economic efficiencies of different types of irrigation investments.

Benefits from irrigation. Only direct benefits from irrigation were counted in this study, those arising from increased crop yield per hectare and increased area planted, particularly in the dry season. Benefits were determined by comparing the *with project* condition, represented by sample farmers served by the system, and the *without project* condition, represented by rainfed farmers randomly selected in a comparable area adjacent to the system. Net benefits were estimated on the basis of the difference in gross margin of production for with- and without-project conditions for both wet and dry seasons.

Information on yields, inputs, and other relevant production and cost data were collected through personal interviews with sample farmers from each type of system for crop year 1979-80. Gross margin per hectare was calculated by deducting the cost of

current inputs from the value of production. Cost of inputs includes cost of fertilizers, chemicals, seeds, and labor. To reduce the effect on benefits of varying prices of inputs and outputs, a constant wage rate was used in computing the gross margin of production. However because of the lack of uniformity in units of output and inputs for such nonrice crops as tobacco, cotton, and mungbean, actual prices reported by each farmer were used.

A summary of the gross margin of production per hectare and of net farmer benefits for irrigation in each of the 12 sample systems is in Table 22.

No clear pattern emerges among the values of irrigation benefits in the 12 systems studied. Benefits vary, not only among the different types of systems but also among different systems of the same type. BPIP, a large surface pump system, produced the highest net benefits ($429) among all systems studied. However, Safari, also a surface pump system, had quite low net benefits ($136). Benefits among other types varied similarly.

Prenza, one of the big communal systems of the gravity diversion type, had negative net benefits. However, that does not imply that irrigation causes negative benefits to the farmer. The data collected for the benefits estimation show that the negative benefit was caused by the unusually high wet-season yield of rainfed rice farms (3.97 t/ha) compared with that of the irrigated farms (3.40 t/ha). The reasons for this unique situation may be the abnormally high yields of rainfed farms during the season when the study was conducted, the unusual favorable rainfall pattern in the area, the better type of soil in rainfed farms than in irrigated farms, the incomparability of rainfed samples to irrigated samples, and the upward bias in yields reported by rainfed farmers.

Table 22. Gross margin of production at 1980 prices with and without project conditions, sample systems, Central Luzon, Philippines, combined 1979-1980 wet and dry seasons.

Type of system	Gross margin of production ($/ha)		
	With project	Without project	Farmer's net benefits
Gravity diversion systems			
Sibul	460	267	193
Salapungan	407	2	405
SFRIS[a]	457	139	318
Prenza	376	417	-41
Combination of pump and gravity			
Caingin	35	1	34
Surface pumps			
BPIP[b]	576	147	429
Small pumps	447	156	291
Safari	125	-11	136
Halina	336	119	217
Deepwell pumps			
GP-4	424	132	292
GP-3	408	95	313
GP-19	209	54	155

[a]San Fernando River Irrigation System. [b]A large surface pump system.

Rate of return to irrigation investment. Two commonly used tools of project evaluation — benefit-cost ratio (B:C) and internal rate of return (IRR) — were used in the analyses. The cost and benefit flows in the B-C ratio analyses were discounted at 12% interest rate, the rate commonly applied to development loans in the Philippines. Other assumptions adopted for calculating the B:C and IRR were 60- year life span for dam and other diversion structures, 30-year life span for canals and farm-level facilities, and 15-year life span for pumps and engines. The cost and benefit flows were assumed to continue at 1980 levels through the usable life of the project.

Table 23 summarizes B-C ratio and IRR estimates for each project. Two communal gravity diversion systems, Salapungan and Sibul, yielded extremely high returns, a B:C of 6-7, and an IRR of around 90%. A B:C of 0.5 and an IRR <0.001 for Caingin show that it is not economically advisable to build a system under conditions where flooding prevents wet-season cropping and where functional canals are not provided, which forces farmers to use pumps to lift water to irrigate in the dry season. No conclusion could be arrived at for the Prenza system because of the unusual data on yields during the period of analysis.

Thus, the communal diversion gravity systems represent two polar cases, one yielding a very high return (Sibul and Salapungan) and the other one an extremely low return (Caingin and Prenza). However, the data on communal gravity diversion systems suggest that, when these systems are built at appropriate places and are of appropriate sizes and have complete structures for diverting water from the source to the fields, investments are highly profitable. The same is true for the national gravity system represented by SFRIS, which yielded a moderately high rate of return (38% IRR and B:C 3.0).

Table 23. Estimated benefit-cost ratio (B:C) and internal rate of returns (IRR) for 12 sample systems, Central Luzon, Philippines.[a]

Type of system	B:C	IRR
Gravity diversion systems		
Sibul	7.3	99.1
Salapungan	6.4	83.6
SFRIS[b]	3.1	38.2
Prenza	–	–
Combination of pump and gravity		
Caingin	0.5	<0.001
Surface pumps		
BPIP[c]	2.2	48.3
Small pumps	2.1	55.3
Safari	1.8	29.4
Halina	0.9	6.6
Deepwell pumps		
GP-4	0.9	8.6
GP-3	0.7	6.1
GP-19	0.4	<0.001

[a]Computations based on 12% interest rate, 60 years life span for dam, 30 years for canals, and 15 years for pump and engine. [b]San Fernando River Irrigation System. [c]A large surface pump system.

Among the surface pumps, only the Halina pump exhibited a low B:C (0.92) and an IRR (8%) lower than the assumed standard rate of interest. The three other surface pump systems yielded moderately high returns, a mean B:C of 2.0 and IRRs of 30-50%. Unfavorable results for the Halina pump system can be attributed to the pump's high O&M costs and the fact that it is operating below designed capacity.

All deepwell pump systems studied yielded a B:C less than 1.0 and an IRR less than the standard rate of interest. The implication is that the benefits derived from investment in deepwell systems is not enough to pay for the investment.

A comparison of the relative economic efficiency of the three groups of systems showed that gravity systems are generally more lucrative investments, followed by surface pump systems. None of the deepwell pump systems gave an economic return.

Soil and crop management
Land characterization

Agronomy and Soil Chemistry Departments

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DEVELOPING A CLASSIFICATION OF ASIAN DRYLAND RICE ENVIRONMENTS

Agronomy and Soil Chemistry Departments

The diverse rainfed rice-growing environments of the world vary widely in soils, landscape, climate, management systems, and pest problems. As IRRI became more involved in varietal improvement of rainfed rice and in the development of better management practices and cropping systems, it became increasingly clear that environmental diversity would be a major constraint to the development and diffusion of new rice technology.

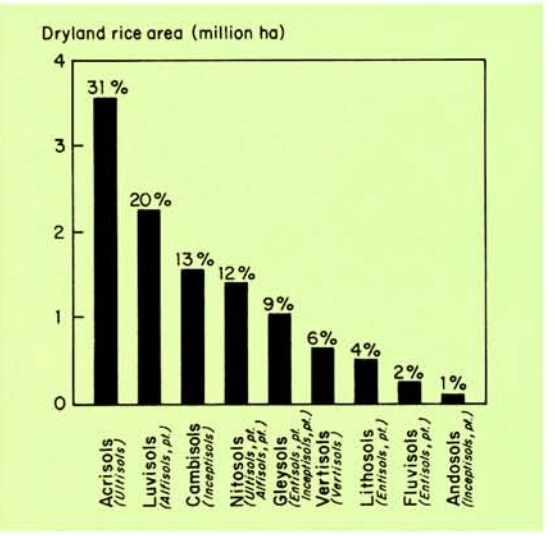
World rice-growing environments have been classified into six major rice cultural types. To identify and quantify environmental diversity within each cultural type, a detailed but functional classification of rice environments was initiated.

Dryland rice was selected for the initial work. Maps of dryland rice distribution in Asia constructed at IRRI were superimposed on the FAO Soils Maps of the World. Data on soil mapping unit, slope class, and soil texture were recorded for each of the nearly 4,000 locations shown. The dryland rice distribution maps were then laid over specially constructed maps of gross climatic conditions during the dryland rice-growing season. Data on rainfall, potential evaporation, and length of growing season were sorted to reveal the land units and their relative importance.

Distribution of dryland rice by soil unit (*Agronomy*). Correlation of IRRI maps of dryland rice areas with the Soil Map of the World (Fig. 1) shows a clear pattern, even though assignment of individual dots to specific soil map units may be uncertain.

By far the largest soil mapping unit on which dryland rice is grown is Acrisols (3.5 million ha) — 31% of the total area in dryland rice — followed by Luvisols, 2.3 million ha; Cambisols, 1.5 million ha; and Nitosols, 1.4 million ha (Table 1). Gleysols (1.0 million ha) and Vertisols (0.6 million ha) are the other important soil groups for dryland rice.

Of the dryland rice in Southeast Asia, 63% is on Acrisols. Orthic Acrisols, the single most important dryland rice soil unit, is chemically poor, strongly acid and weathered, and low in organic matter. In most Southeast Asian countries, between one-third and two-thirds of the dryland rice is produced on this one soil mapping unit.



1. Distribution of Asian dryland rice by soil mapping unit. IRRI, 1981.

In South Asia, no one soil has as clear a degree of dominance as does Orthic Acrisols in Southeast Asia.

Distribution of dryland rice by soil fertility rating and slope (*Agronomy*). Each of the 51 soil units associated with dryland rice was given a rating (scale of 1-9), indicative of its natural fertility characteristics. The rating was based on acidity, cation exchange capacity, organic matter level, natural NPK status, and the likelihood of micronutrient toxicities or deficiencies (Table 2).

The majority of the dryland rice area was rated unfavorable to highly unfavorable (Fig. 2). In Southeast Asia, an insignificant proportion (only 11%) of the dryland rice is on favorable units.

In South Asia, dryland rice is grown predominantly on fairly level landscapes (Fig. 3). In Southeast Asia, most dryland rice is on steeper slopes.

Climate of dryland rice areas (*Agronomy*). There is a marked contrast in length of growing season between the dryland rice areas of South Asia and Southeast Asia (Fig. 4). In most dryland rice areas in South Asia, the growing season is less than 5 months long; in 76% of such areas in Southeast Asia, it exceeds 5 months. Although the dryland rice soils of the subcontinent, in general, are superior to those of Southeast Asia, the short growing season requires significantly earlier maturing cultivars than are necessary in Southeast Asia.

Table 1. Extent of dryland rice on units of the Soil Map of the World for South and Southeast Asia.[a]

Map unit	Dryland area (million ha)			Percentage of	
	Extent	Area planted	Total[b]	Mapping unit	Total dryland rice
Acrisols *(Ultisols)*[c]	198		3.55	1.8	31
Orthic		2.08			
Ferric		0.80			
Gleyic		0.47			
Plinthic		0.14			
Luvisols *Alfisols, pt.)*	98		2.27	2.3	20
Ferric		1.14			
Chromic		0.76			
Orthic		0.32			
Cambisols *(Inceptisols)*	122		1.55	1.3	13
Eutric		0.92			
Dystric		0.24			
Calcic		0.14			
Nitosols	38		1.38	3.7	12
Dystric *(Ultisols)*		0.89			
Eutric *(Alfisols)*		0.48			
Gleysols *(Entisols, pt., Inceptisols, pt.)*	50		1.04	2.1	9
Eutric		0.70			
Calcaric		0.30			
Vertisols *(Vertisols)*	58		0.64	1.1	6
Chromic		0.55			
Lithosols *(Entisols, pt.)*	90		0.48	0.5	4
Fluvisols *(Entisols, pt.)*	55		0.24	0.4	2.1
Eutric		0.15			
Andosols *(Inceptisols)*	7.4		0.14	1.9	1.2
Ochric		0.11			
Total	716		11.3		98
South & Southeast Asia	898		11.6	1.2	100

[a]Five main mapping units, not listed in the table, with 0.07 million ha or less of dryland rice each, are Ferralsols, Arenosols, Regosols, Podzols, and Phaeozems. The crop occupies 0.5% or less of the mapping unit. [b]Totals for main mapping units include units with less than 0.1 million ha dryland rice. [c]Corresponding soil order in the Soil Taxonomy. If a significant portion of the soil order does not fall into the FAO soil unit, then the name is followed by *pt.* indicating *part.*

This suggests the need for quite different approaches to improving dryland rices for each region.

Soil chemical characteristics important to land evaluation for wetland rice (*Soil Chemistry*). Most rice lands in the tropics are either Entisols or Inceptisols, with little genetic horizon differentiation or aquic associates of other soil orders. Because most rice lands are alluvia, with low permeability or a high water table during the rice season, both internal and external drainage are poor. But, because most wetland rice soils are plowed wet and puddled, physical properties are unimportant. In irrigated rice lands, the chemical properties of the top 15-20 cm of the soil determine its capacity to provide proper amount and balance of plant nutrients for rice growth.

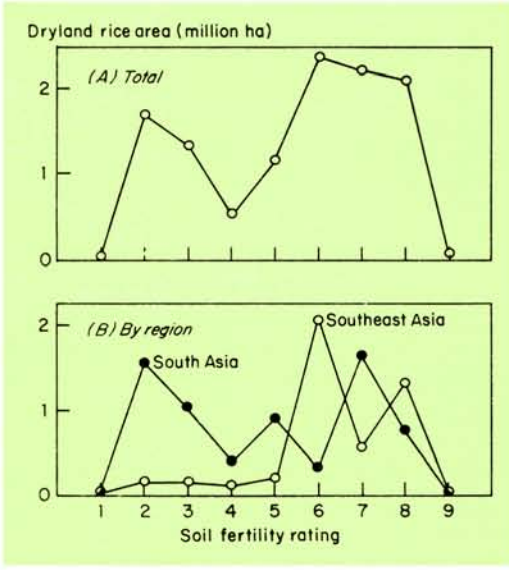
The properties that would classify rice lands as highly suitable (S_1) include:

pH	5.0-6.5
Electrical conductivity of the saturation extract (dS/m)	<2
Redox potential (Eh) after submergence) (V)	+0.2 to -0.2

Table 2. Soil mapping units of dominant importance for dryland rice, by region.

Soil unit	Dryland rice area (million ha)	Percentage of dryland rice within the region	Soil fertility rating[a]
Southeast Asia	4.67		
Orthic Acrisols *(Tropudults)*	1.97	42	6
Ferric Acrisols *(Tropudults)*	0.60	13	8
Gleyic Acrisols *(Aquults)*	0.47	10	8
Dystric Nitosols *(Rhodudults)*	0.44	9	7
Ochric Andosols *(Andepts)*	0.11	2	4
South Asia	6.93		
Ferric Luvisols *(Ustalfs)*	1.13	16	7
Eutric Cambisols *(Tropepts, Tropaquepts)*	0.89	13	2
Chromic Luvisols *(Alfisols)*	0.68	10	5
Eutric Gleysols *(Tropaquepts)*	0.60	9	5
Chromic Vertisols *(Vertisols)*	0.54	7	3

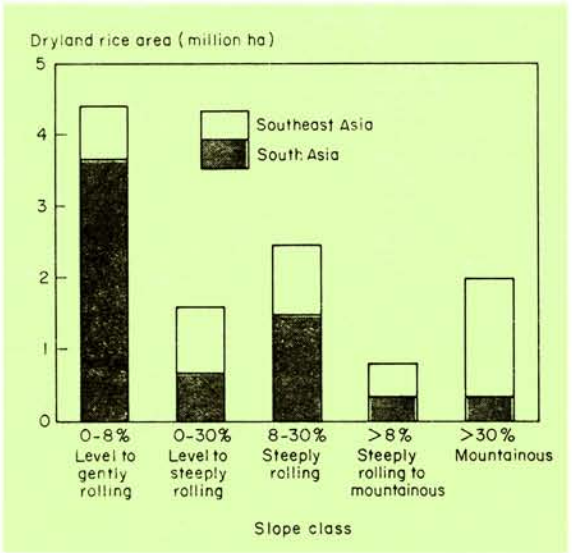
[a]Scale: 1-2: highly favorable; 3-4: favorable; 5-7: unfavorable; 8-9: highly unfavorable.



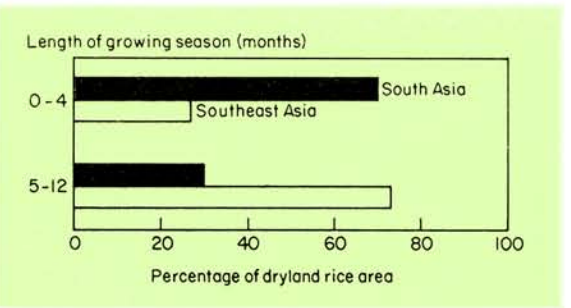
2. The distribution of dryland rice soils by their inherent fertility status rating: A) both regions combined, and B) comparison of the distribution between regions. Rating scale: 1 = highly favorable, 9 = highly unfavorable.

Organic carbon (%)	2.0-3.0
Total nitrogen (%)	>0.2
Total phosphorus (%)	>0.02
Olsen phosphorus (mg/kg)	10-15
Exchangeable potassium (mmol/kg)	>2
Available sulfur (mg/kg)	>10
Cation exchange capacity (mmol/kg)	>200
Active iron (%)	>0.5
Active manganese (%)	>0.05
Available zinc (mg/kg)	>1
Available boron (mg/kg)	<5
Clay composition	50% montmorillonite

Slight deviations would put lands in the moderately suitable (S_2) class, and a pH of <3.5 or >8.5, an electrical conductivity of the saturation extract (EC_e) >12 dS/m, or an organic carbon content of >20% would render them marginally suitable. Deep oligotrophic peats are perhaps the only kind of land that falls into the permanently unsuitable (N_2) class.



3. Area of dryland rice falling into 5 slope classes, South and Southeast Asia, IRRI, 1981.



4. Proportion of dryland rice area in long and short growing seasons, South and Southeast Asia. Growing season = number of months in which rainfall exceeds potential evaporation by 20%. IRRI, 1981.

Table 3. Effect of nitrogen fertilization on the yield of 10 salt-tolerant rices on a saline soil, Minalin, Pampanga, Philippines, 1981 wet season.

Variety	Yield (t/ha)	
	0 kg N/ha	50 kg N/ha
IR36	3.2	4.0
IR42	4.8	4.8
IR46	3.7	3.5
IR50	3.6	4.0
IR52	3.8	3.7
IR54	3.3	2.4
IR5657-33-2	4.7	4.5
IR9884-54-3	4.0	3.6
IR10198-66-2	4.0	4.2
IR19746-28-2	4.6	4.8
Mean	4.0	4.0

Table 4. Effect of nitrogen fertilization on the yield of 5 rices on a saline soil, Taal, Batangas, Philippines, 1981 wet season.

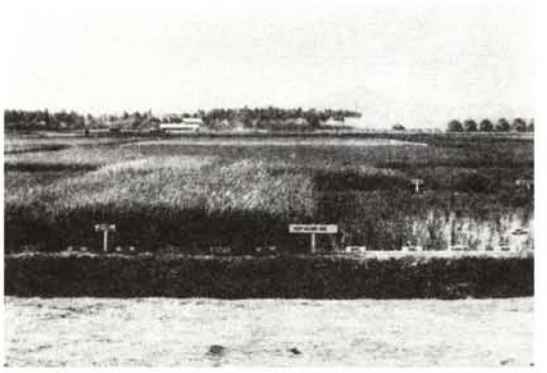
Variety	Yield (t/ha)	
	0 kg N/ha	50 kg N/ha
IR28	1.9	2.2
IR42	2.3	2.7
IR52	2.7	2.5
IR54	3.1	3.1
IR9884-54-3	2.6	3.0
Mean	2.5	2.7

Coastal saline soils (*Soil Chemistry*). Because coastal saline soils in the humid tropics are frequently flooded by brackish water, they usually are well supplied with plant nutrients. To ascertain whether nitrogen fertilizer is necessary on such soils, replicated studies with and without 50 kg N/ha and without P and K fertilizer were made in the wet season at 5 locations in the Philippines.

The soils were nearly neutral in reaction, were well supplied with phosphorus and potassium, and contained moderate amounts of nitrogen. The (EC_e) at sowing ranged from 2 to 10 dS/m. Heavy rains, typhoons, and rat damage spoiled the tests at three locations, but visual observations and partial yield data showed no response to nitrogen fertilizer. Yields at the two locations for which complete data are available showed no significant response to nitrogen (Table 3, 4).

Acid sulfate soils (*Soil Chemistry*). The main factors limiting wetland rice growth on acid sulfate soils are aluminum toxicity in the early stages of flooding, iron toxicity after soil reduction, and phosphorus deficiency. Excess electrolyte and a low manganese content are accessory adverse factors.

Aluminum toxicity disappears after some weeks of flooding because of the pH increase that accompanies soil reduction. Then iron toxicity is the main retarding factor, but its severity diminishes with duration of flooding. Lime depresses the concentration of water-soluble iron whereas manganese physiologically counteracts the adverse effects of excess iron. Because little information is available on methods for improving acid sulfate soil productivity, field experiments on amelioration measures



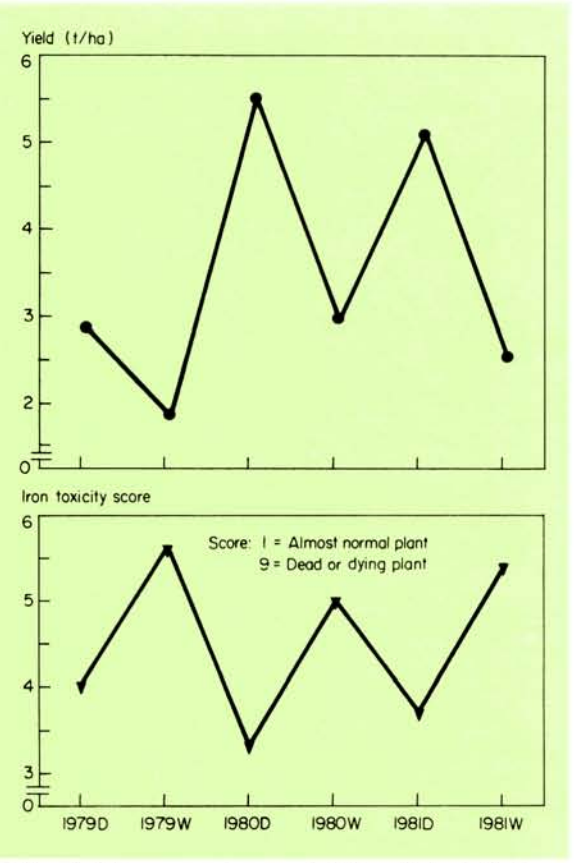
5. Acid sulfate soil in concrete beds. Left, continuously flooded, right, dried between crops. IRRI, 1981.

were conducted on an acid sulfate soil transported to concrete beds.

Water management. When acid sulfate soils are kept submerged, pH increases and aluminum and iron toxicities are virtually eliminated. Figure 5 shows the benefits of prolonged submergence on a Sulfaquept with an aerobic pH of 3.5 in concrete beds. Table 5 shows the kinetics of water-soluble iron and pH 10 weeks after transplanting. Figure 6 illustrates the striking seasonal correlation between yield and iron toxicity scores in a Sulfaquept (pH 3.5). Higher yields in the dry season were due partly to soil wetness at the start of the dry season.

Soil amendments. Lime virtually eliminates aluminum toxicity but only alleviates iron toxicity. Because acid sulfate soils are low in active manganese (0.001-0.01%) and because manganese physiologically counteracts iron toxicity, the effects of manganese dioxide with and without lime were studied in two experiments on three acid sulfate soils in Albay Province, Philippines. Soil pH ranged from 3.4 to 3.8 and the exchangeable sulfate sulfur content from 0.13 to 0.20%.

Manganese dioxide and lime produced highly significant increases in grain yield in the dry season (Table 6). Raising manganese dioxide level from 50



6. Iron toxicity scores are lower and yields are higher in the dry season (D) than in the wet (W) because the soil is still wet at the start of D. IRRI, 1981.

to 100 kg/ha did not increase yield. In the wet season, when the yields were low, manganese dioxide was less effective (Table 7).

Peat soils (*Soil Chemistry*). About 20 ha of wetlands in the vicinity of the acid sulfate soil experimental field in Albay Province, are uncultivated. The soil is an acid peat (pH 4.8, organic carbon 23%) high in boron (15 mg/kg). Plant analysis indicated severe boron toxicity (120 mg/kg) and marginal zinc deficiency (20 mg/kg). Because soil amendments are not feasible on such lands, varietal adaptation was explored. Among 15 IR culti-

Table 5. Influence of water management on the kinetics of water-soluble iron and soil solution pH 10 weeks after transplanting (WT) in an acid sulfate soil.

Water regime	Iron (mg/liter)						pH
	0 WT	1 WT	3 WT	5 WT	8 WT	10 WT	10 WT
Flood fallow	304	350	330	175	36	20	6.5
Dry fallow	62	430	470	867	807	690	5.5

Table 6. Grain yields averaged for 2 varieties, at 3 levels of manganese dioxide (MnO_2) and 2 levels of lime on an acid sulfate soil at Cabunturan, Albay, Philippines, 1981 dry season.

MnO_2 (kg/ha)	Grain yield (t/ha)		
	No lime	Lime (5 t/ha)	MnO_2 mean[a]
0	2.4	4.3	3.4 b
50	3.4	5.0	4.2 a
100	3.3	4.7	4.0 a
Lime mean	3.0	4.7	3.9

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

Table 7. Effects of lime and manganese dioxide (MnO_2) on yield of IR4683-54-2 at 2 locations, Albay, Philippines, 1981 wet season.

MnO_2 (kg/ha)	Lime (t/ha)	Yield[a] (t/ha)	
		Balza	Burabod
0	0	0.2 b	0.7 b
0	5	0.2 b	3.5 a
25	0	0.2 b	1.1 b
25	5	1.5 a	3.6 a
50	0	0.7 b	1.7 b
50	5	2.0 a	3.8 a

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

vars and lines, IR52 and IR13149-43-2 withstood the adverse conditions best.

Because peat soils strongly immobilize copper and zinc, the effects of slow-release copper and zinc compounds and the soluble sulfates were compared in a greenhouse experiment. On a peat soil (pH 5.8, organic carbon 26%), copper and zinc in combination, regardless of form, improved vegetative growth but not grain yield.

The need for micronutrients on peat soils was confirmed in another greenhouse experiment using the same soil. A combination of 20 mg zinc/kg, 5 mg copper/kg, and 0.5 mg molybdenum/kg gave the best yield.

Sulfur-deficient soils (*Soil Chemistry*). Soil tests, plant performance, and plant tissue analyses were used in studying the availability of sulfur to wetland rice in 30 Philippine soils.

The critical concentration of available sulfur based on extraction by calcium phosphate was 9 mg/kg; by lithium chloride, 25 mg/kg; by ammonium acetate, 30 mg/kg; and by hydrochloric acid, 5 mg/kg (Fig. 7). The critical total sulfur limits were 0.11% in the shoot at maximum tillering, 0.05% in the straw at maturity, and 0.065% in the grain. The critical ratio of nitrogen to sulfur was 15 in the shoot at maximum tillering, 14 in the straw at maturity, and 26 in the grain. The critical sulfate sulfur limit was 150 mg/kg in the shoot at maximum tillering and 100 mg/kg in the straw at maturity. The critical ratio of sulfate to total sulfur was 15% in both the shoot at maximum tillering and the straw at maturity.

Plant performance, as judged by appearance (Fig. 8) and yield of dry matter, straw, and grain, was generally poorer in sulfur-deficient soils than in other soils. Although the calcium phosphate and ammonium acetate methods gave better correlations between plant performance and available sulfur, the four methods used separated sulfur-deficient soils from nondeficient ones (Fig. 9). The simple and versatile hydrochloric acid method merits further study.

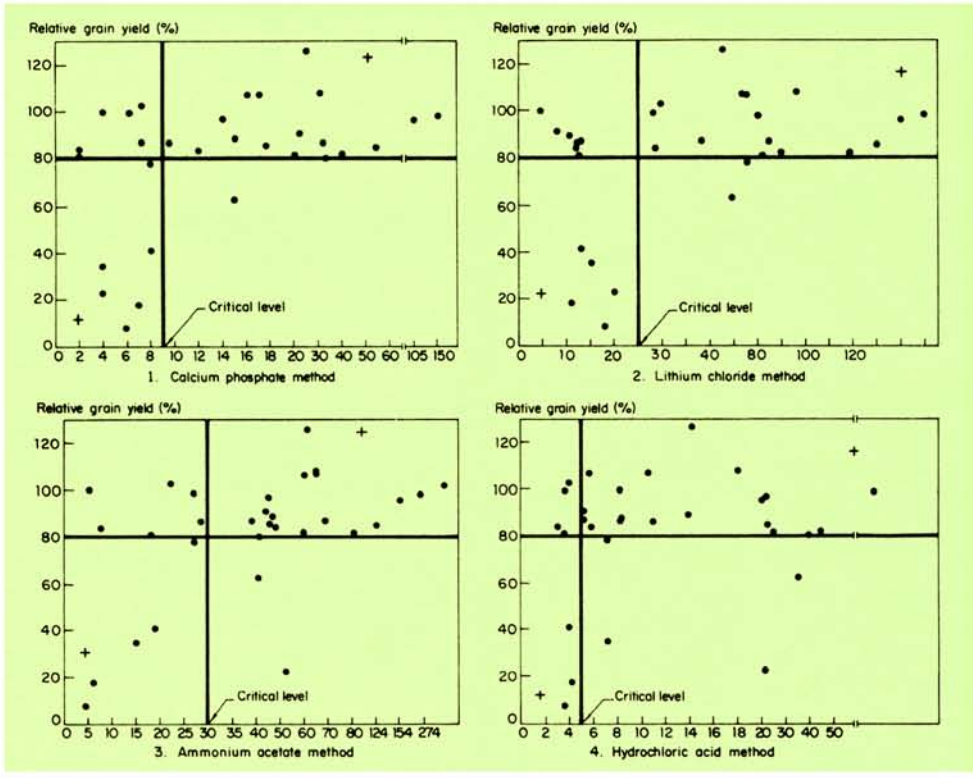
Zinc-deficient soils (*Soil Chemistry*). Zinc deficiency is widespread in wetland rice. Studies with over 300 Philippine rice soils and 10 other soils showed that zinc deficiency is associated with one or more of these soil characteristics:

pH	>6.8
Organic carbon	>3.0%
Available zinc	<1.0 mg/kg
Olsen phosphorus	>15 mg/kg
Water-soluble silicon	>100 mg/kg
Magnesium-calcium ratio	>1
Total chromium	>0.1%

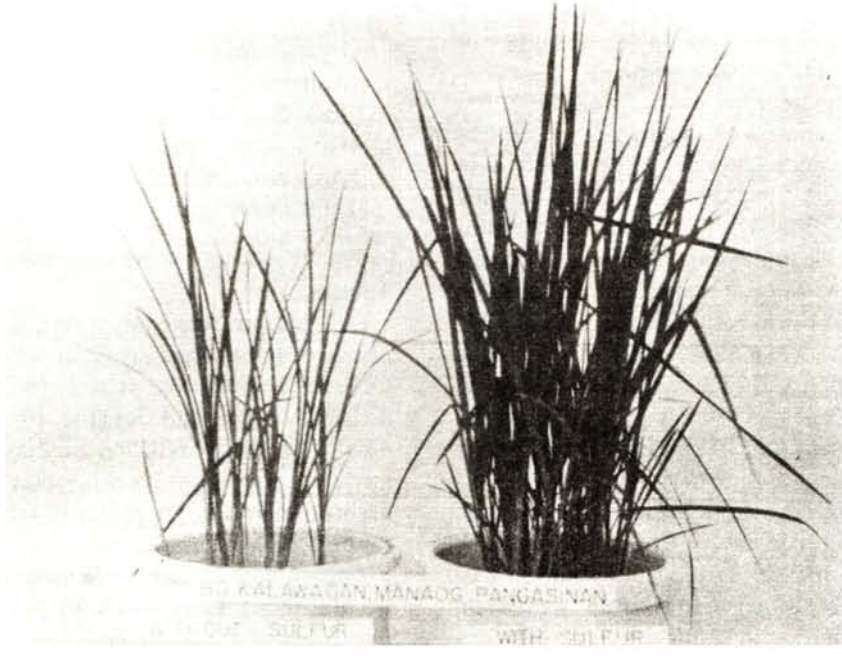
Zinc responses on the soil studied are listed in Table 8.

Soil pH, carbon content, and available phosphorus (routinely measured in all soil-testing laboratories) are simple and reliable indicators of zinc deficiency in wetland rice (Fig. 10, 11, 12). Measures of any one characteristic may be used as a guide to zinc fertilization in areas where atomic absorption spectrophotometers are not available for determining zinc content.

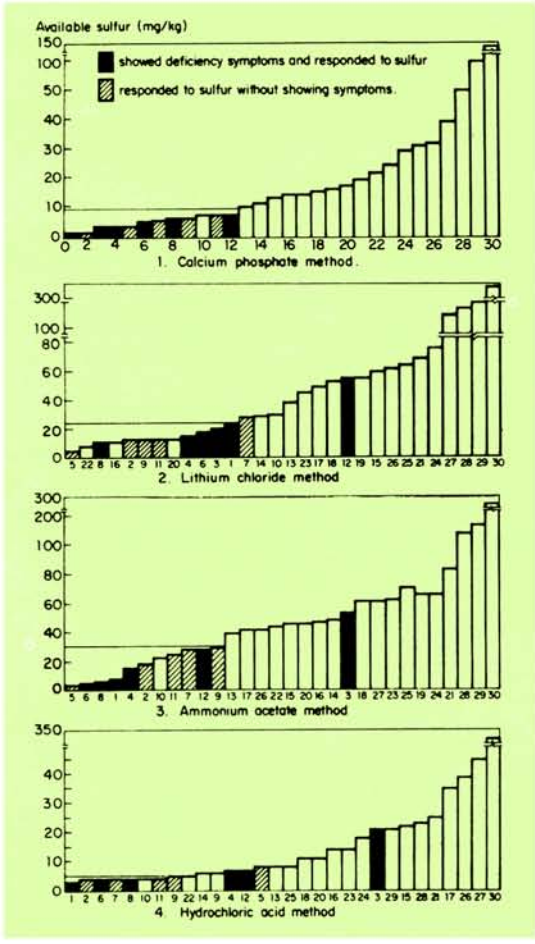
Cadmium pollution (*Soil Chemistry*). Cadmium is a poisonous element present as a contaminant in phosphate and zinc fertilizers and as a pollutant near zinc mines and smelters. Factors that affect



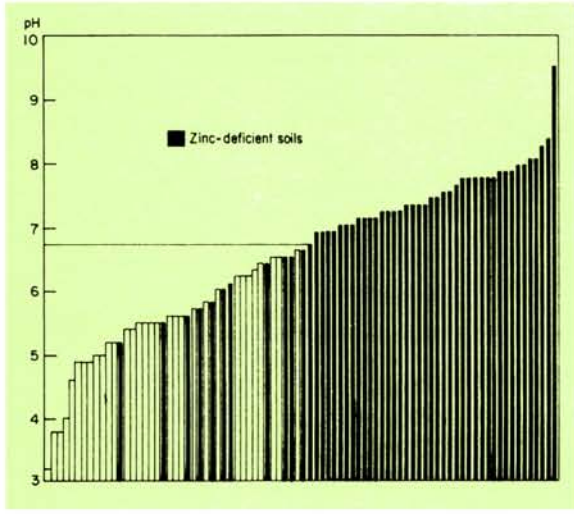
7. Relative grain yield and available sulfur, as measured by 4 methods. IRRI, 1981.



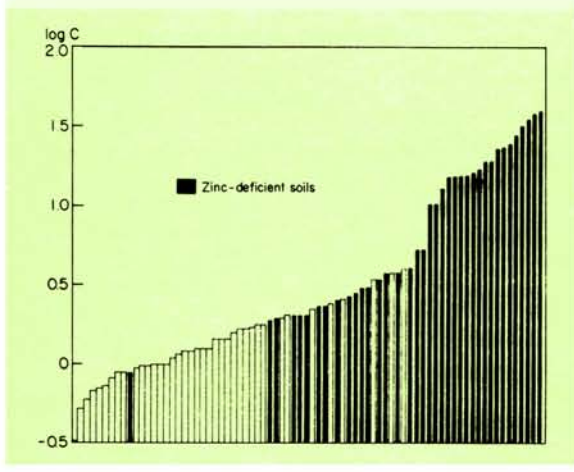
8. Sulfur deficiency in rice (left) corrected by applying sulfur (right). IRRI, 1981.



9. Soils in order of increasingly available sulfur, as measured by 4 methods, and plant response. IRRI, 1981.



10. Mineral soils in the order of increasing pH. IRRI, 1981.



11. Soils in the order of increasing organic matter content. IRRI, 1981.

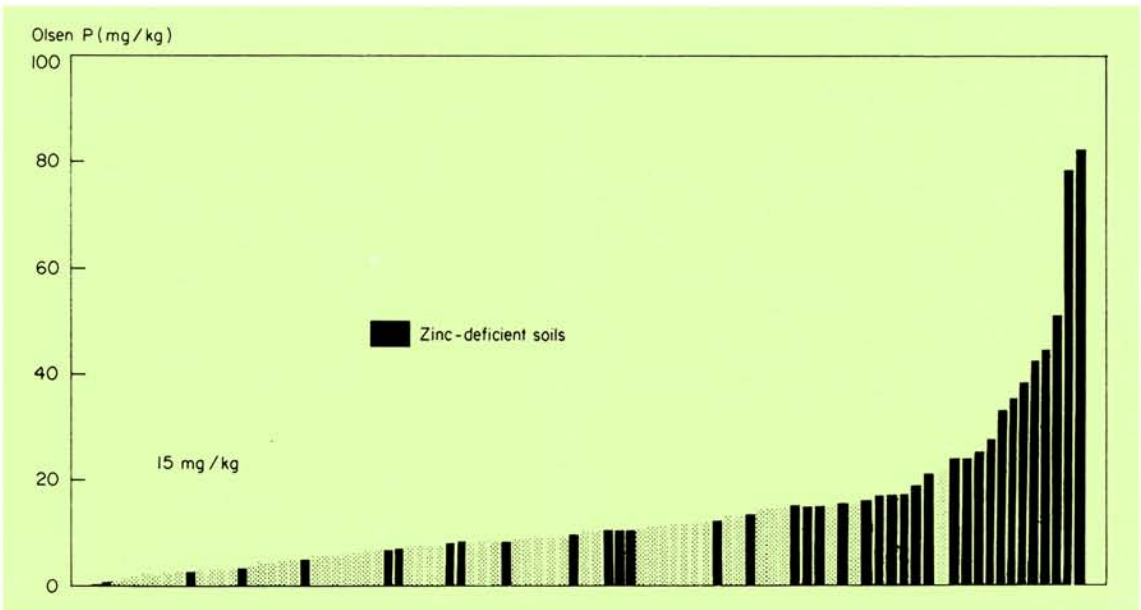
Table 8. Response to zinc of wetland rice on some zinc-deficient soils.

Kind of soil	Varieties (no.)	Mean yield (t/ha)		
		No zinc	With Zn	Difference
Alkali	34	0.9	2.6	1.5
Calcareous	1	2.8	4.9	2.1
Peat	27	1.8	2.2	0.4
High silica	20	2.0	3.1	1.1
High chromium	2	0.0	2.4	2.4

cadmium uptake by rice were studied in a greenhouse experiment.

Cadmium concentration in IR36 grains exceeded the FAO/WHO safety limit as the concentration of cadmium chloride added to submerged Maahas clay (pH 6.1, organic carbon 1.6%, Olsen phosphorus 3 mg/kg, available zinc 0.8 mg/kg, available cadmium 0.1 mg/kg) was raised to 10 mg cadmium/kg soil. Neither zinc nor phosphorus significantly depressed cadmium uptake by rice. Cadmium concentration in the grain correlated highly ($r = 0.75^{**}$) with soil cadmium extracted by the 0.05 *M* HCl method.

Thermodynamic criteria showed that after soil reduction, cadmium was present as cadmium sulfide, with a pK_{sp} of 26 to 27.



12. Mineral soils in the order of increasingly available phosphorus content. IRRI, 1981.

Table 9. Effect of water regime on nutrient status and yield, averaged for 3 soils after the 31st crop in an outdoor drum study, IRRI, 1981.

Water regime	pH	Total nitrogen (%)	Organic carbon (%)	Olsen phosphorus (mg/kg)	Uptake (g/drum)			Grain yield (g/drum)
					Nitrogen	Phosphorus	Potassium	
Flood fallow	7.3	0.184	1.62	18.3	1.93	0.36	1.68	109
Dry fallow	7.4	0.131	1.13	20.3	0.90	0.14	0.86	45
Difference	-0.1**	0.053**	0.49**	-2.0**	1.03**	0.22**	0.82**	64**

Water regime and soil nutritional status (*Soil Chemistry*). Soil and plant analyses and rice response confirmed earlier findings that flood fallowing improved the nitrogen and carbon content of the soil and increased nutrient uptake and yields more than did the usual practice of dry fallowing between crops (Table 9). Flood fallowing led to nitrogen accumulation at an average rate of about 60 kg/ha per year. Algae appeared to be the main source of the increase.

Soil and crop management

Management of soil and fertilizer nitrogen

Agronomy, Soil Chemistry, and Soil Microbiology Departments

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MEASURING AMMONIA VOLATILIZATION FROM UREA-AMENDED WETLAND RICE SOILS BY A MICROMETEOROLOGICAL TECHNIQUE **293**

Agronomy Department

Sources of urea and methods of application. Sources of urea and methods of application to increase nitrogen fertilizer efficiency in transplanted wetland rice were evaluated during the 1981 dry and wet seasons. IR36 was the test variety. Recommended cultural practices were followed.

Dry season. In the irrigated site, broadcast and incorporated, controlled-release forestry-grade sulfur-coated urea (SCU) produced the highest yield (5.9 t/ha) (Table 1), followed by deep-placed urea supergranules (5.8 t/ha). Both sources gave significantly higher yields than the recommended or researchers' split application. Farmers' timing of split application produced a significantly lower yield (4.6 t/ha) than the researchers' (5.4 t/ha). Unfertilized plots yielded significantly lower (2.4 t/ha) than the fertilized plots.

Total nitrogen uptake at harvest was consistent with grain yield data. This suggests that higher yields were due to the rice crop's use of higher nitrogen fertilizer for grain production. These results confirm previous reports that yields from the use of controlled-release fertilizers or deep placement of urea supergranules in the dry season are significantly higher than yields from the researchers' split application of urea under good water control and at optimum levels of insect and weed control.

In a field experiment comparing the sources of urea, yields were not significantly different (Table 2). However, yields from SCU supergranule-treated plots were significantly lower than those from other fertilized plots but were comparable to those from plots that received a split application of urea. All nitrogen treatments gave significantly higher yields than the no-nitrogen treatment.

Wet season. In the irrigated site, all plots fertilized at 58 kg N/ha gave significantly higher yields than did the unfertilized plots. Broadcast and incorporated forestry-grade SCU produced significantly higher yields than urea applied with a plowsole during primary tillage operations. Forestry-grade SCU, used for controlled-release effects, was not superior to uncoated forestry-grade urea.

Table 3 shows data on grain yield from an experiment on irrigated and rainfed rice. Grain yields of irrigated rice were considerably higher than those of rainfed rice. In the rainfed trial, yields from plots that received basal application of urea/dicyandiamide during final land preparation were significantly higher than those from unfertilized plots. Severe and prolonged drought during reproductive and ripening stages reduced grain yields and fertilizer response in the rainfed experiment.

Forms of urea and methods of application. A field trial at the IRRI farm during the 1981 dry and wet seasons evaluated nitrogen efficiency in wetland rice (IR36). Nitrogen sources were prilled urea and its modified slow-release forms, supergranules, and forestry-grade SCU. An IRRI-developed plowsole applicator was tested for deep placement of required amounts of prilled urea 1 week before transplanting. Urea supergranules were placed at 10- to 12-cm soil depth between 4 rice hills immediately after transplanting. SCU was broadcast and incorporated before transplanting. All required

Table 1. Effect of sources of urea and application methods at 3 nitrogen rates on yield and nitrogen uptake of IR36.[a] IRRI, 1981 dry season.

Treatment	Grain yield (t/ha)				Total nitrogen uptake at harvest (kg N/ha)
	58 kg N/ha	87 kg N/ha	116 kg N/ha	Mean	
No fertilizer nitrogen	–	–	–	2.4 d	38 d
Urea, farmers' split[b]	4.0	4.1	5.6	4.6 c	76 c
Urea, researchers' split[c]	4.7	5.6	6.0	5.4 b	84 b
SCU,[d] broadcast and incorporated	5.0	6.1	6.6	5.9 a	101 a
Placement as urea supergranules	5.2	5.8	6.5	5.8 a	100 a
Mean	4.7 c	5.4 b	6.2 a		

[a] Av of 3 replications. Separation of means in a column or row by Duncan's multiple range test at the 5% level. [b] Two equal splits, 10 days after transplanting and 5-7 days after panicle initiation. [c] Two-thirds basal and incorporated and one-third topdressed 5-7 days before panicle initiation. [d] Forestry-grade sulfur-coated urea.

Table 2. Effect of sources of urea at 87 kg N/ha on the yield of IR36. IRRI, 1981 dry season.

Treatment	Grain yield[a] (t/ha)
No fertilizer nitrogen	3.6 c
Forestry-grade sulfur-coated urea, broadcast and incorporated	5.8 a
Urea/dicyandiamide[b], broadcast and incorporated	5.8 a
Placement of sulfur-coated urea supergranules	5.4 b
Plowsole application of urea	5.7 a
Split application of urea[c]	5.6 ab

[a]Av of 4 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]With nitrification inhibitor, active ingredient is dicyandiamide. [c]Two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation.

Table 3. Effect of urea source and application method at 58 kg N/ha on yield of irrigated and rainfed IR36 rice. IRRI, 1981 wet season.

Treatment	Grain yield[a] (t/ha)	
	Irrigated	Rainfed
No fertilizer nitrogen	3.8 c	1.0 b
Split application of prilled urea[b]	5.2 ab	1.4 ab
SCU[c], broadcast and incorporated	5.6 a	1.5 ab
Urea/dicyandiamide[d], broadcast and incorporated	5.2 ab	1.7 a
Plowsole application of prilled urea	5.1 b	1.3 ab
Forestry-grade urea, broadcast and incorporated	5.4 ab	1.5 ab

[a]Separation of means in a column 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. [c]Forestry-grade sulfur-coated urea. [d]With nitrification inhibitor, active ingredient is dicyandiamide.

Table 4. Effect of forms, rates, and methods of urea application on yield of IR36. IRRI, 1981.

Treatment	Yield[a] (t/ha)	
	Dry season	Wet season
No fertilizer nitrogen	2.6 d	3.9 c
	54 kg N/ha	*29 kg N/ha*
Urea by plowsole applicator	3.2 bcd	4.6 a
Urea by researchers' split[b]	3.6 abc	4.5 ab
Urea by farmer's split[c]	3.1 cd	4.1 abc
Urea supergranules placement 10-12 cm	3.7 ab	4.5 ab
SCU broadcast and incorporated[d]	3.6 abc	4.4 abc
	108 kg N/ha	*58 kg N/ha*
Urea by plowsole applicator	4.0 a	4.6 a
Urea by researchers' split[b]	3.8 a	4.2 abc
Urea by farmer's split[c]	3.5 abc	4.2 abc
Urea supergranules placement 10-12 cm	3.8 a	4.3 abc
SCU broadcast and incorporated[d]	3.8 a	4.0 bc
	150 kg N/ha	*75 kg N/ha*
Urea by best split	4.0 a	4.5 ab

[a]Separation of means in a column, for each season, by Duncan's multiple range test at the 5% level. [b]2/3 N broadcast and incorporated before transplanting, 1/3 N topdressed 5-7 days before panicle initiation. [c]1/2 N topdressed at 10 days after transplanting, 1/2 N topdressed at booting stage. [d]Forestry-grade sulfur-coated urea 33% N.

nitrogen was applied in a single dose. These methods were compared with researchers' split application (2/3 N broadcast and incorporated before transplanting, 1/3 topdressed 5-7 days before panicle initiation) and farmer's split (1/2 N topdressed 10 DT, 1/2 N topdressed at booting stage).

During the dry season, yields from plots fertilized at 54 kg N/ha (except plowsole application and farmer's split methods) were significantly higher than those from unfertilized plots (Table 4). Placement of supergranules, incorporation of SCU, and researchers' split application of prilled urea appeared promising at 54 kg N/ha. Yields from plots with prilled urea applied by plowsole applicator, urea applied by researchers' split method, deep-placed urea supergranules, and incorporated SCU at 108 kg N/ha were not significantly different. These application methods had yields comparable to those from researchers' split application of 150 kg N/ha.

In the wet season, the highest yields were from plowsole application of prilled urea at both low and high rates. This application technique yielded 0.7 t/ha more than the control (Table 4). The modified slow-release forms, urea supergranules, and SCU appeared to be better when applied at rates lower than 58 kg N/ha. Increasing nitrogen to 75 kg/ha by researchers' split method improved yields significantly over similar application techniques at lower rates.

Evaluation of forms of urea. An experiment compared the effectiveness of 2 methods of application of urea supergranules — surface broadcast, and broadcast and incorporated — with that of point placement at 10- to 12-cm soil depth. Forestry-grade urea and SCU were compared with prilled urea.

In the dry season, the yield of IR50 with broadcast and incorporated SCU was highest (7.5 t/ha) and similar to that with point-placed urea super-

granules (7.3 t/ha). Yields were significantly lower with broadcast and incorporated or surface broadcast urea supergranules than with placement (Table 5). With broadcast and incorporated SCU, yields were higher than with surface-applied SCU. That confirmed the superiority of point-placed urea supergranules and broadcast and incorporated SCU over other forms of urea and methods of application. Applied by both methods, forestry-grade urea and prilled urea performed similarly.

In the wet season, yields with surface-applied or broadcast and incorporated forestry-grade urea were high, similar to those with point-placed urea supergranules and broadcast and incorporated SCU. When surface applied, both urea supergranules and SCU were less effective, as was prilled urea.

AGRONOMIC EFFECTIVENESS OF SILICA-POLYMER-COATED FORESTRY-GRADE UREA

Agronomy Department

A factorial field experiment during the 1981 dry season evaluated the agronomic effectiveness and fertilizer efficiency of silica-polymer-coated forestry-grade urea (PCU) at three delayed-release times and four nitrogen rates. Critical periods of nitrogen uptake were determined by path analysis. Uncoated forestry-grade urea was the check fertilizer. IR36 was transplanted in the field at 20- × 15-cm hill spacing. Recommended cultural practices were followed.

Response depended on rate of nitrogen applied (Table 6). At all rates, PCU 25-day delayed-release treatment produced the highest yield. Average yields at the 4 nitrogen rates showed that coating forestry-grade urea with silica-polymer (sodium silicate with acrylic latex) to delay release of nitrogen significantly increased yields.

Floodwater samples were taken at 3, 5, 7, 10, and 15 days after fertilizer application to determine the amount of NH_4-N. Floodwater NH_4-N values were higher in uncoated forestry-grade urea-treated plots, particularly at high nitrogen levels (Fig. 1). The highest value, 4.2 ppm NH_4-N, was obtained with forestry-grade urea at 100 kg N/ha 3 days after fertilizer application. That suggests the efficient incorporation of the nitrogen fertilizers into the soil. Floodwater NH_4-N diminished with time after fertilizer application.

Soil samples were taken at different growth stages and at 3 soil depths (0-8 cm, 8-20 cm, and 20-40 cm) for 50- and 100-kg N/ha rates to determine NH_4-N. NH_4-N decreased with time, lowering rate of nitrogen applied and increasing soil depth (Fig. 2). More was detected in the upper 0- to 8-cm layer than at deeper layers, indicating that the applied nitrogen fertilizers were incorporated at that depth. NH_4-N was less at 8-20 cm and much less at 20-40 cm. The highest NH_4-N, measured at 0-8 cm soil depth during critical tillering stage (20 days after transplanting), was in the PCU 25-day delayed-release treatment at the highest nitrogen level (Fig. 3).

Under field conditions, the 50-day delayed-release PCU did not actually release nitrogen at the

Table 5. Effect of form of urea on yield of IR50. IRRI, 1981.

Urea form	Application method	Grain yield[a] (t/ha)	
		Dry season 87 kg N/ha	Wet season 58 kg N/ha
–	No fertilizer nitrogen	3.0 d	3.3 d
Prilled	Broadcast and incorporated	4.8 c	4.8 c
Forestry-grade	Broadcast and incorporated	4.9 c	5.4 ab
Supergranule	Broadcast and incorporated	6.3 b	4.9 bc
Forestry-grade SCU[b]	Broadcast and incorporated	7.5 a	5.4 ab
Forestry-grade	Surface broadcast	4.7 c	5.5 a
Supergranule	Surface broadcast	5.9 b	4.9 bc
Forestry-grade SCU[b]	Surface broadcast	6.0 b	4.9 bc
Prilled	2/3 basal + 1/3 5-7 DBPI[c]	5.2 c	4.9 c
Supergranule	Placement[d]	7.3 a	5.2 abc

[a]Separation of means by Duncan's multiple range test at the 5% level. [b]Sulfur-coated urea. [c]Days before panicle initiation. [d]Point placed at 10- to 12-cm soil depth.

Table 6. Response of IR36 to uncoated and silica-polymer-coated forestry-grade urea (PCU) with 3 delayed-release times at 4 nitrogen levels. IRRI, 1981 dry season.

Treatment[a]	Grain yield[b] (t/ha)				
	25 kg N/ha	50 kg N/ha	75 kg N/ha	100 kg N/ha	Mean
No fertilizer nitrogen	–	–	–	–	3.8 d
Forestry-grade urea (no coating)	4.3 a	4.8 b	5.7 b	5.9 b	5.2 c
PCU, 15-day delayed release	4.9 a	5.9 a	6.1 ab	6.5 ab	5.8 ab
PCU, 25-day delayed release	5.0 a	5.9 a	6.6 a	6.8 a	6.1 a
PCU, 50-day delayed release	4.9 a	5.8 a	6.3 ab	6.0 b	5.7 b
Mean	4.8	5.6	6.2	6.3	

[a]All fertilizers were broadcast and incorporated using a power weeder during the final land preparation. [b]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

prescribed time (50 days after application ± 10 days) but tended to release nitrogen gradually from the time of fertilizer application until flowering.

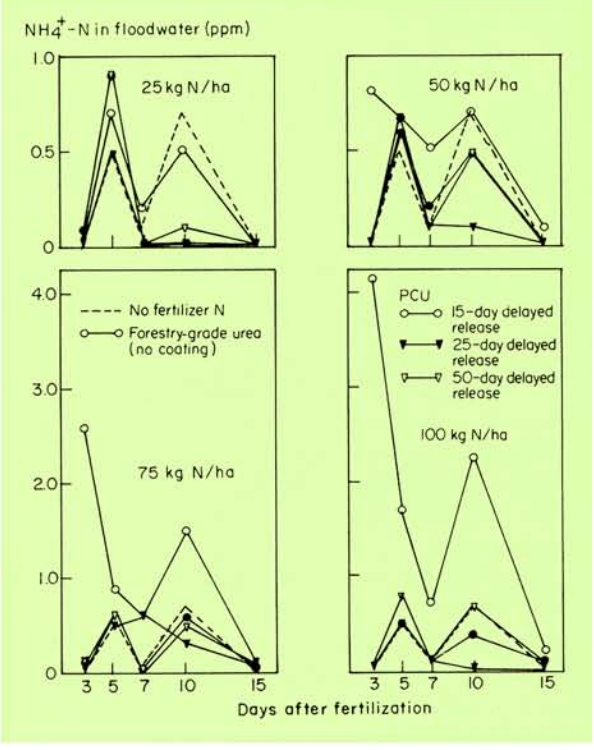
Figure 4 shows the total nitrogen uptake at different growth stages. At 100 kg N/ha, PCU 25-day delayed release gave higher nitrogen uptake at flowering than did PCU 50-day delayed release and forestry-grade urea. That may explain the significant yield differences between the treatments.

The path analysis showed that most of the differences in yield were due primarily to variation in number of spikelets per panicle and number of panicles per square meter. The critical periods for nitrogen absorption to promote the development of the two most nitrogen-sensitive yield components were determined from nitrogen uptake data. The product of the two nitrogen-sensitive yield components, the number of spikelets per unit area, can be considered as the potential yield. The period from flowering to harvest had the largest direct effect on realizing the potential yield.

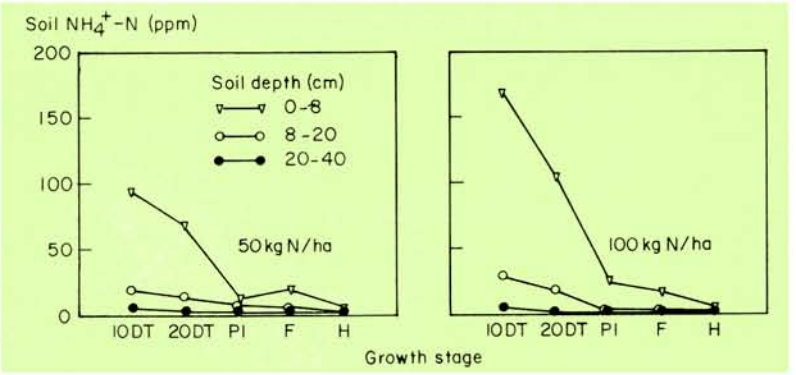
EFFECTS OF APPLICATION METHOD, PARTICLE SIZE, AND COATING ON UREA EFFICIENCY FOR WETLAND RICE

Agronomy Department

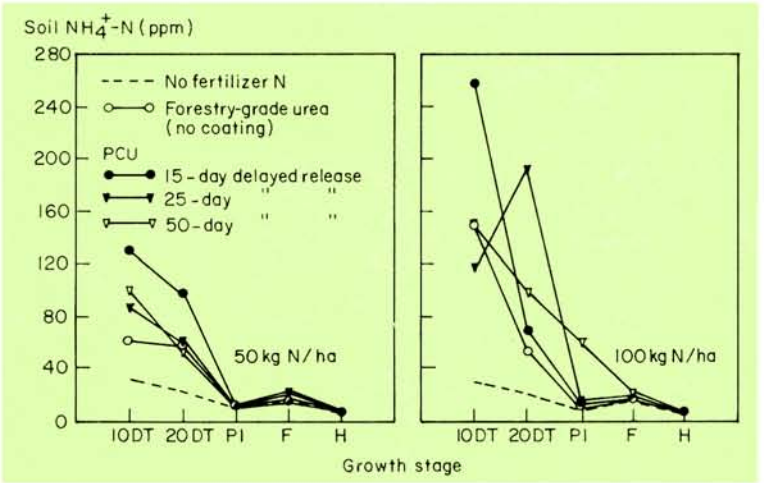
A factorial field experiment was conducted during the 1981 crop seasons in collaboration with the International Fertilizer Development Center (IFDC) to evaluate the effects of application methods, particle size, and coating on the efficiency of urea for IR36. Two application methods (broadcast and incorporated, and surface broadcast), and three particle sizes (prilled, forestry grade, and 1-g supergranule), with and without sulfur coating, were evaluated. Two rates of nitrogen were used — 58 and 87 kg N/ha in the dry season and 29 and 58 kg N/ha in the wet.



1. NH_4^+-N in floodwater after application of uncoated and silica-polymer-coated forestry-grade urea (PCU) with 3 delayed-release times at 4 nitrogen levels. IRRI, 1981 dry season.



2. Soil NH_4^+-N at different soil depths and growth stages of IR36 after application of uncoated and silica-polymer-coated forestry-grade urea with 3 delayed releases at 2 nitrogen levels. DT = days after transplanting, PI = panicle initiation, F = flowering, H = harvest. IRRI, 1981 dry season.



3. Effect of uncoated and silica-polymer-coated forestry-grade urea (PCU) with 3 delayed releases at 2 nitrogen levels on soil NH_4^+-N (0-8 cm soil depth) at different growth stages of IR36. DT = days after transplanting, PI = panicle initiation, F = flowering, H = harvest. IRRI, 1981 dry season.

Dry season. Averaged data for fertilizer treatments showed significant increases in grain yield over control (Table 7).

Yield differences between the two application methods were not significant. At 58 kg N/ha, urea supergranules (1 g) gave higher yields than prilled urea. Plots with forestry-grade urea (without sulfur coating) and those with prilled urea and urea supergranules had comparable yields. Forestry-grade SCU gave the highest yield, 4.9 t/ha, a significant increase of 1.4 t/ha over uncoated forestry-grade urea.

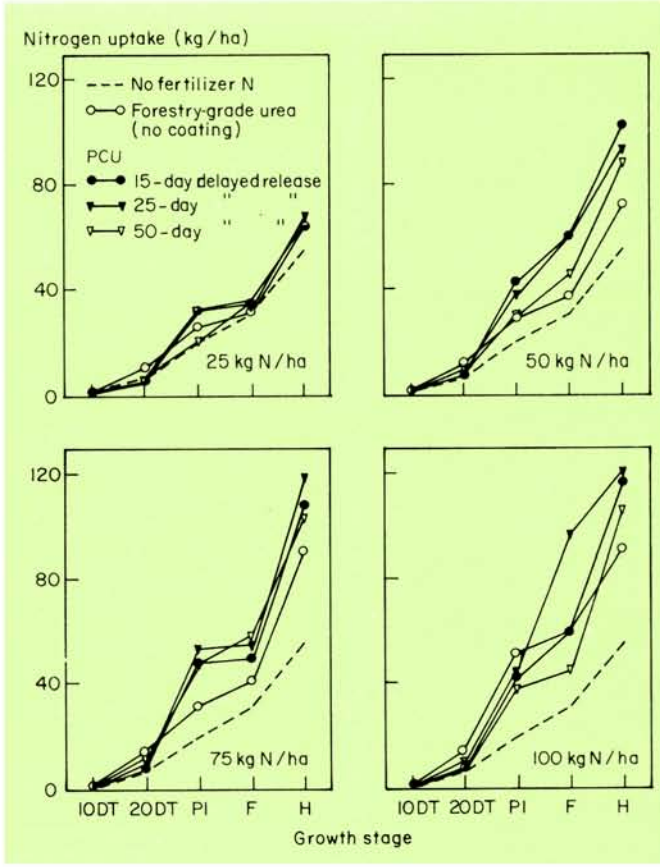
At 87 kg N/ha, there were no significant differences among treatments with forestry-grade urea, forestry-grade SCU, and urea supergranules. Both the plots with forestry-grade SCU and urea supergranules yielded significantly higher than those with prilled urea.

Wet season. There were no significant differences among treatments, nitrogen rates, and application methods. However, at 58 kg N/ha, all fertilizer treatments yielded significantly higher than the unfertilized control (Table 8).

EFFECT OF PLACEMENT METHOD ON RECOVERY OF APPLIED N BY RICE

Agronomy Department

The effect of placement methods on fertilizer efficiency was studied during the 1981 dry and wet



4. Effect of uncoated and silica-polymer-coated forestry-grade urea (PCU) with 3 delayed releases at 4 nitrogen levels on total nitrogen uptake at different growth stages of IR36. DT = days after transplanting. PI = panicle initiation, F = flowering, H = harvest. IRRI, 1981 dry season.

Table 7. Effect of urea particle size and coating at 2 nitrogen rates on yield of IR36. IRRI, 1981 dry season.[a]

Urea source	Grain yield (t/ha)		*F* mean
	58 kg N/ha	87 kg N/ha	
No fertilizer nitrogen	–	–	2.7 c
Prilled urea	3.1 c	3.9 b	3.5 b
Forestry-grade urea	3.5 bc	4.3 ab	3.9 b
Forestry-grade SCU[b]	4.9 a	4.8 a	4.8 a
Urea supergranule (1 g)	4.2 b	4.7 a	4.4 a
Mean	3.9	4.4	

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

seasons using ^{15}N-labeled urea. Three placement methods — uniform placement at 10-cm depth before transplanting by evenly removing 10 cm surface soil, broadcasting fertilizer, and immediately restoring the soil; band placement at 10-cm soil depth between 2 rows rice; and point placement of urea supergranules (SGU) at 10-cm soil depth at the center of 4 rice hills — were compared with split application — 2/3 basal + 1/3 at 5-7 days before panicle initiation — and control. A randomized complete block design was used with three replications in the dry season and four replications in the wet. Residual effects of ^{15}N urea after one crop season also were evaluated.

In the dry season, uniform placement and SGU point placement gave the highest yields (Table 9), but the two treatments were not statistically different. Band placement and split application had the next highest yield and unfertilized control the lowest.

In the wet season, point placement of urea supergranules alone gave the highest yield (Table

Table 8. Effect of application method, particle size, and coating of urea on IR36. IRRI, 1981 wet season.

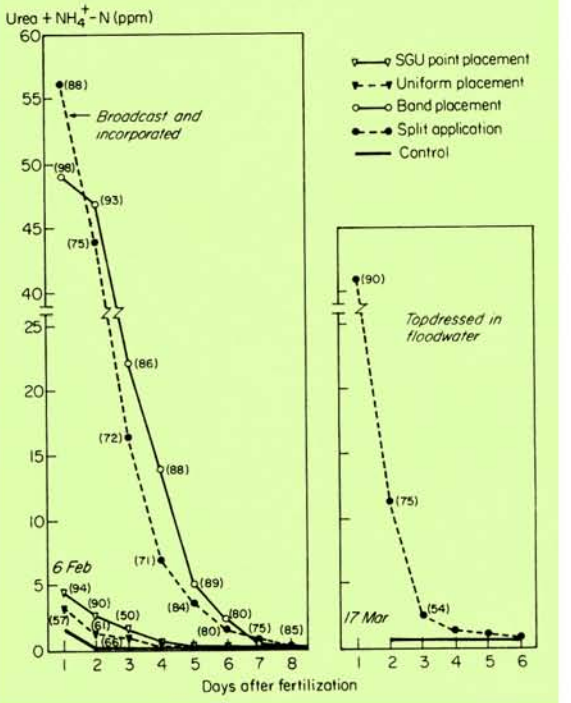
Urea source	Application method[a]	Grain yield[b] (t/ha)
No fertilizer nitrogen		3.8 d
29 kg N/ha		
Prilled urea	BI	4.6 abc
	SB	4.6 abc
Sulfur-coated prilled urea	BI	4.6 abc
	SB	4.3 abcd
Forestry-grade urea	BI	4.2 bcd
	SB	4.4 abcd
Sulfur-coated forestry-grade urea	BI	4.3 abcd
	SB	4.8 ab
Urea supergranules	BI	4.6 abc
	SB	4.3 abcd
Sulfur-coated supergranule urea	BI	4.4 abcd
	SB	4.0 cd
58 kg N/ha		
Prilled urea	BI	4.8 ab
	SB	4.5 abc
Sulfur-coated prilled urea	BI	4.8 ab
	SB	4.6 abc
Forestry-grade urea	BI	4.7 abc
	SB	4.7 abc
Sulfur-coated forestry-grade urea	BI	4.8 ab
	SB	4.7 abc
Urea supergranules	BI	4.9 a
	SB	4.6 abc
Sulfur-coated supergranule urea	BI	4.6 abc
	SB	4.8 ab

[a]BI = broadcast and incorporated; SB = surface broadcast. [b]Av of 4 observations except for control, which is av of 8 observations. Separation of means by Duncan's multiple range test at the 5% level.

Table 9. Effect of urea placement method on yield of IR36. IRRI, 1981.

Treatment	Grain yield[a] (t/ha)		
	Dry season (87 kg N/ha)		Wet season (54 kg N/ha)
	Main crop	Residual effects[b]	
No nitrogen	1.9 c	2.3 c	2.3 c
Uniform placement at 10-cm depth	6.4 a	3.8 ab	3.5 b
Band placement at 10-cm depth	5.0 b	3.3 b	3.5 b
Point placement with SGU[c] at 10-cm depth	6.4 a	4.3 a	4.4 a
Split application 2/3 basal + 1/3 5-7 DBPI[d]	4.5 b	3.1 b	3.2 b
CV (%)	7	12	11

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]From applied nitrogen during the dry season. [c]Supergranule urea. [d]Days before panicle initiation.

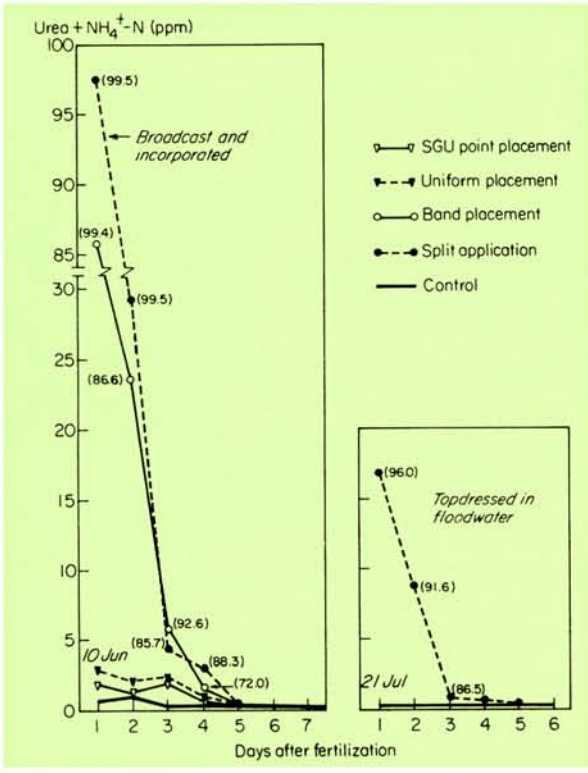


5. Effect of placement method on total nitrogen (urea and NH_4^+) in floodwater at 1330 hours. IRRI, 1981 dry season. Numbers in parentheses show urea-N as % urea plus NH_4^+-N.

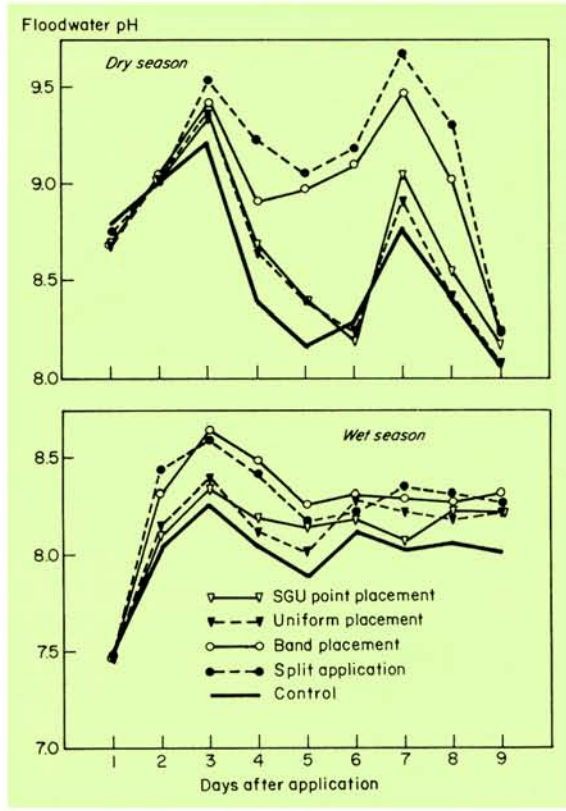
9). There was no statistical difference among the other three methods.

Split application and band placement were inefficient in both seasons (Table 9), suggesting that extensive losses of fertilizer nitrogen occurred after application. Higher total nitrogen (NH_4 + urea) concentration in floodwater (Fig. 5, 6) and higher floodwater pH (Fig. 7) indicated greater NH_3 volatilization with those two methods. In fact, less than 5 ppm total nitrogen in floodwater was detected from uniform placement and point placement of urea supergranules in both seasons, demonstrating the efficiency of these methods in reducing nitrogen losses. This confirmed the difficulty of practicing band placement in flooded rice fields because floodwater can carry dissolved fertilizer nitrogen back to the surface before the band can be covered by soil.

Crop recovery of ^{15}N urea at harvest in both seasons is presented in Table 10. As high as 73% of applied nitrogen in the dry season and 65% in the wet were recovered from urea supergranule point



6. Effect of placement method on total nitrogen (urea + NH_4^+) in floodwater at 1330 hours. IRRI, 1981 wet season. Numbers in parentheses show urea as % urea plus NH_4^+-N.



7. Effect of placement method on floodwater pH at 1330 hours. IRRI, 1981.

placement. However, the improved efficiency of urea supergranule point placement is not due to nitrogen concentration at certain points but to deep placement itself, as shown by the effects of uniform placement methods on yield, ^{15}N recovery, and total nitrogen concentration in floodwater.

The second-season rice crop can only recover as much as 4.5-6.5% of applied ^{15}N fertilizer after harvest of the first-season crop (Table 11), indicating the slight residual effects of applied nitrogen.

^{15}N BALANCE STUDIES WITH UREA AND MODIFIED UREA PRODUCTS IN IRRIGATED RICE

Agronomy Department

Relatively undisturbed soil and soil core samples were taken from the experimental plots of placement methods studies for ^{15}N and total nitrogen analyses. ^{15}N balance studies suggest that in the wet season, 31-42% of the applied nitrogen remained in the soil at harvest (Table 12). That may be due to immobilization of nitrogen in the organic fractions. ^{15}N balance data showed that about 35% of the applied nitrogen was lost with split applied urea and 39% with band placement of prilled urea. However, only 40% of the applied nitrogen was unaccounted for with point placement of urea supergranules and 8% with uniform placement of prilled urea (Fig. 8). That suggests negligible gaseous losses with the two placement methods.

RELEASE AND FIXATION OF NH_4-N IN WETLAND RICE SOILS

Agronomy Department

The content and mobility of nonexchangeable ammonium under submerged conditions were studied at three locations varying in clay mineralogy — Iloilo (Santa Rita clay), Cabuyao (Guadalupe clay), and Maligaya (Maligaya silty clay loam) (Table 13).

During the 1981 dry and wet seasons, soil sam-

Table 10. Effect of placement method on recovery of ^{15}N-labelled urea in IR36 at harvest. IRRI, 1981.

Treatment[a]	Applied ^{15}N recovered (%)					
	Dry season (87 kg N/ha)			Wet season (54 kg N/ha)		
	Straw	Grain	Total	Straw	Grain	Total
Uniform placement at 10-cm depth	20 a	69 a	89 a	19 ab	31 b	50 b
Band placement at 10-cm depth	13 c	48 c	61 c	9 c	18 d	27 c
Point placement with SGU at 10-cm depth	19 ab	54 b	73 b	23 a	43 a	66 a
Split application 2/3 basal + 1/3 5-7 DBPI	9 d	24 d	33 d	9 c	23 c	32 c
CV (%)	12	7	5	19	7	10

[a]SGU = supergranule urea. DBPI = days before panicle initiation.

Table 11. Influence of urea placement method on uptake of residual ^{15}N-labeled urea by second crop of IR36. IRRI, 1981 wet season.

Treatment[a]	Recovery of initially applied N (%)		
	Straw	Grain	Total
Uniform placement at 10-cm depth	1.2	3.3	4.5
Band placement at 10-cm depth	1.6	4.4	6.0
Point placement with SGU at 10-cm depth	1.2	3.4	4.6
Split applied 2/3 basal + 1/3 5-7 DBPI	1.9	2.8	4.7

[a]SGU = supergranule urea. DBPI = days before panicle initiation.

ples were taken from long-term nitrogen response experiments (Table 13).

Santa Rita clay (Iloilo) had the highest nonexchangeable ammonium content, followed by Guadalupe clay (Cabuyao) and Maligaya silty clay loam (Maligaya) (Table 14). The degree of mobility is more important than the content of this pool.

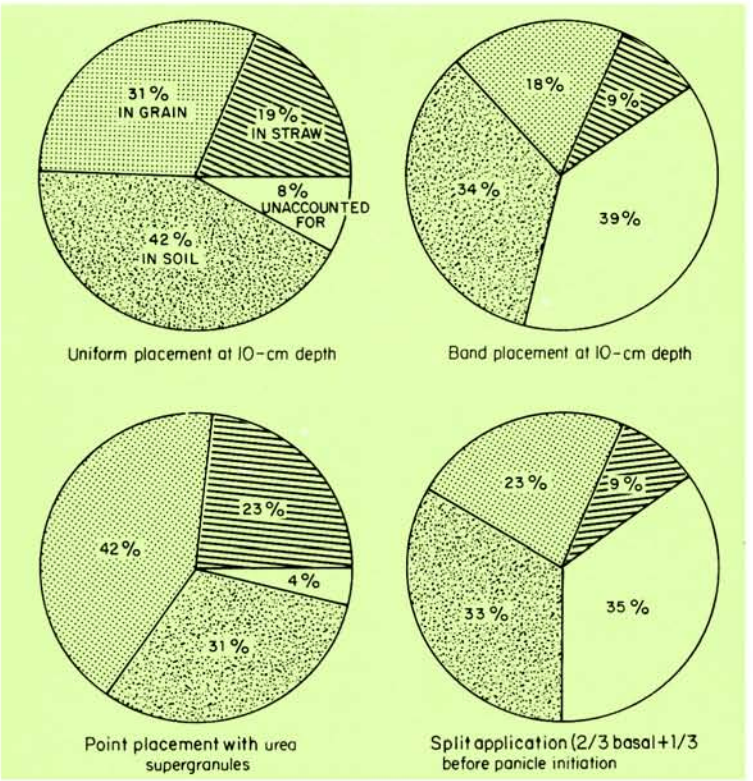
During the dry season, nonexchangeable ammonium increased after fertilizer application in all locations (Fig. 9, 10, 11). In the wet season, response was similar in Maligaya (Fig. 12), but not clear at Cabuyao and Iloilo (Fig. 13, 14). The increase in nonexchangeable ammonium content after fertilizer application at Maligaya could be attributed to the presence of vermiculite in clay minerals. Vermiculite can entrap ammonium ions better than montmorillionite.

Soil samples taken during the dry season indicate an apparent decrease of nonexchangeable ammonium during the first 20 days after transplanting in all locations except the no-fertilizer nitrogen plots in Cabuyao (Fig. 9, 10, 11). This tendency was more clear in the wet season at all nitrogen levels at all locations (Fig. 12, 13, 14) probably because a longer duration, 30 days after transplanting, enabled the crop to use the nonexchangeable ammonium pool.

Table 12. Balance of ^{15}N-labeled fertilizer with placement method.[a] IRRI, 1981 wet season.

Placement method	Applied nitrogen									
	Uptake				Remaining in soil (including roots)		Unaccounted for		Total	
	Straw		Grain							
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Uniform placement[b]	10	19	17	31	23	42	4	8	54	100
Band placement[b]	5	9	10	18	18	34	21	39	54	100
Point placement[b] of SGU[c]	12	23	23	42	17	31	2	4	54	100
Split application[d]	5	9	12	23	18	33	9	35	54	100

[a]Data are averages of 4 replications. [b]At 10-cm depth. [c]Supergranule urea. [d]2/3 basal + 1/3, 5-7 days before panicle initiation.



8. Effect of placement method on balance of ^{15}N-labeled urea at harvest. IRRI, 1981 wet season.

From 30 to 40 days after transplanting up to maturity, nonexchangeable ammonium was not released at all locations (Fig. 9-14). Rather, it increased to more or less constant levels.

The amounts of nonexchangeable ammonium released and their availability to the crop are being studied in ^{15}N experiments to obtain more quantitative details about the fixation and release patterns of the soils.

EFFECT OF NEEM CAKE ON NITRIFICATION

Soil Microbiology Department

A population count of ammonium-oxidizing bacteria and nitrite-oxidizing bacteria in field plots treated with 100 kg neem cake/ha showed temporary depression of nitrifying bacteria. The quantitative assays of nitrification using undisturbed soil cores were made in the same plots where nitri-

Table 13. Clay mineralogy at 3 locations in the Philippines. 1981.

Soil	Location	Clay mineralogy	Nonexchangeable NH_4^+-N	
			ppm	% of total N
Santa Rita clay	Iloilo	Montmorillonite (practically all)	194	13
Guadalupe clay	Cabuyao	Montmorillonite Vermiculite (minor)	59	3
Maligaya silty clay loam	Maligaya	Montmorillonite Vermiculite (major)	56	4

Table 14. Soil sampling plan to study content and mobility of nonexchangeable ammonium under submerged conditions at 3 locations in the Philippines. 1981.

Location	Soil	Nitrogen fertilizer (kg/ha)		Test cultivar
		Dry season[a]	Wet season[b]	
Iloilo	Santa Rita clay	0, 90, 150	0, 60, 120	IR6
Cabuyao	Guadalupe clay	0, 100, 150	0, 80, 120	IR8
Maligaya	Maligaya silty clay loam	0, 90, 150	0, 60, 120	IR36

[a]Sampling dates: 60 days before transplanting; transplanting (TPL); 20, 40, 60 days after transplanting (DT). [b]Sampling dates: TPL, 30, 60 DT.

fying bacteria were counted. In control plots that received 120 kg N/ha as ammonium sulfate, the nitrification rate was less than 330 g N/ha. Nitrification after ammonium application did not increase. Development of the oxidized layer had not occurred by the 6th week after fertilizer application, probably because the surface layer was disturbed by frequent heavy rain. The depressing effect on nitrification of neem cake was apparent from the 1st to the 5th week after neem cake application.

Relative rates of nitrification in neem-treated plots each week after neem and ammonium application were 0.66 at week 1, 0.54 at week 2, 0.50 at week 3, 0.27 at week 4, and 0.75 at week 6.

THE ROLE OF SUBSOIL IN SUPPLYING NITROGEN TO RICE PLANTS

Soil Microbiology Department

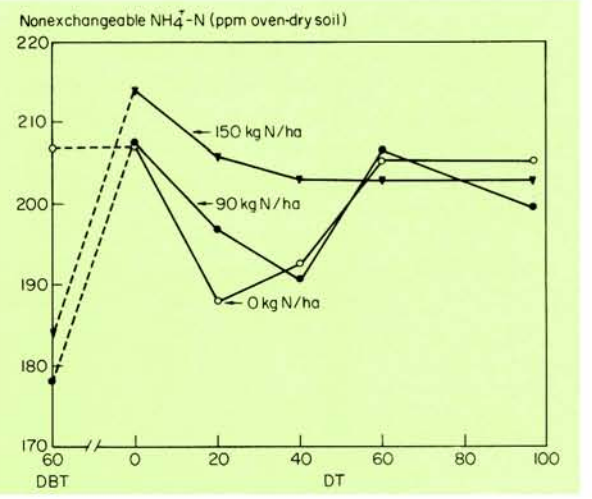
The organic matter-rich layer (total N >0.15%) develops up to 50 cm deep or deeper in the field at IRRI. A plastic film was placed at 20-cm depth to cut nutrient supply from beneath the plow layer. Rice growth in test plots was compared with that in plots without film. The growth and nutrient uptake of three consecutive crops were measured. In control plots, 3 crops of rice yielded totals of 10.4 t grain/ha and 20 t dry matter/ha. In shallow-soil plots, yields were 7 t grain/ha and 14 t dry matter/ha. Nitrogen uptake was 173 kg N/ha in control plots and 96 kg N/ha in shallow-soil plots. That may mean that 40% of the nitrogen absorbed by the rice plant could be attributed to soil below the plow layer. After 3 crops, ammonium nitrogen had accumulated just beneath the film, indicating that mineralized nitrogen remained.

SIMULATED RAINFED RICE STUDIES

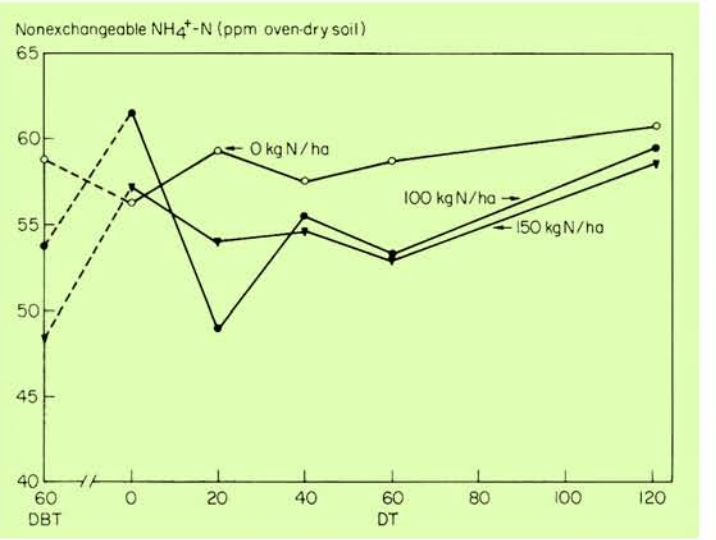
Agronomy and Soil Chemistry Departments

Field. For the first time a line source sprinkler system was used on puddled lowland rice to establish eight water regimes, ranging from continuously flooded through intermittently flooded to continuously dry over the water stress period. In each water regime, urea was either broadcast and incorporated at four rates or point deep-placed as supergranules at three rates. The objective was to evaluate plant response. IR36 was the test variety. Information on plant water stress and the effect of water-nitrogen interactions on growth and grain yield also was sought.

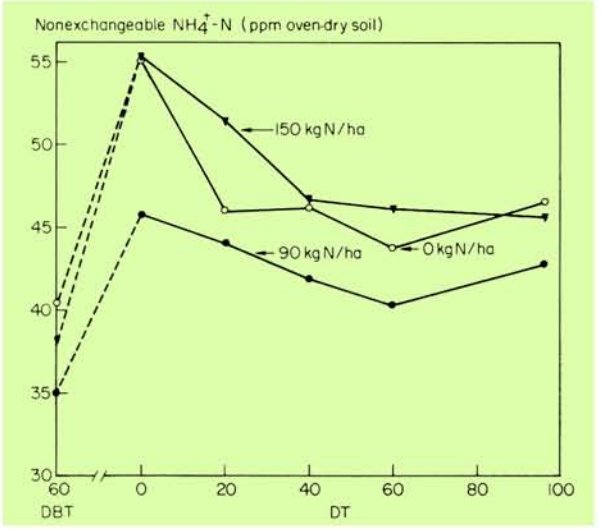
The line source was applied at 12 days after transplanting (DT) and continued to 38 DT, when the field was reflooded for the duration of crop



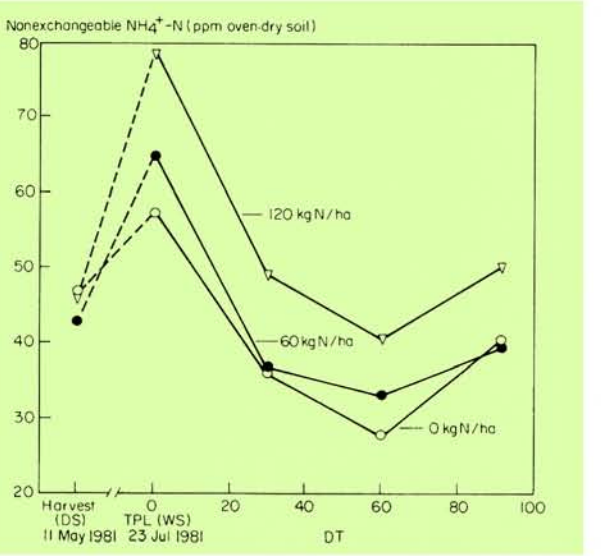
9. Content of nonexchangeable ammonium in nitrogen-response experiments at Iloilo station, Philippines, 1981 dry season. DBT = days before transplanting, DT = days after transplanting.



10. Content of nonexchangeable ammonium in nitrogen-response experiments at Cabuyao, Philippines, 1981 dry season. DBT = days before transplanting, DT = days after transplanting.



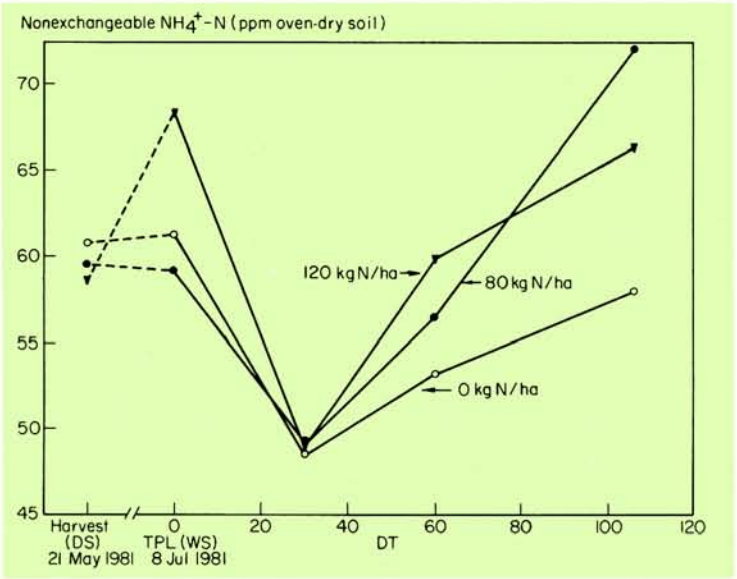
11. Content of nonexchangeable ammonium in nitrogen-response experiments at Maligaya station, Philippines, 1981 dry season. DBT = days before transplanting, DT = days after transplanting.



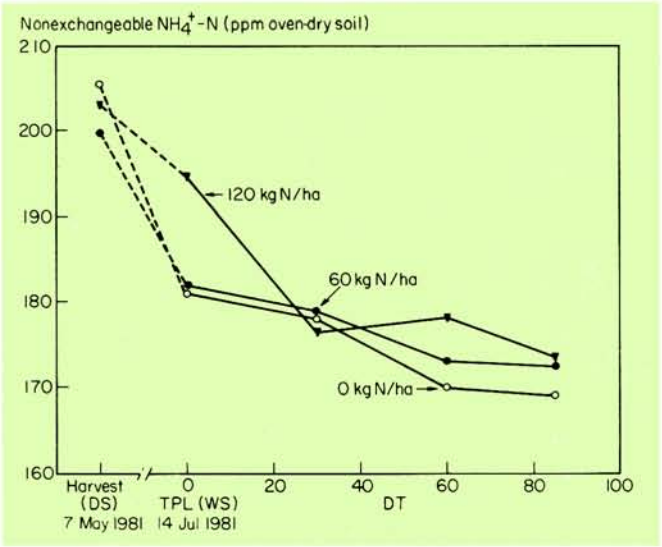
12. Content of nonexchangeable ammonium in nitrogen-response experiments at Maligaya station, Philippines, 1981 wet season (WS). DS = dry season, TPL = transplanting, DT = days after transplanting.

growth. Water equal to the evapotranspiration of the continuously flooded treatments, as determined with the use of microlysimeters, was applied every 4 days. Soil and plant material were collected on the day preceding irrigation to evaluate changes in soil mineral nitrogen pools, soil moisture, plant weight, plant nitrogen uptake, leaf elongation rate, leaf area index, and leaf water potential. Additional samples were collected at flowering, and grain yield was determined at harvest.

^{15}N-labeled urea or urea supergranules were used in three water regimes to evaluate the effect of water and nitrogen management on the loss of fertilizer nitrogen from the plant-soil system. ^{15}N-labeled microplots were sampled at 12 DT, 38 DT (except urea supergranules), flowering, and



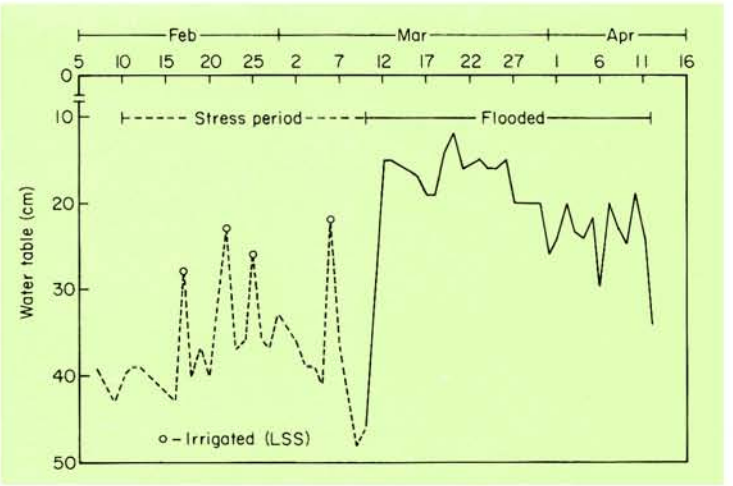
13. Content of nonexchangeable ammonium in nitrogen-response experiments at Cabuyao, Philippines, 1981 wet season (WS). DS = dry season, TPL = transplanting, DT = days after transplanting.



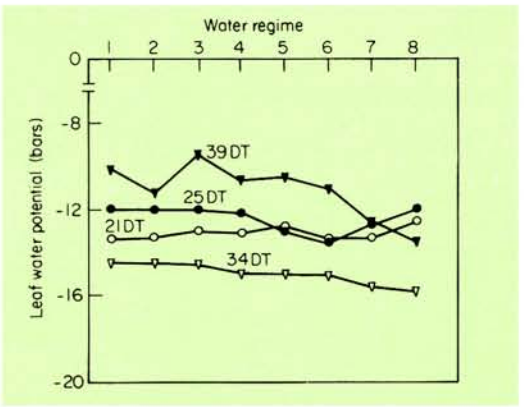
14. Content of nonexchangeable ammonium in nitrogen-response experiments at Iloilo station, Philippines, 1981 wet season (WS). DS = dry season, TPL = transplanting, DT = days after transplanting.

harvest.

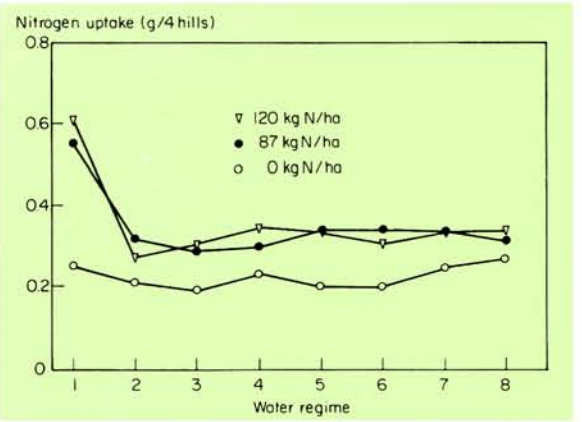
A linear decrease in water supply from the line source aided the establishment of gradients in soil moisture at 0- to 10- and 10- to 20-cm depths. However, at 30- and 40-cm depths, no gradient was discernible, probably because of the proximity of the water table (Fig. 15). Except for the last sampling period (39 DT), there was little change in midday leaf water potential across the eight water regimes (Fig. 16). On the other hand, leaf elongation rate (LER) was affected appreciably. LER at all three rates of nitrogen showed a decreasing



15. Water table depth as a function of time, stress, and reflooding periods. IRRI, 1981.



16. Midday leaf water potential as a function of water management. DT = days after transplanting. IRRI, 1981.



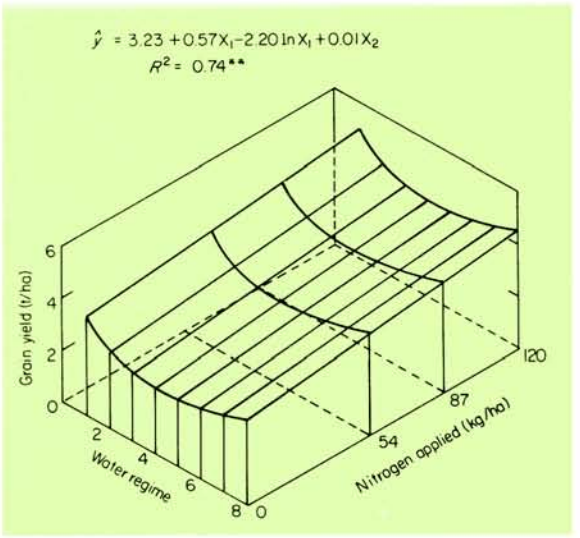
17. Effect of nitrogen rates on nitrogen uptake in different water regimes. IRRI, 1981.

trend with water management regime and sampling time. The highest LER from the continuously flooded regime (WR_1) fertilized with 120 kg N/ha was 5.3 cm/day at 20 DT. The lowest LER, from WR_5 at the same nitrogen rate, was 1.2 cm/day on 20 DT. This confirms previous IRRI reports that LER is a more sensitive measure of water stress in rice, because water stress affects expansive growth.

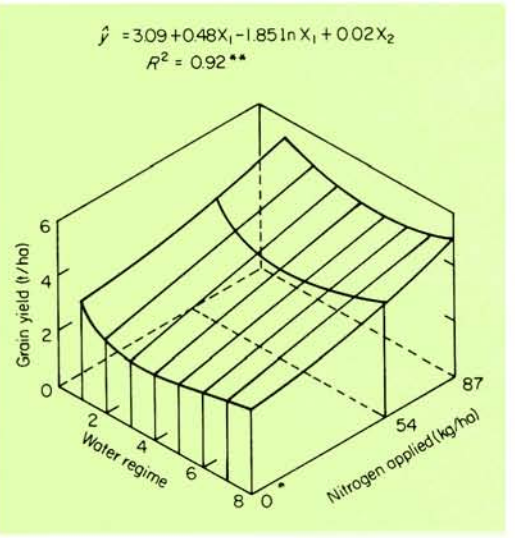
Decreasing the water supply had no significant effect on dry matter production in the absence of additional nitrogen. However, rates of dry matter accumulation were significantly lower in the drier regimes than in the continuously or intermittently flooded regimes, which received comparable levels of urea-nitrogen. Nitrogen uptake was reduced where floodwater was not maintained (Fig. 17). However, no further decrease in uptake occurred with decreasing supply of water where urea-nitrogen was surface incorporated.

Grain yields for the urea broadcast-and-incorporated treatments and urea supergranule treatments are presented in Figures 18 and 19. In general, grain yield increased linearly with added nitrogen. Response to water was logarithmic. In WR_1, the maximum predicted yield for urea supergranules applied at 87 kg N/ha was 5.3 t/ha while that for broadcast and incorporated prilled urea at 120 kg N/ha was 5 t/ha.

W_8, the farthest from the line source, received 26 mm water 12-38 DT. Urea supergranule-amended plots yielded the equivalent of 4.8 t/ha at 87 kg N/ha, compared with 4.4 t/ha from urea



18. Response surface showing combined effects of water regime and nitrogen rates (urea as supergranule) on yield. IRRI, 1981.



19. Response surface showing combined effects of water regime and nitrogen rates (prilled urea) on yield. IRRI, 1981.

Table 15. Effect of water regime[a] and nitrogen management on ^{15}N recovered[b] at flowering. IRRI, 1981.

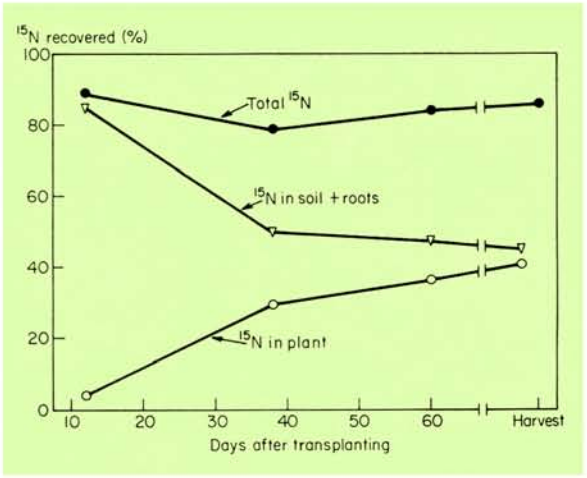
Floodwater regime	^{15}N recovered (%)			
	Soil and roots	Panicles	Straw	Total
Urea broadcast and incorporated[c]				
Continuously flooded	48 (48)	11 (7)	25 (24)	84 (79)
Intermittently flooded[d]	51 (35)	6 (6)	14 (18)	71 (59)
Without floodwater[d]	48 (33)	4 (4)	14 (13)	66 (50)
Urea supergranules point placed at 10-cm depth				
Continuously flooded	22	20	50	92
Intermittently flooded[d]	25	9	29	63
Without floodwater[d]	25	7	29	61

[a] All plots maintained flooded from transplanting to 12 days after transplanting (DT) and from 38 DT to harvest. [b] From 1.2- x 1.2-m microplots. [c] Figures in parentheses represent recoveries from 20- x 40-cm submicroplots. [d] Floodwater condition 12-38 DT. Water added through line-source sprinkler.

Table 16. Effect of water regime and nitrogen management on ^{15}N recovered at harvest. IRRI, 1981.

Floodwater regime[a]	^{15}N recovered (%)			
	Soil and roots	Grain	Straw	Total
Urea broadcast and incorporated				
Continuously flooded	45	29	12	86
Intermittently flooded	45	14	6	65
Without floodwater	45	16	5	66
Urea supergranules point placed at 10-cm depth				
Continuously flooded	24	56	17	97
Intermittently flooded	22	30	9	61
Without floodwater	27	26	7	60

[a] All plots maintained flooded from transplanting to 12 DT and from 38 DT to harvest. Water added through line source sprinkler 12-38 DT, resulting in different floodwater conditions.



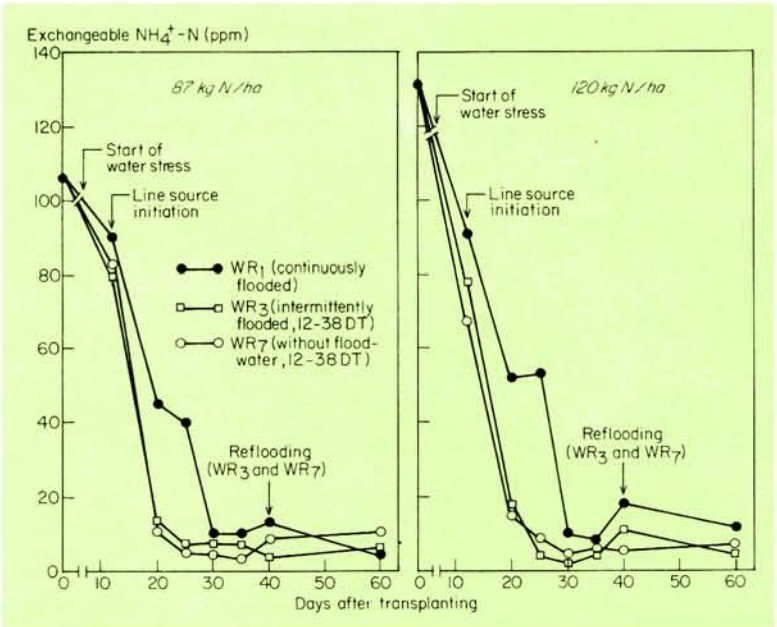
20. Recovery of ^{15}N over time from continuously flooded urea broadcast and incorporated treatment. IRRI, 1981.

broadcast and incorporated amended plots receiving 120 kg N/ha. Predicted yield at each level of nitrogen addition was lowest in WR_4 plots that underwent significant wetting and drying.

The ^{15}N balance obtained at flowering and that at final harvest are presented in Tables 15 and 16. A high ^{15}N recovery was achieved in the continuously flooded urea supergranule and urea broadcast and incorporated treatments, reflecting the effectiveness of the incorporation procedures adopted. However, only 36% of the ^{15}N urea applied was recovered in the plot at flowering for the urea broadcast and incorporated treatment, compared with 70% for the urea supergranule treatment. The ^{15}N balance and distribution between plant and soil was unchanged at final harvest.

Substantially lower ^{15}N recoveries were obtained where floodwater was not maintained. The loss of ^{15}N was greater from urea supergranule than from urea broadcast and incorporated treatments, although the amount of ^{15}N recovered in the plant material was higher where urea supergranules were used (Table 15, 16). This apparent anomaly indicates that, in intermittently flooded soils, a complex set of factors control the total recovery of ^{15}N, on the one hand, and the availability of fertilizer nitrogen to the plant, on the other.

For the continuously flooded urea broadcast and incorporated treatment, the loss of ^{15}N over time is shown in Figure 20. The major loss of ^{15}N had occurred before 12 DT, suggesting that NH_3 volatilization may have been responsible for the loss. ^{15}N samples taken at the end of water stress



21. Effect of nitrogen application rate and water regime on soil exchangeable NH_4^+-N in urea broadcast and incorporated treatment. IRRI field, 1981. DT = days after transplanting. IRRI, 1981.

Table 17. ^{15}N recovered over time (13-34 days after fertilizer incorporation) in continuously flooded and intermittently flooded Maahas soil. Greenhouse pot experiment, IRRI, 1981.

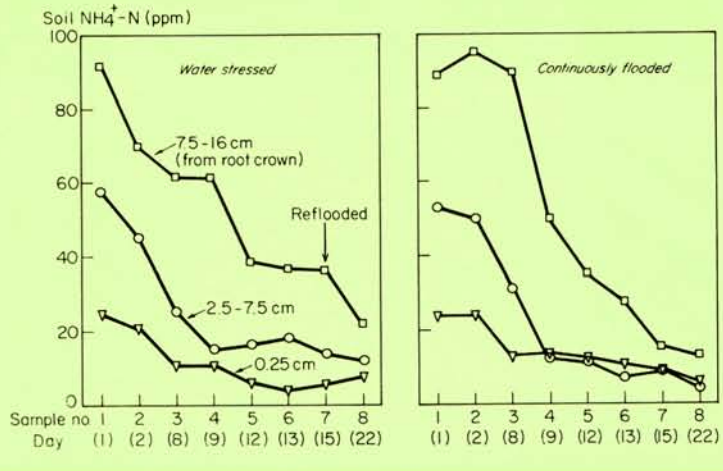
^{15}N distribution	^{15}N recovered (%)							
	13 days		19 days		27 days		34 days	
	Continuously flooded	Stressed[a]	Continuously flooded	Stressed	Continuously flooded	Stressed[b]	Continuously flooded	Stressed[c]
Soil exchangeable NH_4^+N	46	41	33	37	3	17	1	7
Soil nonexchangeable NH_4^+N	23	22	28	30	30	29	31	27
Plant	3	4	10	10	27	23	30	31
Floodwater	3	6	–	–	1	–	Tr.	Tr.
Total	75	73	72	77	61	68	62	65

[a]Floodwater lost by evapotranspiration. [b]Pots sampled immediately before flooding. [c]Pots sampled 1 week after reflooding.

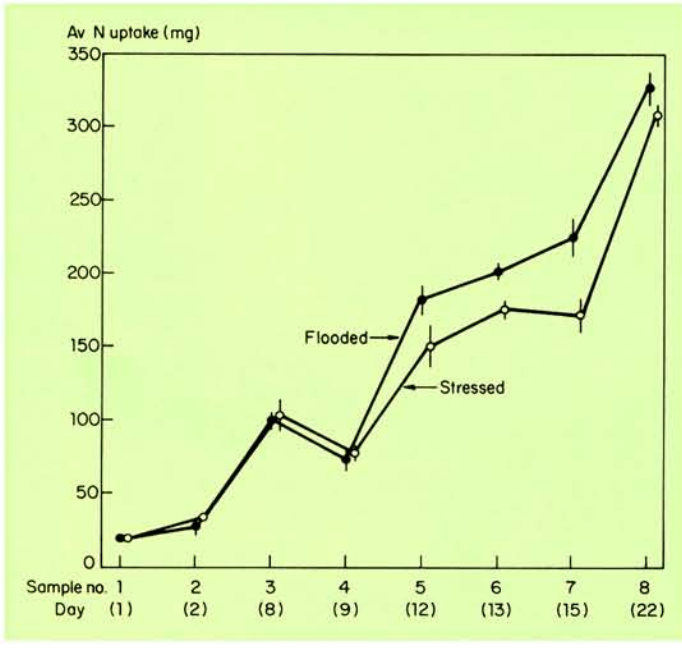
(38 DT) showed that, for intermittently flooded systems, the bulk of the ^{15}N was lost between 12 and 38 DT — presumably through nitrification-denitification or leaching. No appreciable accumulation of nitrate was detected 12-38 DT. The NH_4-N concentrations obtained over the same period show that the exchangeable NH_4-N pool was depleted more rapidly in the intermittently flooded or dry treatments than in the continuously flooded soil (Fig. 21).

Greenhouse. A series of greenhouse pot experiments evaluated the effect of soil drying on the fate of nitrogen fertilizer in puddled soil in more detail. The ^{15}N recovered over time for the continuously flooded and intermittently flooded treatments is shown in Table 17. Most of the ^{15}N loss occurred before the start of water stress. An additional 9-11% of the ^{15}N-labeled fertilizer was lost between 19 and 27 DT. However, soil drying and subsequent reflooding did not increase ^{15}N loss.

The effect of distance from the root crown and water management on soil exchangeable NH_4-N is shown in Figure 22. As expected, the exchangeable NH_4-N pool was depleted first close to the root crown. However, in the "stressed" soil, exploitation of the outer zone of soil was clearly impeded with time. Nitrogen uptake by rice plants in the stress treatment declined 12 days after the initiation of water stress (Fig. 23). These results indicate that the reduced uptake of nitrogen by rice was probably the result of reduced transpiration rate and expansive growth, as represented by lower LER (Fig. 24),



22. Effect of distance from root crown and water management on soil exchangeable NH_4^+-N. IRRI greenhouse, 1981.



23. Effect of water management on nitrogen uptake in rice shoots. IRRI greenhouse experiment, 1981.

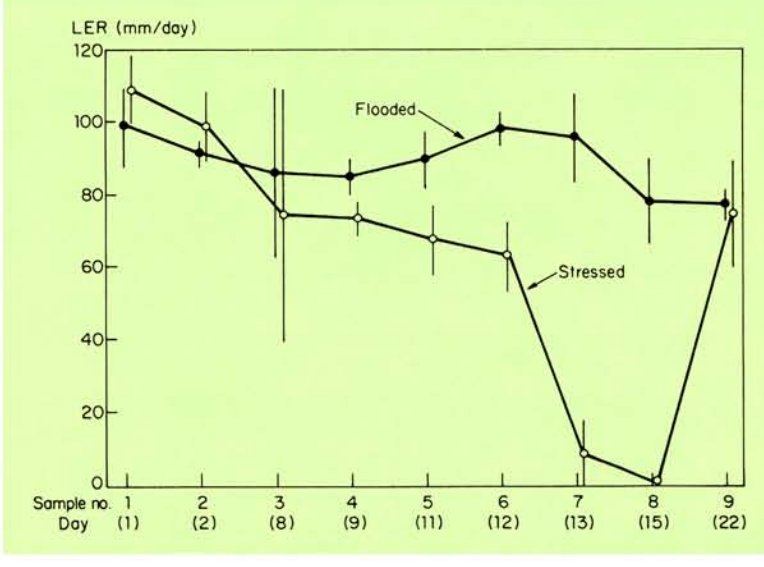
not the reduced availability of soil mineral nitrogen.

EFFECT OF SOIL PROPERTIES ON RECOVERY OF ^{15}N-LABELED FERTILIZERS

Soil Chemistry Department

A greenhouse study evaluated the effect of pH, texture, cation exchange capacity (CEC), and organic matter content on ^{15}N-labeled fertilizers. Prilled urea and ammonium sulfate were broadcast and incorporated; urea supergranules were point placed at 10 cm. The ^{15}N balance was determined 2 weeks after transplanting and at harvest. Floodwater was collected and analyzed for pH, urea, and ammoniacal nitrogen. Soils varied widely in pH, CEC, and soil organic matter content (Table 18).

Floodwater analyses showed high urea and ammoniacal nitrogen levels for all soils when urea was surface incorporated. Urea and ammoniacal



24. Effect of water management on leaf elongation rate (LER). IRRI greenhouse, 1981.

Table 18. Mechanical and chemical analysis of soils used to evaluate the effect of soil properties on recovery of ^{15}N. IRRI, 1981.

Soil	Soil texture	pH	OC[a] (%)	Total N (%)	CEC[b] (meq/100 g)
Luisiana	Clay	4.7	1.9	0.21	28.0
Pangasinan	Silty clay loam	7.4	0.83	0.06	33.0
Maahas	Clay	6.4	1.2	0.13	40.0
Rizal	Clay	6.7	1.17	0.09	37.0
Maros (South Sulawesi)	Silty clay	6.7	2.08	0.10	31.0
Thailand	Heavy clay	4.5	0.99	0.20	19.7

[a]Organic matter. [b]Cation exchange capacity.

Table 19. Recovery of ^{15}N, 14 days after transplanting, from rice soils amended with urea, surface incorporated, or deep-placed. IRRI, 1981

Soil	^{15}N recovered (%)		
	Soil and roots	Plant	Total
Supergranules deep point-placed			
Rizal	96.5	0.1	96.6
Maros, South Sulawesi	100.7	0.1	100.8
Maahas	99.6	0.1	99.7
Pangasinan	101.3	0.1	101.4
Luisiana	103.6	0.1	103.7
Ongkarak series, Thailand	94.1	0.2	94.3
Urea broadcast and incorporated			
Rizal	47.9	1.8	49.7
Maros, South Sulawesi	37.6	0.9	38.5
Maahas	48.5	0.4	48.9
Pangasinan	62.4	0.5	62.9
Luisiana	72.6	1.2	73.8
Ongkarak series, Thailand	49.3	0.8	50.1

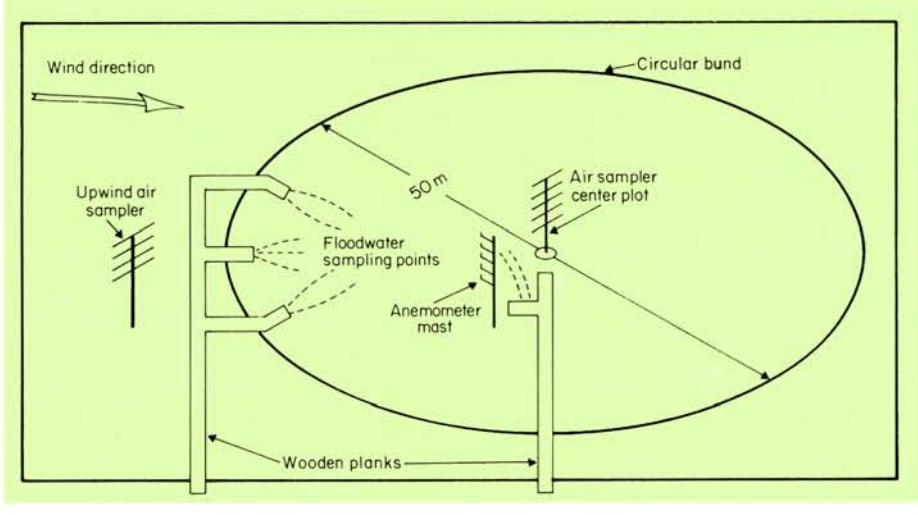
nitrogen were appreciably lower in the supergranule treatments, approaching control levels. Initially, concentrations of ammoniacal nitrogen were lower after the incorporation of ammonium sulfate. However, over time higher concentrations of ammoniacal nitrogen prevailed, reflecting a slower rate of loss of ammoniacal nitrogen in ammonium sulfate-amended soils. Except in Luisiana clay and acid sulfate (Ongkarak series) soils from Thailand, both strongly acid, floodwater pH was above 7 after urea-incorporation and did not reflect soil pH. Floodwater pH values were lower with ammonium sulfate and urea supergranules, consistent with the view that appreciable urea hydrolysis on the soil surface elevates floodwater pH.

The ^{15}N balance obtained at 14 DT (Table 19) showed appreciable loss of urea nitrogen when nitrogen was broadcast and incorporated but complete recovery when urea was deep-placed. Loss of ^{15}N-labeled urea was least in the Luisiana clay. Significantly, only 50% of the urea nitrogen was recovered in the acid-sulfate soil. Ammonia volatilization likely accounted for the loss before 14 DT with alkaline floodwater. It cannot account for the rapid loss of nitrogen from the acid-sulfate soil.

The recovery of ^{15}N was generally lower at harvest than at 14 DT (Table 20). Soil type did not

Table 20. Recovery of ^{15}N at harvest from soil-plant systems amended with urea, surface incorporated or deep point-placed. IRRI, 1981.

Soil	^{15}N recovered (%)			
	Soil and roots	Straw	Grain	Total
Supergranules deep point-placed				
Rizal	21.44	18.96	33.23	76.63
Maros, South Sulawesi	19.84	18.36	35.26	76.46
Maahas	17.93	21.83	35.05	74.81
Pangasinan	23.15	17.80	32.71	73.66
Luisiana	26.41	16.00	40.72	83.13
Ongkarak series, Thailand	30.30	28.29	14.05	72.64
Urea broadcast and incorporated				
Rizal	26.2	5.5	9.6	41.3
Maros, South Sulawesi	13.0	6.2	9.9	29.1
Maahas	15.2	5.2	10.0	30.4
Pangasinan	25.9	6.2	10.1	42.2
Luisiana	18.8	9.3	14.1	42.2
Ongkarak series, Thailand	27.3	12.7	13.8	53.8



25. Field layout for ammonia volatilization studies. IRRI, 1981.

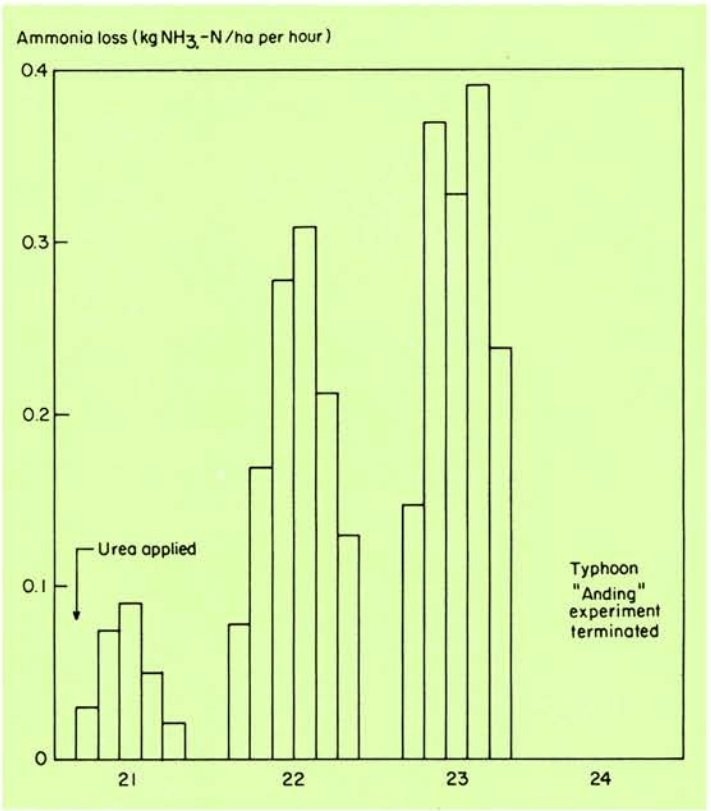
affect recovery of ^{15}N from the urea supergranule treatments at harvest. The lowest ^{15}N recoveries were obtained from the Maros soil (South Sulawesi) and the Maahas clay amended with prilled urea. Plant recovery of ^{15}N was highest in the urea supergranule treatments and lowest in the urea broadcast and incorporated treatments (Table 20). In the broadcast and incorporated treatment, plant recoveries from the more acidic soils were highest.

No close relationship could be drawn between soil properties and final ^{15}N recovery when prilled urea was broadcast and incorporated. For example, the Pangasinan silty clay loam (pH 7.4) and strongly acid Luisiana clay and acid-sulfate soil had similar final ^{15}N recoveries.

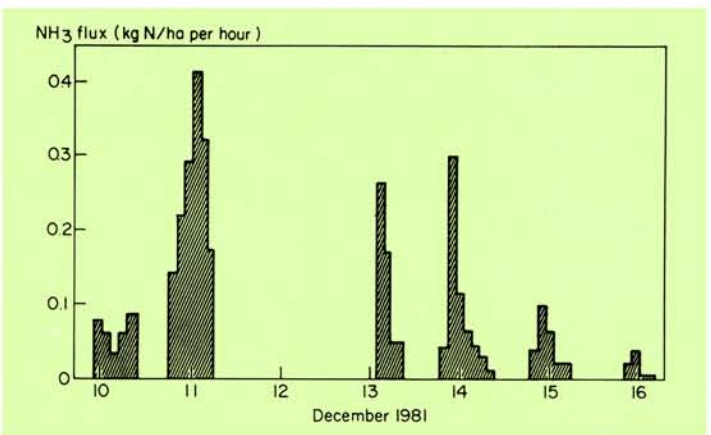
MEASURING AMMONIA VOLATILIZATION FROM UREA-AMENDED WETLAND RICE SOILS BY A MICROMETEOROLOGICAL TECHNIQUE

Agronomy and Soil Chemistry Departments

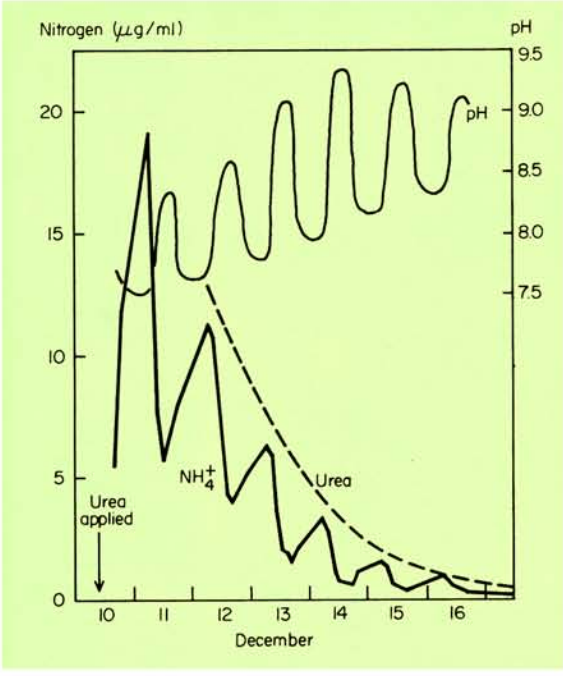
Ammonia volatilization from flooded wetland rice soils was measured by the mass balance flux micrometeorological technique on 50-m-diameter



26. Ammonia fluxes from urea topdressed 14 days after transplanting. IRRI, 1981.



27. Ammonia fluxes from broadcast and incorporated urea. Maligaya Rice Research and Training Center, Nueva Ecija, Philippines, 1981.



28. Urea, ammoniacal nitrogen, and floodwater pH after broadcast and incorporation of 80 kg urea N/ha. Maligaya Rice Research and Training Center, Nueva Ecija, Philippines, 1981.

circular fields (Fig. 25). Urea (80 kg N/ha) was topdressed into the floodwater 14 DT. Ammonia volatilization was detected immediately after urea application (Fig. 26). Peak NH_3 loss approached 0.4 kg N/ha per hour. Ammonia loss followed a diurnal pattern and reflected diurnal changes in floodwater pH and temperature.

Significant loss of NH_3 also was found in a study at the Maligaya Rice Research Training Center, Muñoz, Nueva Ecija (Fig. 27). Peak loss was about 0.4 kg N/ha per hour after urea was broadcast and incorporated (80 kg N/ha). Ammonia volatilization was detected for 7 days. Floodwater ammoniacal nitrogen concentration and pH for the Maligaya study are shown in Figure 28. Ammoniacal nitrogen concentration peaked at 20 ppm, but decreased rapidly. Floodwater pH showed a distinct diurnal pattern; it varied from 7.6 to 9.4. Ammoniacal nitrogen in the floodwater also displayed a diurnal pattern, probably reflecting the ineffectiveness of the flooded soil system in maintaining NH_4-N in floodwater during periods of high NH_3 volatilization.

Soil and crop management

Nitrogen fixation in paddy soils

Soil Microbiology Department

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Varietal differences in stimulating positive nitrogen balance. The presence of a rice plant stimulates the development of a positive nitrogen balance in flooded soil. Six screening experiments measured differences in the ability of 100 rice varieties and wild rices to stimulate a positive nitrogen balance. Three consecutive rice crops were grown in flooded Maligaya soil (0.08% N) in pots. Before transplanting, 15 g straw was added and the soil surface was exposed to light. In the first experiment, there was a significant positive nitrogen balance in all treatments, including fallow (Table 1). In addition, varieties differed significantly in ability to promote a positive nitrogen balance. The distribution of 17 variables was not different from normal. Further data are needed to correlate this ability with specific plant characteristics.

N_2 fixation stimulated by the addition of straw. Straw has been shown to be an energy source for heterotrophic N_2-fixing microorganisms. Three crops of IR28 were grown in pots in the greenhouse. In treatment 1 the straw was removed after each crop. In treatment 2, the straw was incorporated before transplanting a succeeding crop. The two treatments differed significantly in positive nitrogen balance — 312 mg N/pot without straw and 485 mg N/pot with straw. Nitrogen gain corresponded to approximately 5.5 mg N/g straw incorporated.

Straw (N < 0.6%) incorporation did not enhance nitrogen balance of flooded rice soil. In this experiment, the pot surface was either exposed to light or shaded by black cloth. The differences in nitrogen gain between the shaded and open pots were not significant. In shaded pots, nitrogen gain was 119 mg N/pot with straw and 107 mg N/pot without. In open pots, nitrogen gain was 300 mg N/pot with straw and 337 mg N/pot without.

In the experiment that demonstrated the stimulating effect of straw on nitrogen gain, 3 crops of rice absorbed 470-590 mg N/pot. In the experiment that did not show such effect, 3 crops of rice absorbed 716-808 mg N/pot. The differences in nitrogen removal by the crop reflected the availability of soil nitrogen. It is likely that the less stimulating effect of straw on nitrogen gain in the second experiment was related to higher nitrogen availability in the soil.

Table 1. Positive nitrogen balance in flooded soil as affected by *Oryza sativa* cultivars.

Cultivar	Crop duration (av)	Positive N balance[a] (mg N/pot)
Peta	142	538 a
Mashuri	142	485 a
Dular	124	448 ab
O. nivara	99	418 abc
Khao Lo	95	406 abcd
Toyonishiki	95	349 bcd
IR42	115	343 bcde
Blue Bonnet	112	340 bcdef
IR26	114	334 bcdef
TN1	114	296 cdefg
IR20	97	276 defg
Latisail	97	256 efg
OS4	101	247 efg
Palawan	115	211 efg
O. glaberrima	84	205 fg
Fallow	–	191 g
Pokkali	95	188 g

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

Photosynthetic bacteria and nitrogen balance. Photosynthetic bacteria capable of nitrogen fixation frequently are found in flooded rice soils. But little is known about the amount of nitrogen fixed by photosynthetic bacteria. It has been demonstrated that the soil surface is enriched with nitrogen during flooding and that this nitrogen enrichment is dependent on light.

Wratten light filters were used to modify the quality of light on the surface of flooded soil (Hudson silty clay loam, pH 6.5) in pots. A type O filter permitted the passage of the wavelengths of 400-900 nm required for the growth of blue-green algae (BGA) and photosynthetic bacteria. A type 88A filter permitted little light between 400 and 700 nm, precluding photosynthesis by BGA but not by photosynthetic bacteria. A black cloth restricted growth of all BGA and photosynthetic bacteria.

Pots covered by the type O filter accumulated nitrogen in the soil surface (total soil nitrogen increment 0.022%). Type 88A filter and black cloth excluded any nitrogen accumulation in the soil surface. It seems that photosynthetic bacteria make a negligible contribution to the accumulation of nitrogen in the surface of flooded soil.

Nitrogen in rain. Rain water was collected automatically at IRRI for 4 years and its NH_4-N and

NO_3-N contents were analyzed. From 1.0 to 2.0 kg N/ha was obtained from 1,170 to 2,300 mm annual precipitation.

Nitrogen balance and ^{15}N content in rice plants. Using nitrogen balance to demonstrate differences in N_2 fixation is tedious and time consuming. The ^{15}N-dilution technique would be a speedy, approximate approach to finding systems higher in N_2 fixation. The principle of the ^{15}N dilution technique is the comparison of ^{15}N content in a given system with that in a non-N_2 fixation system.

Maahas soil (N = 0.19%) in a 15-liter pot was supplemented with 0.25% sucrose and 0.01% ^{15}N-labeled nitrogen (31.06 atom % excess) as ammonium sulfate on a dry basis. The procedure is to label the available soil nitrogen pool with ^{15}N. Soil was incubated for 10 days at field moisture capacity, followed by 1-week air drying. Pots for wetland growth were flooded and puddled, allowed to stand another week before treatments were added, and transplanted with IR42 seedlings. Two plantings were made, 6 weeks apart.

Treatments were: dryland-unplanted; dryland-planted; wetland-unplanted; wetland-planted; wetland-planted and covered with black cloth; wetland-planted and inoculated twice a crop with azolla and phosphorus; wetland-planted and inoculated with phosphorus, lime, and algae (*Gloeotrichia*); wetland-planted, inoculated with phosphorus and lime, and covered with black cloth.

Positive nitrogen balances in the wetland-planted treatments were statistically significant, but nitrogen gain was not statistically significant in dryland-planted pots (Table 2). This confirms that wetland rice stimulates nitrogen gain more than does dryland rice.

Amount of nitrogen derived from N_2 fixation in the rice plant can be estimated by:

$$\text{N fixed} = \text{total N} \times \left(1 - \frac{\text{atom \% excess (fixing system)}}{\text{atom \% excess (nonfixing system)}}\right)$$

In one assumption, dryland rice is taken as a nonfixing system. The amount of nitrogen fixed is shown in column A in Table 2. The estimate of nitrogen fixation by a plant seems higher than the actual value because the estimated amount of nitrogen fixed exceeds the total positive balance in the plant and flooded soil.

In another assumption, wetland rice covered with black cloth to eliminate photodependent N_2 fixation is taken as a nonfixing system. The amount of nitrogen fixed is shown in column B in Table 2. These figures are likely to be closer to reality.

In wetland conditions, the higher a positive balance, the lower the ^{15}N content in a rice plant. Using ^{15}N dilution as an approximate clue to N_2 fixation in the system seems promising.

ASSOCIATIVE NITROGEN FIXATION

N_2-fixing bacteria growing on hydrogen in wetland rice roots. The ability of major groups of aerobic bacteria isolated from wetland rice root to use

Table 2. Total nitrogen balance, atom %, ^{15}N excess, and estimated N_2 fixation on 2 crops of rice.[a]

Condition		Amendment	Total N balance (mg N/pot)	Atom % excess in plant	N_2 fixation estimate[b] (mg N/pot)	
					A	B
Dryland	Fallow	None	67 b			
	Planted	None	170 b	7.14	–	
Wetland	Fallow	None	-710 c			
	Planted	None	860 a	3.90	800 b	182 bc
	Planted	Covered	-38 b	4.35	640 c	–
	Planted	Azolla + P	890 a	3.62	910 a	310 a
	Planted	Alga + P + Ca	990 a	3.80	900 ab	240 ab
	Planted	Covered P + Ca	110 b	4.08	750 bc	110 c

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]A = nonfixing system in dryland rice, B = nonfixing system in covered wetland rice.

hydrogen for growth and nitrogen fixation was examined. *Pseudomonas* H8, H3, KLH76, and *Azospirillum lipoferum* 34H isolated from wetland rice were found to have oxygen-dependent hydrogenase activity, the capability to grow under $CO_2 + H_2 + O_2$ with minimum amounts of organic substrates (yeast extract 0.05 g/liter), and hydrogen-dependent acetylene-reduction activity.

Bacteria were isolated from tryptic soy (0.1%) agar inoculated with dilutions of oxidized-surface paddy soil, reduced soil, rhizosphere soil, washed root of wetland rice, upland soil and washed root of dryland rice. Bacteria were tested for acetylene-reduction activity after 3 days' growth on glucose-yeast extract semisolid agar and for growth under $H_2 + O_2 + CO_2$ (20, 2, 5%) on mineral yeast extract agar. Growth on $H_2 + CO_2$ was checked against the plate under $CO_2 + O_2$ atmosphere and against a positive strain (*Pseudomonas facilis*) and a negative strain (*Ps. cepacia*).

Bacteria that grew better under $H_2 + CO_2 + O_2$ than under $CO_2 + O_2$ were recorded as being capable of autotrophic growth (Table 3). N_2-fixing bacteria capable of autotrophic growth on $H_2 + CO_2$ predominate bacteria isolated from wetland rice roots and their rhizosphere. The predominance of facultatively (conditionally) autotrophic nitrogen-fixing bacteria associated with wetland rice roots suggests that hydrogen, which is evolved from paddy soils, has a role in establishing nitrogen-fixing bacteria in or on the wetland rice root and in nitrogen fixation associated with wetland rice.

Table 3. Presence of nitrogen-fixing bacteria capable of autotrophic growth on hydrogen.

Condition	Bacteria (no./g dry sample)	Nitrogen-fixing bacteria[a] (%)	
		Capable of autotrophic growth	Incapable of autotrophic growth
Wetland rice			
Oxidized soil	9.2×10^7	0	0
Reduced soil	2.7×10^7	9.8	2.0
Rhizosphere soil	0.9×10^9	53	3
Rice root	1.0×10^9	71	10
Basal shoot	1.0×10^9	20	32
Dryland rice			
Soil	5.0×10^6	6.5	40[b]
Rice root	1.1×10^9	1.4	5.6

[a]Nitrogen-fixing bacteria to number of bacteria tested. [b]Acetylene-reduction activity of the isolates was more than 10 times lower than that from wetland rice roots.

Serological grouping of aerobic N_2-fixing bacteria isolated from wetland rice. *Pseudomonas* and *Azospirillum* are major groups of aerobic nitrogen-fixing bacteria isolated from wetland rice root. To identify these bacteria among isolates and in roots and soil, immunological identification techniques — fluorescent antibody and immunodiffusion — were developed.

Antibodies were prepared from untreated or heat-killed cells, or both, of *Azospirillum* isolated from wetland rice. Fluorescent antibody (FA) reaction and immunogel diffusion reaction of the prepared antibodies were tested against a type culture collection of *Azospirillum lipoferum, Az. brasilense,* and other isolates. Antibody antigen reactions were species specific and the species classification of the isolates by serological method coincided well with physiological characteristics. Both *Az. brasilense* and *Az. lipoferum* were identified among isolates from wetland rice roots and shoots. Major nitrogen-fixing bacteria isolated from wetland rice roots resemble *Pseudomonas* in many of their physiological and morphological characteristics. Antisera prepared from wetland rice root isolates and suspected to be *Pseudomonas* sp. showed one or two bands with cells of *Pseudomonas facilis* in immunogel diffusion reaction, but not with cells of *Azospirillum, Klebsiella,* and *Derxia.* Antisera from *Ps. facilis* showed one band with cells of those isolates, indicating a similarity to *Pseudomonas.*

N_2-fixing activity and population of bacteria in acid soil. The population of aerobic N_2-fixing bacteria and acetylene-reduction activity (ARA) associated with roots of IR26 were surveyed in an acid soil-Luisiana silty clay soil (pH 4.8, available P_2O_5 8.0 ppm, organic matter 2.6%). Field ARA for 24 hours ranged from 3 to 5 μmol C_2H_4/hill during 1 crop of rice.

Five-hour ARA measured by water culture method was less than 1 μmol/hill. These values are 3-5 times lower than those in Maahas soil at IRRI. The populations of aerobic N_2-fixing bacteria using glucose ranged from 4×10^5 to 8×10^7/g dry root and the populations using malate ranged from 4×10^5 to 1×10^7. These values also were lower than those in Maahas soil.

Percentages of N_2-fixing bacteria among the colonies developed on tryptic soy agar were about

20-10, also lower than in Maahas soil. This demonstrates that this acid soil would be suitable for inoculation experiments with associative N_2-fixing bacteria.

AUTOTROPHIC NITROGEN FIXATION

Blue-green algae nitrogen in paddy soils. Uptake by rice of ^{15}N from a labeled BGA (*Nostoc* sp.) was studied in pot and field experiments. Availability of nitrogen from dried BGA incorporated into the soil was 23-28% for the first crop and 27-36% for 2 continuous crops (Table 4). When BGA were surface applied, nitrogen availability was higher in the field than in pots, where nitrogen availability from fresh BGA was similar to that from dried BGA. When BGA were incorporated, much more nitrogen was available from fresh BGA.

^{15}N balance in plant and soil after two crops (pot experiment, dried BGA) showed that losses from ^{15}N ammonium sulfate were more than twice those from BGA, regardless of mode of application.

Losses from BGA nitrogen occurred mainly during the first crop; losses from ammonium sulfate continued during the second. Availability of algal nitrogen to the current and following crop was almost equal to the availability of ammonium sulfate to the current crop. Because of its slow-release nature, BGA are less susceptible to nitrogen losses than are inorganic fertilizers. However, the low C-N ratio (5-6) of algal material gives a better nitrogen availability than do the C-N ratios of organic fertilizers such as farmyard manure.

N_2 fixation by epiphytic blue-green algae on deepwater rice. To demonstrate N_2 fixation and the availability of the fixed nitrogen to aerial plant parts, $^{15}N_2$ gas was fed to the aquatic parts of deepwater rice. After 9 days' exposure at heading stage, a deepwater rice plant had fixed about 8 mg N, of which about 40% was translocated to aerial parts (leaves and grains) up to maturity. The nodal roots and leaf sheaths under water had high ^{15}N enrichment. They are regarded as active N_2-fixing sites by epiphytic BGA.

Effect of neem cake on blue-green algae and their N_2 fixation in soil. The oil extraction residue (cake) of neem (*Azadirachta indica*) seeds has insecticidal and insect antifeedant activities. Because synthetic insecticides stimulate BGA growth and N_2-fixing activities, the effect of neem cake on BGA was examined in greenhouse and field experiments.

In the greenhouse, the addition of neem cake to small beakers at 6-12 g/m^2 maintained the population of BGA and photodependent N_2 fixation (acetylene reduction) much longer than control. Without neem cake, the initial buildup of BGA quickly disintegrated, probably because of the grazing action by soil fauna (Table 5). Neem cake also mitigated the depressing effect of inorganic nitrogen on BGA growth and N_2 fixation.

In the field experiment, the effect was not clear-cut because of disturbances by typhoon and greater variation of algal growth from one plot to another. Among 3 neem cake-treated plots, thick algal growth ($>$ 250 g fresh weight/m^2) appeared on 2 plots 9 weeks after transplanting. Two of 3 control plots recorded algal biomass of less than 10 g/m^2.

Enhancing blue-green algae biomass and N_2 fixation by regulating grazers. The effect of invertebrate grazing was examined by controlling the population of mollusks and ostracods with selective pesticides.

In a 1-m^2 subplot surrounded by a metal frame

Table 4. Recovery of ^{15}N in soil and plants after 2 crops of rice.

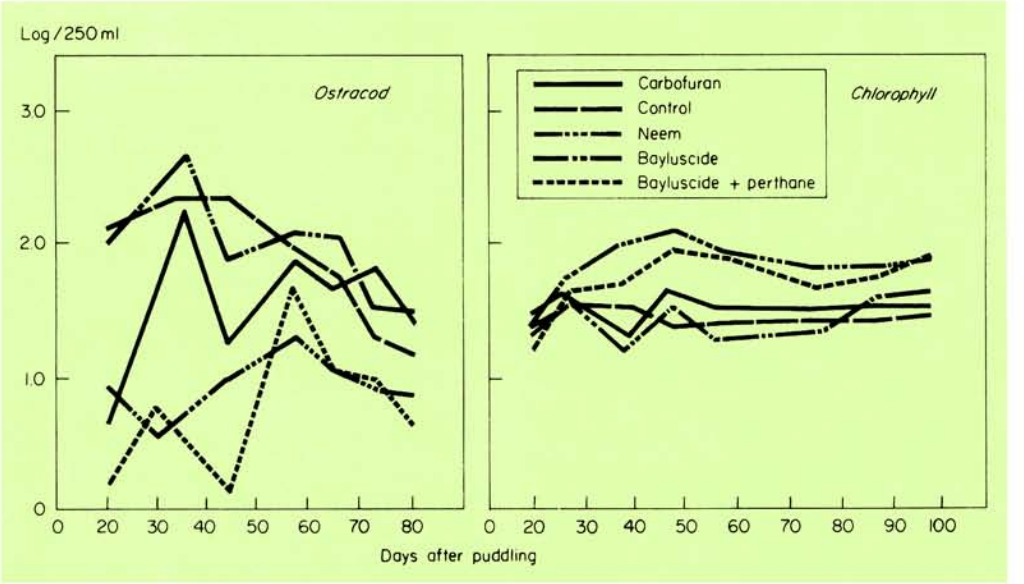
Experiment	^{15}N recovered (%)							
	BGA incorporated				Surface applied			
	1st crop	2nd crop	Soil	Unaccounted	1st crop	2nd crop	Soil	Unaccounted
Fresh, pot	38	5	53	4	13	8	73	6
Dried algae, pot	28	8.5	58	55	14	7	57	22
Dried algae, field	23.5	3.5	33[a]	40	23	4	32	41

[a] In the 0- to 15-cm layer of the soil. Because of climatic disturbances (typhoon), a downward movement of the algal material led to an overestimation of the loss.

Table 5. Effect of neem cake on photodependent N_2 fixation in beakers of soil from IRRI field, block 900, from 10 to 45 days after application.

Treatment[a]	Log[b] (μmol C_2H_4/h per m^2)				
	10 days	17 days	24 days	34 days	45 days
Control	0.74 b	2.52 b	2.73 b	1.54 c	0.93 b
57 kg NC/ha	1.69 a	2.96 a	3.04 a	3.10 a	2.59 a
60 kg N	0.35 bc	0.87 c	2.19 c	2.70 b	2.63 a
N + NC	0.70 b	2.57 b	2.94 ab	2.70 b	2.47 a
N + 114 kg NC	0.15 c	2.29 b	2.41 c	2.81 b	2.79 a

[a]NC = neem cake. N = ammonium sulfate. [b]Separation of means by Duncan's multiple range test at the 5% level.



1. Ostracod population and chlorophyll content as affected by pesticides. IRRI, 1981.

in paddy field, 4 pesticides — carbofuran (3 kg a.i./ha), Bayluscide (1 kg a.i./ha), Perthane (2.2 kg a.i./ha), and crushed nut of neem tree (100 kg/ha) — were applied 10, 24, 44, and 60 days after puddling and flooding. Perthane was combined with Bayluscide. Populations of ostracods, mollusks, chlorophyll contents, and photodependent ARA were monitored during a crop cycle.

Bayluscide controlled populations of mollusks; perthane, populations of ostracods. Neem nuts also controlled ostracods. Depressing the mollusk populations did not enhance algal biomass and photodependent ARA because the mollusks were replaced by ostracods. When populations of ostracods were reduced by perthane + Bayluscide and neem nut treatments, algal biomass and N_2 fixation were enhanced from 30 to 60 days after puddling and flooding (Fig. 1).

Soil and crop management

Management of organic manures

Soil Chemistry and Soil Microbiology Departments

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DECOMPOSITION OF ORGANIC MATTER IN ANAEROBIC SOILS

Soil Chemistry Department

The decomposition of native and applied organic matter was studied in the laboratory and in the field.

Incubation studies. Decomposition products of 3 kinds of organic matter (rice straw, green manure, and compost) in 3 soils (pH 4.7, 6.6, and 7.5) incubated anaerobically at 20° and 35° C were identified and their kinetic patterns established. Substances formed within 2 weeks of incubation were:

Gases	Alcohols	Volatile acids	Phenolic acids
Carbon dioxide	methanol	acetic	ferulic
Methane	ethanol	propionic	p-coumaric
Ethylene	n-propanol	butyric	sinapic
Nitrogen	n-butanol	isovaleric	vanillic
Hydrogen sulfide			p-hydroxy benzoic

Kinetics and peak concentrations of these products varied with soil, kind of organic matter, and temperature. The addition of straw and green manure (especially) increased the production of alcohols and volatile acids. Straw favored the formation of phenolic acids. Low temperature and soil acidity favored the production of phenolic acids.

The highest concentrations of major decomposition products were:

Gases	*Concn (mmol/kg)*
Carbon dioxide	47
Methane	50
Nitrogen	40
Nongases	*Concn (mmol/kg)*
Methanol	0.27
Ethanol	0.12
Acetic acid	4.00
Butyric acid	0.13
Isovaleric acid	0.32
Propionic acid	0.18
Ferulic acid	0.074
p-coumaric acid	0.049
Sinapic acid	0.042

Field studies. Rice straw labeled with ^{14}C was incorporated with puddled soil inside 20-cm-diameter plastic tubes placed in an IRRI farm field. The soil solution was extracted and its activity measured by scintillation counting. Figure 1 shows the changes of activity in solutions at four depths. For carbon dioxide and methane analysis, solutions were degassed in the apparatus shown in Figure 2. Changes in specific activities with time are shown in Figure 3. Carbon dioxide reached a plateau in the second week, methane in the fourth. The carbon dioxide was produced almost exclusively from the incorporated straw, but about 90% of the methane came from soil organic matter.

STRAW AS A SOURCE OF NUTRIENTS

Soil Chemistry Department

Straw incorporation increased the content of organic matter, nitrogen, and potassium, but depressed that of zinc (Table 1).

On a neutral soil at IRRI that had received no nitrogen fertilizer, straw incorporation for 7 seasons yielded in the 18th season 2.9 t/ha, compared with 2.2 t/ha for straw removal. On an unfertilized acid soil in a farmer's field, the corresponding yields in the 4th season were 2.1 t/ha for straw incorporation and 1.7 t/ha for straw removal. Although all plots appeared to be nitrogen deficient, straw-treated plots were greener than untreated plots.

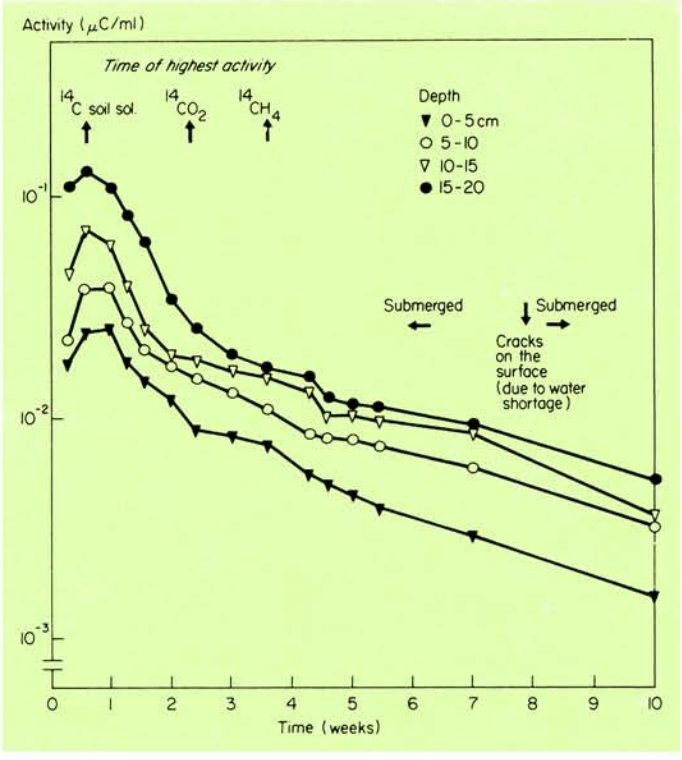
The benefits of straw incorporation on rice yield were confirmed in a drum study of three soils of widely differing properties (Table 2).

AZOLLA-ANABAENA SYMBIOSIS

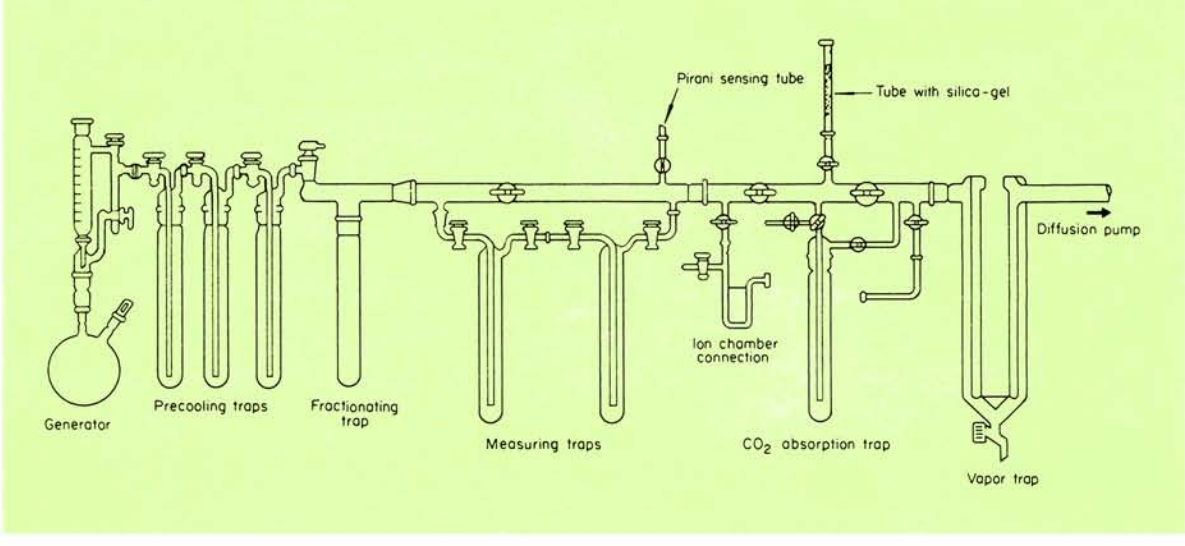
Soil Microbiology Department

Dual culture of rice and azolla by wide-row spacing. Rice crops 6 and 7 were grown in 1981. For crop 6, a mixture of *A. pinnata* and *A. caroliniana* was used for one crop of azolla before transplanting. The results are summarized in Table 3.

Azolla growth was poor in December 1980 and June-August 1981. Fresh-weight yield was less than 800 g/m^2. Rice growth at the early stages was better in a chemical nitrogen-fertilized plot than in azolla plots, but after panicle initiation, rice growth



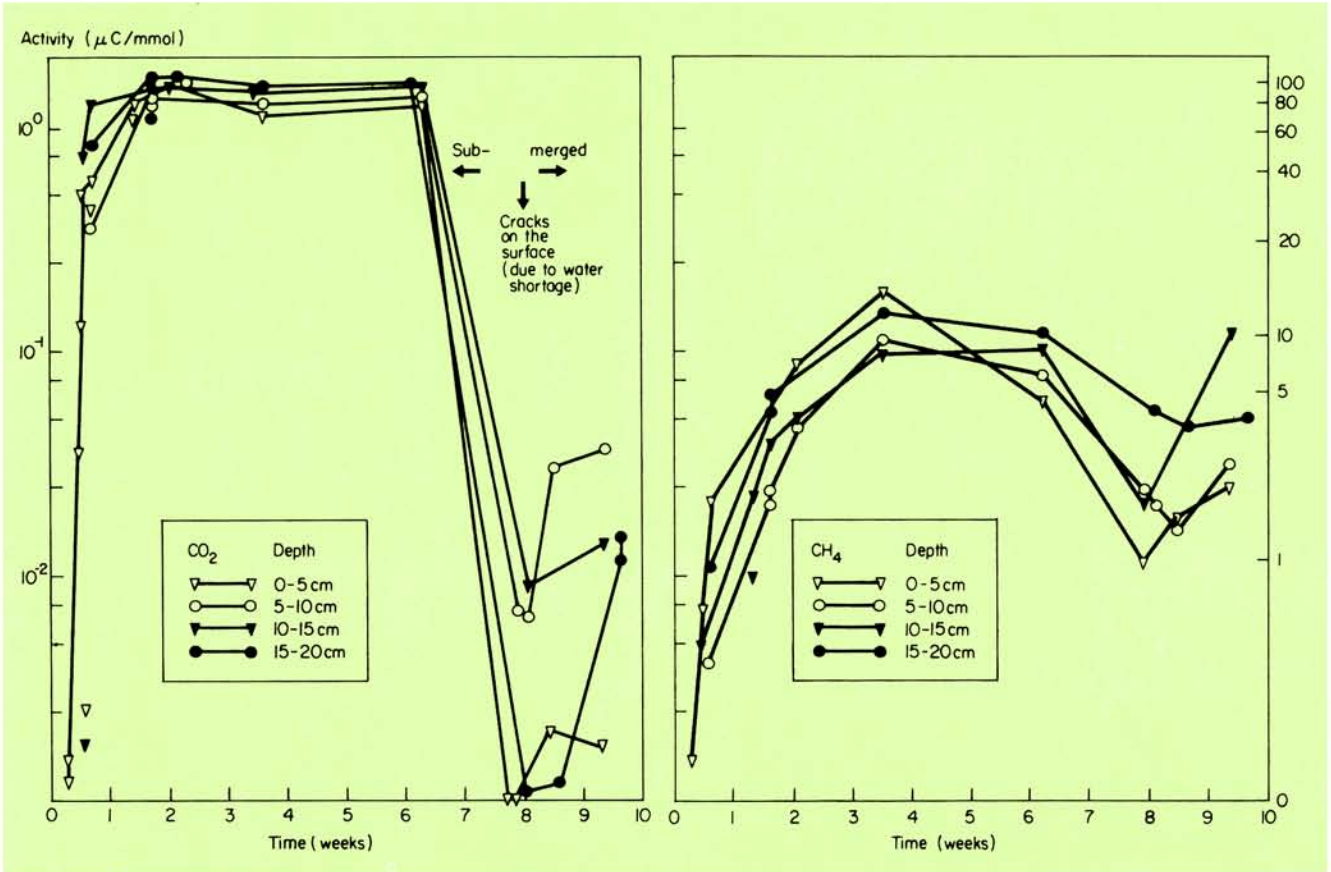
1. Activity of soil solution after ^{14}C-labelled rice straw was incorporated into Maahas clay. IRRI, 1981.



2. High vacuum line for gas-phase counting of $^{14}CO_2$ and $^{14}CH_4$. IRRI, 1981.

in azolla plots was comparable to or better than that in chemical-nitrogen plots.

Temperature response of azolla strains and species. *A. pinnata* strains were obtained from the Philippines (24, 36), China (31, 32, 33), Japan (27, 28), Indonesia (40, 41, 42), Australia (39), and Africa (25, 26, 35); an *A. filiculoides* strain (105) from Germany, and *A. caroliniana* (302), *A. mexi-*



3. Specific activity of CO_2 and CH_4 in soil solution of Maahas clay after incorporation of ^{14}C-labeled rice straw. IRRI, 1981.

Table 1. Comparison of effects of 7 years' straw incorporation and straw removal on nutrient content, average for 3 soils. IRRI, 1981.

Straw	Organic carbon (%)	Total nitrogen (%)	Olsen phosphorus (mg/kg)	Exchangeable potassium (meq/100 g)	Available zinc (mg/kg)
Removed	1.27	0.145	7.7	0.28	5.1
Plowed in	1.53	0.175	8.4	0.76	2.2
Difference	0.26**	0.030**	0.7	0.48**	-2.9**

Table 2. Effect of straw incorporation on rice yield and nitrogen uptake (11th season, average for 3 soils). IRRI, 1981.

Straw	Yield (g/drum)		Nitrogen uptake (g/drum)
	Straw	Grain	
Removed	68	77	1.194
Incorporated	89	112	1.583
Difference	21**	35**	0.389**

Table 3. Rice yields in azolla-rice culture.

Trial sequence	Cropping duration (from transplanting to harvest)	Chemical nitrogen applied (split ratio)	Amt of azolla incorporation and its nitrogen content	Grain yield (t/ha)		
				No nitrogen	Chemical-nitrogen	Azolla
6th (dry season)	Dec 1980-Apr 1981 IR42	100[a] (2:1:1)	5 crops 121 kg N/ha	3.8	6.3	6.6
7th (wet season)	Jun 1981-Oct 1981 IR42	60[a] (1:1:1)	5 crops 70 kg N/ha	5.4	7.5	6.5

[a] Applied at 0, 14, and 50 days after transplanting.

cana (202, 204), and *Euazolla* species (species is not identified, 401-420) from Latin America. The growth at average temperatures (8° difference between day and night) of 33°, 29°, and 22° C was examined for strains 24, 28, 32, 35, 36, and 39. Growth at 33° C of African strains of *A. pinnata* (*A. Africana*) was poorer than that of Asian strains. At 22° C, A. sp. 417 from Paraguay produced a maximum biomass comparable to that of *A. filiculoides* by multilayer growth. At 33° C, *A. filiculoides* grew very poorly but A. sp. 417 yielded a biomass comparable to that of *A. pinnata*. The Paraguay strain appears to have a wider temperature adaptability.

Identification of blue-green algae in azolla cavities by fluorescent antibody. An immunochemical approach was undertaken to discover if symbiont blue-green algae are common among various species of azolla. Antisera were prepared from two *Anabaena* strains reportedly isolated from azolla in China and in USA. Fluorescent pigment conjugated antibodies did not react with *Anabaena* cells in the cavity of azolla. The antibody from *Anabaena* physically isolated from azolla is now being prepared.

Soil and crop management

Management of other nutrients

Agronomy Department

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IRRI. The 35th (dry-season) and 36th (wet-season) consecutive crops were completed at IRRI in 1981. IR36 and IR42 responded favorably to complete fertilizers with inorganic sources alone or in combination with 10 t compost/ha. In the dry season, the plots treated with nitrogen alone gave a highly significant response compared with the control plots or the treatments with P_2O_5 alone or K_2O alone. IR36 showed significant response to 30 kg P_2O_5/ha; IR42 did not. Neither variety responded to K_2O. Because of its disease susceptibility, IR8 gave very low yields.

In the wet season, trends in yield response were similar, except that IR36 did not respond to P_2O_5 (Table 1).

Philippine Bureau of Plant Industry stations. *Maligaya.* During the dry season, all three varieties responded to complete fertilizer NPK treatment (Fig. 1). Mean yields showed that further application of 30 kg K_2O/ha provided no added advantage. Response to 140 kg N/ha alone was minimal; response to 60 kg P_2O_5/ha applied in combination with 140 kg N/ha was highly significant.

In the wet season, differences between control, the treatment with nitrogen alone, and the treatment with nitrogen and K_2O were not significant. Yields with nitrogen and P_2O_5 almost equalled yields with NPK, and with NPK and additional 30 kg K_2O/ha.

Bicol. In the dry season, response to NPK fertilization varied with variety. IR36 and IR42 showed favorable response to NPK and to NPK plus 30 kg K_2O/ha; IR8 did not. IR36 responded better to nitrogen and P_2O_5 than to nitrogen alone or to nitrogen and K_2O. Yields of IR42 were significantly higher with nitrogen and K_2O than with nitrogen and nitrogen and P_2O_5.

In the wet season, the response to nitrogen only and to nitrogen and K_2O was minimal. The response of the three varieties to nitrogen and P_2O_5 was dramatic and comparable to their response to NPK and to NPK plus 30 kg K_2O (Fig. 2).

Iloilo. Plots fertilized with nitrogen and K_2O gave no significant yield increases over nonfertilized plots. Response to the addition of phosphorus and nitrogen was dramatic. All three varieties had similar yield response trends although they varied in magnitude. Yields from treatments with nitrogen and phosphorus did not significantly differ from yields from treatments with NPK and NPK

Table 1. Effects of nitrogen-phosphorus-potassium fertilizers on yields of IR8, IR36, and IR42 in the 35th (dry-season) and 36th (wet-season) consecutive crops. IRRI, 1981.

Fertilizer (kg/ha)			Yield[a] (t/ha)		
N	P_2O_5	K_2O	IR8	IR36	IR42
			Dry season		
0	0	0	1.2 kl	1.9 hijk	3.9 ef
140[b]	0	0	2.1 hij	4.8 d	5.9 bc
0	30	0	1.1 l	2.8 efg	3.2 e
0	0	30	1.2 kl	2.0 hij	2.5 fgh
140[b]	30	0	2.2 ghi	5.9 c	6.4 abc
140[b]	0	30	2.1 ghij	4.8 d	5.8 c
140[b]	30	30	1.9 hijk	5.8 c	6.6 ab
140[bc]	30	30	1.5 ijkl	6.1 bc	7.0 a
			Wet season		
0	0	0	1.1 h	2.8 g	3.7 f
60[b]	0	0	1.5 h	4.0 def	5.2 ab
0	30	0	1.4 h	2.8 g	4.0 def
0	0	30	1.4 h	2.9 g	3.8 ef
60[b]	30	0	1.2 h	4.5 cd	5.1 ab
60[b]	0	30	1.7 h	4.5 cd	5.4 a
60[b]	30	30	1.5 h	4.8 bc	5.5 a
60[bc]	30	30	1.4 h	4.4 cde	5.5 a

[a] Separation of means in a column for each season by Duncan's multiple range test at the 5% level. [b] Includes 40 kg N/ha topdressed 5-7 days before panicle initiation (DBPI) during the dry season and 20 kg N/ha topdressed 5-7 DBPI during the wet. [c] 10 t compost/ha applied every cropping season, with the balance applied as inorganic nitrogen to make up for the rate stipulated for that season.

plus 30 kg K_2O/ha.

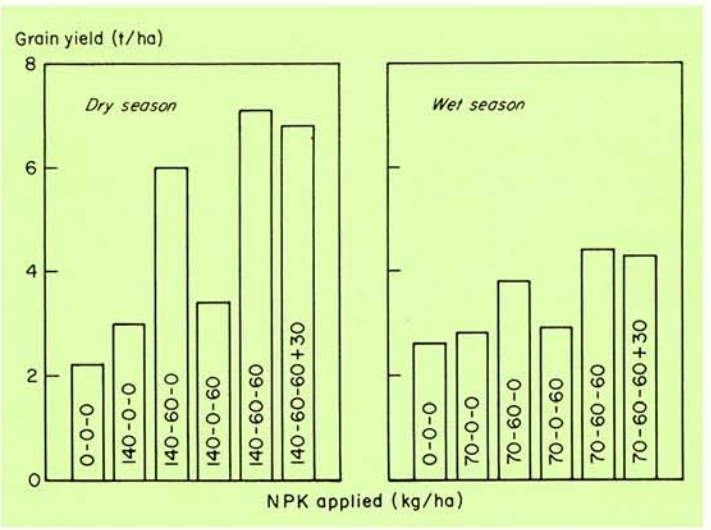
A similar pattern is discernible in the wet-season data. However, the response to nitrogen fertilizers was minimal. Potassium with nitrogen was no better than nitrogen alone (Fig. 3).

After 14 wet-season and 10 dry-season crops in the long-term fertility experiment at the Visayas Experiment Station, it appears that combinations of nitrogen and phosphorus should be applied if high yields are to be sustained (Table 2).

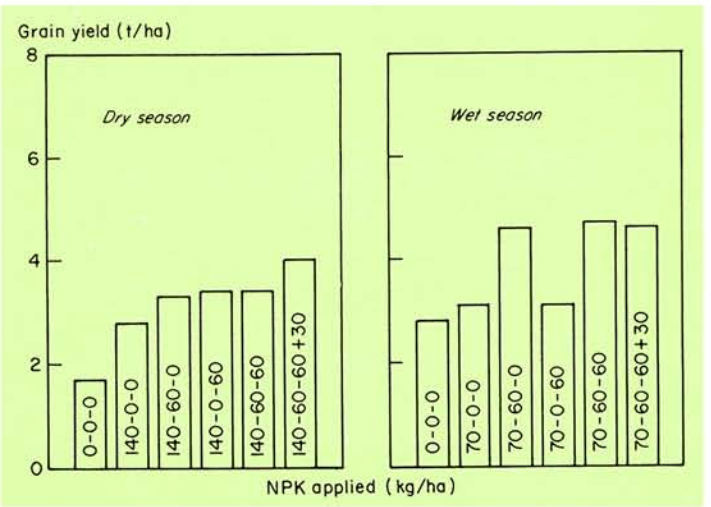
Farmers' fields. The 10th and 11th consecutive crops in Luisiana, Laguna, and the 9th crop in Tanay, Rizal, were continued in 1981. The 1981 dry-season crop was not planted in Tanay because dam construction by the Philippine National Irrigation Administration had not been completed.

Luisiana soil (pH 5.1). Variety and fertilizer treatments interacted significantly in both seasons (Table 3). Response to nitrogen, phosphorus, and potassium, applied singly or in combination, was, in most cases, higher in the dry season but observed mostly in the wet season.

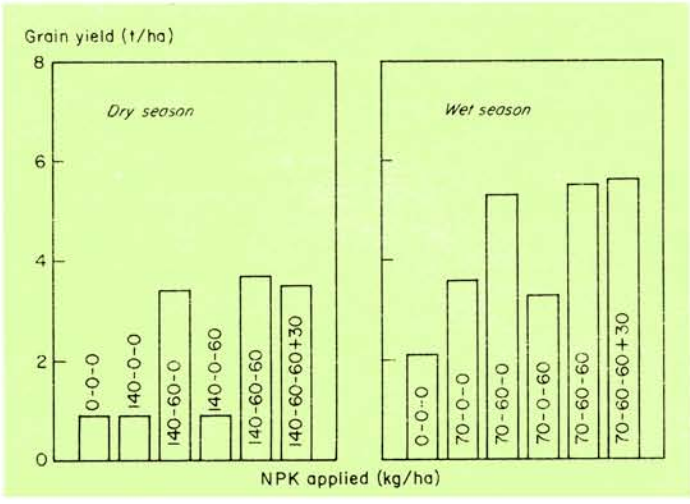
Nitrogen response after 11 consecutive crops was consistent with both varieties in both seasons.



1. Effect of nitrogen-phosphorus-potassium (NPK) fertilizers on mean yield of 3 varieties in the 27th (dry-season) and 28th (wet-season) successive crops on Maligaya silty clay loam soil. Long-term fertility trials, Maligaya Rice Research and Training Center, Nueva Ecija, Philippines, 1981.



2. Effect of nitrogen-phosphorus-potassium (NPK) fertilizers on mean yield of 3 varieties in the 27th (dry-season) and 28th (wet-season) successive crops on Pili clay soil. Long-term fertility trial, Bicol Experiment Station, Camarines Sur, Philippines, 1981.



3. Effect of nitrogen-phosphorus-potassium (NPK) fertilizers on mean yield of 3 varieties in the 10th (dry-season) and 14th (wet-season) crops in Santa Rita clay soil. Long-term fertility trial, Visayas Experiment Station, Iloilo, Philippines, 1981.

The highest significant responses to nitrogen were 3.6 t/ha in the dry season and 1.6 t/ha in the wet. This marked variation in seasonal response suggests that the rate of 60 kg N/ha in the wet season may not be enough to obtain high grain yields.

The highest response to phosphorus was 1.9 t/ha and to potassium 0.7 t/ha. The consistent response to phosphorus (NPK vs. NK) and the observed response to potassium may suggest the need to apply more phosphorus (soil-available P, 4.4 ppm Bray 2) and potassium (soil-exchangeable K, 0.12 meq/100 g) since the potassium status in the soil is low.

Tanay soil (pH 7.1). The interaction between variety and fertilizer treatment was significant (Table 4). A 1.1-t/ha response to phosphorus in IR36 (NPK vs. NK) indicated that this calcareous (exchangeable Ca, 34.8 meq/100 g) soil is low in available phosphorus (available P, 3.5 ppm Olsen).

Response to nitrogen (total N, 0.19%) was almost the same as in the Luisiana soil during wet-season planting. However, response to potassium (NPK vs. NP) was higher (0.9 t/ha) in Tanay soil (exchangeable K, 0.18 meq/100 g) than in Luisiana.

PHOSPHORUS SOURCES FIELD TRIALS

Residual plantings were continued to evaluate the residual effects of three sources of phosphorus fertilizers on two soils — Binangonan clay (Vertisols) in Teresa, Rizal, and Luisiana silty clay (Ultisols) in Lucban, Quezon. These plantings were begun in 1980 after applications of phosphorus fertilizers for five consecutive crops.

A new trial was started on a Buenavista silty clay loam (Alfisols) in the wet season in Bulacan to evaluate fresh applications of phosphorus fertilizers.

Yields varied with soils and among previous phosphorus treatments (Table 5). Response to residual phosphorus was observed on Binangonan clay in both seasons and on Luisiana silty clay in the dry season.

Dry season. Without previously applied phosphorus, yields were lower in Binangonan clay than in Luisiana silty clay. However, yield difference was highest between treated plants and control on Binangonan clay (3.1 t/ha).

In both soils, the response to residual phosphorus was usually higher with increased rates of phosphorus. Ordinary superphosphate (OSP) applied fresh at 60 kg P_2O_5/ha produced the highest yield response. At the highest rate of phosphorus, guano fertilizer was superior to phospal and comparable to phosmak and fresh OSP.

Wet season. Performance of phosphorus sources varied markedly on both soils. In Luisiana silty clay, response was highest (0.5 t/ha) with fresh OSP at 60 kg P_2O_5/ha. In Binangonan clay, guano at 120 kg P_2O_5/ha produced the highest response, 1.7 t/ha.

Table 2. Effects of nitrogen-phosphorus-potassium fertilizers on yields of IR8, IR36, and IR42 in the 27th (dry-season) and 28th (wet-season) consecutive crops at the Maligaya Rice Research and Training Center, Maligaya, Muñoz, Nueva Ecija, and the Bicol Experiment Station, Pili, Camarines Sur, and in the 10th (dry-season) and 14th (wet-season) crops at the Visayas Experiment Station, Hamungaya, Jaro, Iloilo City, 1981.

Fertilizer (kg/ha)			Yield[a] (t/ha)								
			Maligaya			Bicol			Visayas		
N	P_2O_5	K_2O	IR8	IR36	IR42	IR8	IR36	IR42	IR8	IR36	IR42
						Dry season					
0	0	0	1.8 e	2.7 de	2.2 de	1.7 ij	1.5 j	2.0 hij	0.5 c	1.0 c	1.3 c
140[b]	0	0	2.8 de	2.9 de	3.4 d	2.7 efgh	3.2 defg	2.5 ghi	0.8 c	0.9 c	1.1 c
140[b]	60	0	5.9 c	6.2 bc	5.8 c	2.6 fghi	4.1 bcd	3.2 defg	3.0 g	3.8 ab	3.4 b
140[b]	0	60	3.0 de	2.4 de	4.9 d	2.5 ghij	3.5 cdef	4.3 abc	0.8 c	1.0 c	0.8 c
140[b]	60	60	6.2 bc	7.8 a	7.2 ab	2.0 hij	4.7 ab	3.6 cde	3.7 ab	4.2 a	3.3 b
140[b]	60	60+30	6.4 bc	8.0 a	7.4 ab	2.2 ghij	5.1 a	4.8 ab	3.5 ab	3.7 ab	3.2 b
						Wet season					
0	0	0	2.7 d	2.7 d	2.5 d	2.5 f	2.6 f	3.3 def	1.8 g	2.4 efg	2.1 fg
70[b]	0	0	3.0 d	2.5 d	2.9 d	3.4 def	2.9 ef	4.0 cde	3.1 def	3.4 cde	4.2 bc
70[b]	60	0	4.1 ab	3.2 cd	3.9 oc	3.9 de	4.3 bcd	5.5 a	5.0 ab	5.5 a	5.3 a
70[b]	0	60	3.1 cd	2.9 d	2.6 d	2.4 f	3.0 ef	3.8 de	2.9 def	3.4 cde	3.5 cd
70[b]	60	60	4.2 ab	4.0 ab	4.8 a	3.2 def	5.7 a	5.2 ab	5.0 ab	5.9 a	5.5 a
70[b]	60	60+30	4.2 ab	4.0 ab	4.5 ab	3.3 def	5.0 abc	5.5 a	5.4 a	5.7 a	5.7 a

[a]Separation of means in a column for each season by Duncan's multiple range test at the 5% level. [b]Includes 40 kg N/ha topdressed 5-7 days before panicle initiation (DBPI) during the dry season and 20 kg N/ha topdressed 5-7 DBPI during the wet.

Table 3. Effects of nitrogen-phosphorus-potassium fertilizers on yields of IR36 and IR42 in the 10th (dry-season) and 11th (wet-season) consecutive crops on Luisiana silty clay, Luisiana, Laguna Province, Philippines, 1981.

Fertilizer treatment[a]	Yield[b] (t/ha)			
	Dry season		Wet season	
	IR36	IR42	IR36	IR42
Control	3.2 f	3.1 d	2.5 h	2.5 h
Nitrogen	4.7 cd	4.8 c	3.8 bc	2.9 f
Phosphorus	3.7 ef	3.5 d	2.7 fgh	3.0 ef
Potassium	3.8 ef	3.0 d	2.9 fg	2.5 gh
Nitrogen + phosphorus	6.3 b	6.4 b	4.2 ab	3.7 cd
Phosphorus + potassium	4.2 de	3.5 d	2.6 fgh	3.0 f
Nitrogen + potassium	5.1 c	5.4 c	3.7 cd	3.4 de
Nitrogen + phosphorus + potassium	7.0 a	7.1 a	4.2 ab	4.3 a

[a]For dry season, 120 kg N/ha; for wet, 60 kg N/ha; 40 kg/ha for phosphorus and potassium in both seasons. CV = 8.1%, both seasons. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 4. Effects of nitrogen-phosphorus-potassium fertilizers on yields of IR36 and IR42 in the 9th (wet-season) crop on Bay clay, Tanay, Rizal Province, Philippines, 1981.

Fertilizer treatment[a]	Yield[b] (t/ha)	
	IR36	IR42
Control	3.3 e	3.4 d
Nitrogen	4.6 b	4.7 a
Phosphorus	3.7 de	4.0 bc
Potassium	4.0 cd	3.8 cd
Nitrogen + phosphorus	4.5 b	4.8 a
Phosphorus + potassium	3.6 de	4.0 bc
Nitrogen + potassium	4.3 bc	4.5 ab
Nitrogen + phosphorus + potassium	5.4 a	4.8 a

[a]60 kg N/ha for phosphorus and 40 kg/ha for potassium. CV = 7.0%.
[b]Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 5. Effect of different phosphorus sources on yield of IR36 on Binangonan clay, Teresa, Rizal Province; Luisiana silty clay, Lucban, Quezon Province; and Buenavista silty clay loam, San Ildefonso, Bulacan Province, 1981.

Treatment (source and kg P_2O_5/ha)	Grain yield[a] (t/ha)				
	Binangonan clay[b]		Luisiana silty clay[b]		Buenavista silty clay loam[c]
	Dry season	Wet season	Dry season	Wet season	Wet season
No phosphorus (control)	3.1 f	3.5 d	3.4 e	3.6 b	5.6 a
Ordinary superphosphate					
20	3.6 ef	3.9 cd	4.5 d	3.7 ab	5.5 a
40	4.3 d	4.2 bc	5.4 bc	3.7 ab	5.5 a
60[d]	6.2 a	4.6 b	6.2 a	4.1 a	5.8 a
Rock phosphate[e]					
20	3.8 de	3.8 cd	4.4 d	3.4 b	5.5 a
40	4.0 de	4.2 bc	5.0 cd	3.7 ab	5.4 a
60	4.4 cd	3.8 cd	5.8 ab	3.8 ab	5.4 a
Guano					
40	5.0 bc	3.9 cd	4.9 cd	3.7 ab	5.6 a
80	5.1 b	4.3 bc	5.9 ab	3.7 ab	5.4 a
120	5.8 a	5.2 a	5.8 ab	3.8 ab	5.6 a

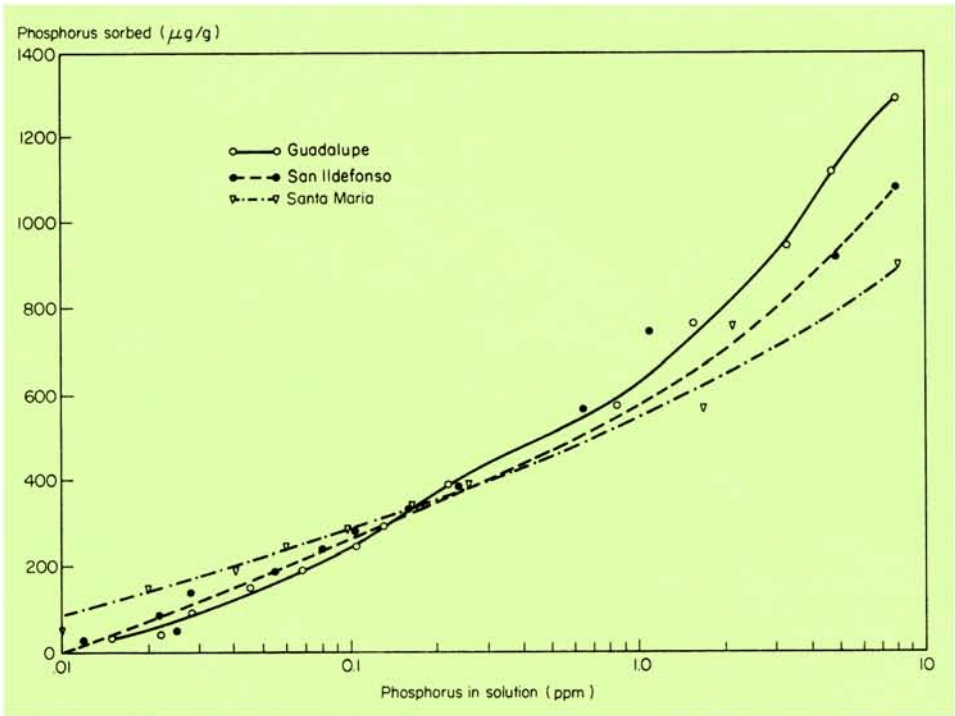
[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Residual plantings. [c]New trial. [d]Fresh applications. [e]Phospal for Binangonan clay and phosmak for Luisiana silty clay and Buenavista silty clay loam.

In Luisiana silty clay, all treatments, except that with fresh OSP, were comparable to the control. However, in Binangonan clay more treatments were significantly different from the control. Also, in Binangonan clay, guano at the highest phosphorus application rate produced significantly higher yields than all other treatments.

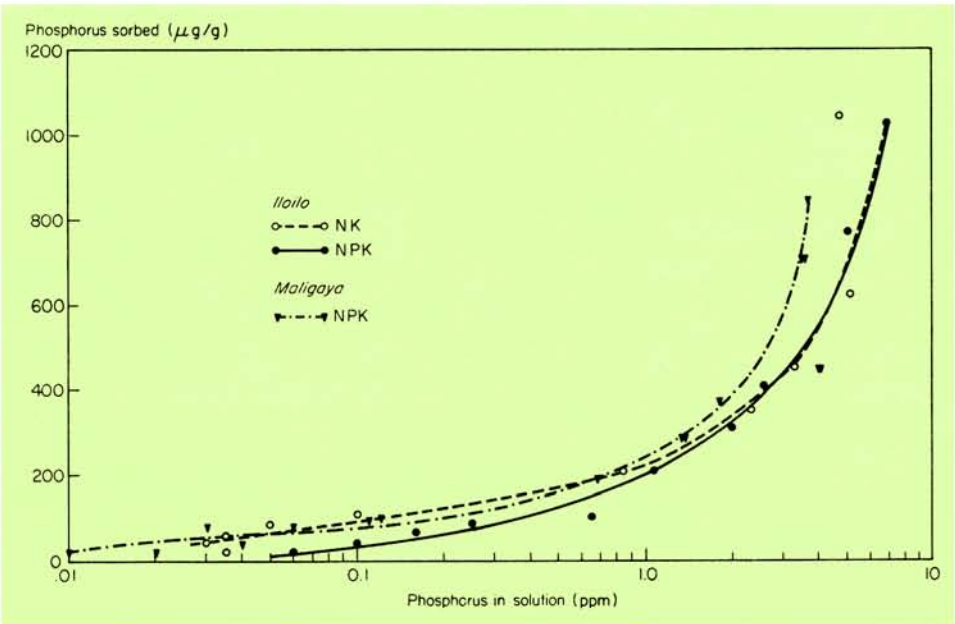
The trial on Buenavista silty clay loam showed no significant differences among phosphorus sources, although OSP gave the highest mean yield of 5.8 t/ha, apparently because the trial was the first and wet-season crop.

PHOSPHORUS SORPTION ISOTHERM OF SOME PHILIPPINE SOILS GROWN TO WETLAND RICE

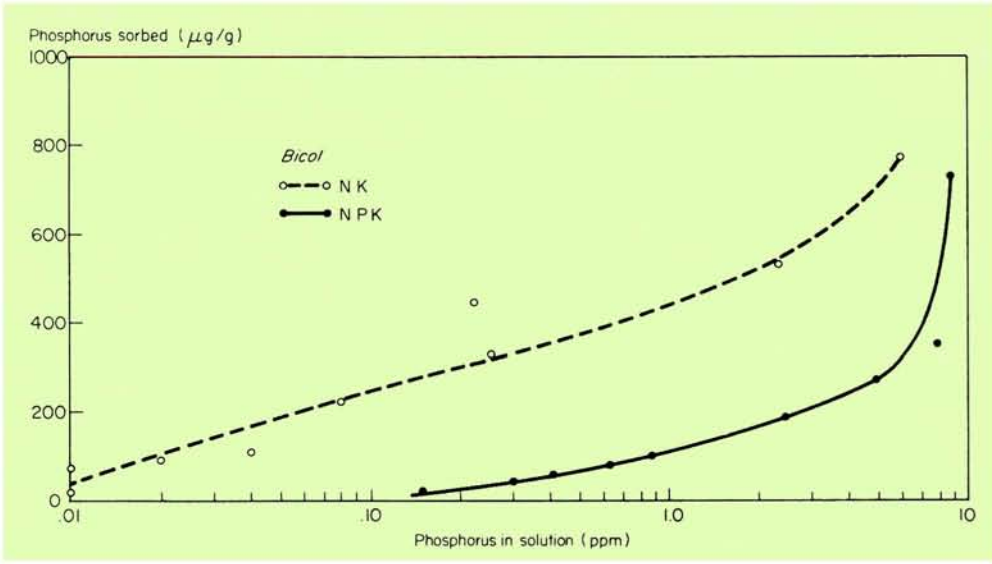
The phosphorus sorption isotherm of the soils used for the long-term fertility experiment in Bicol, Iloilo, and Maligaya and some soils reported to be phosphorus deficient were determined under re-



4. Phosphorus sorption by reduced soils from Santa Rosa, Laguna (Guadalupe clay); San Ildefonso, Bulacan (Buenavista clay); and Santa Maria, Bulacan (Prensa clay), Philippines, 1981.



5. Phosphorus sorption by reduced soils from Iloilo and Maligaya, Philippines, 1981.



6. Phosphorus sorption by reduced soil from Pili, Camarines Sur, Philippines, 1981.

duced condition.

The soils from Bulacan (Buenavista clay and Prensa clay) and Santa Rosa, Laguna (Guadalupe clay), showed similar phosphorus sorption isotherms (Fig. 4), with phosphorus sorption of 360 ppm P at 0.2 ppm P in solution. No response to phosphorus in Buenavista clay was observed in the 1981 wet season.

The phosphorus sorption isotherms of the soil in the long-term fertility experiments in Iloilo and Maligaya showed similar patterns (Fig. 5). Phosphorus treatment did not change the phosphorus sorption in the Iloilo soil, although a response to phosphorus was highly significant. The phosphorus sorption isotherm of the soil in Bicol was affected by the phosphorus treatment (Fig. 6).

Soil and crop management

International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)

Agronomy Department

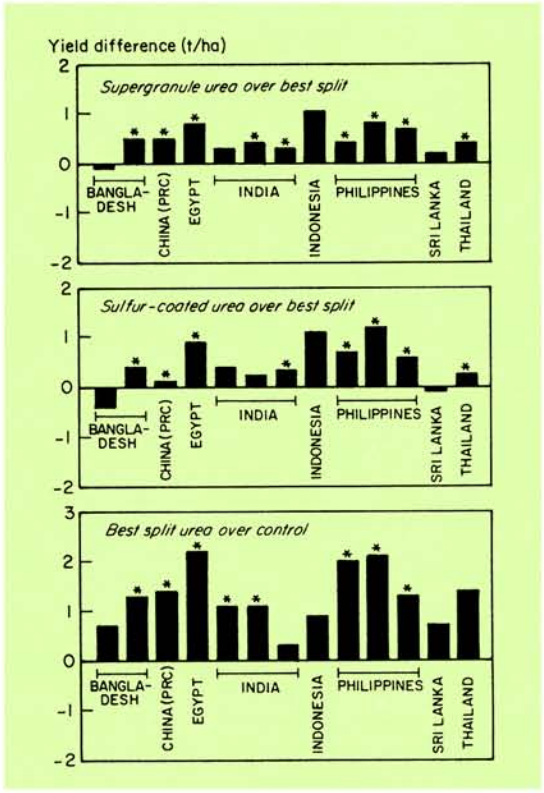
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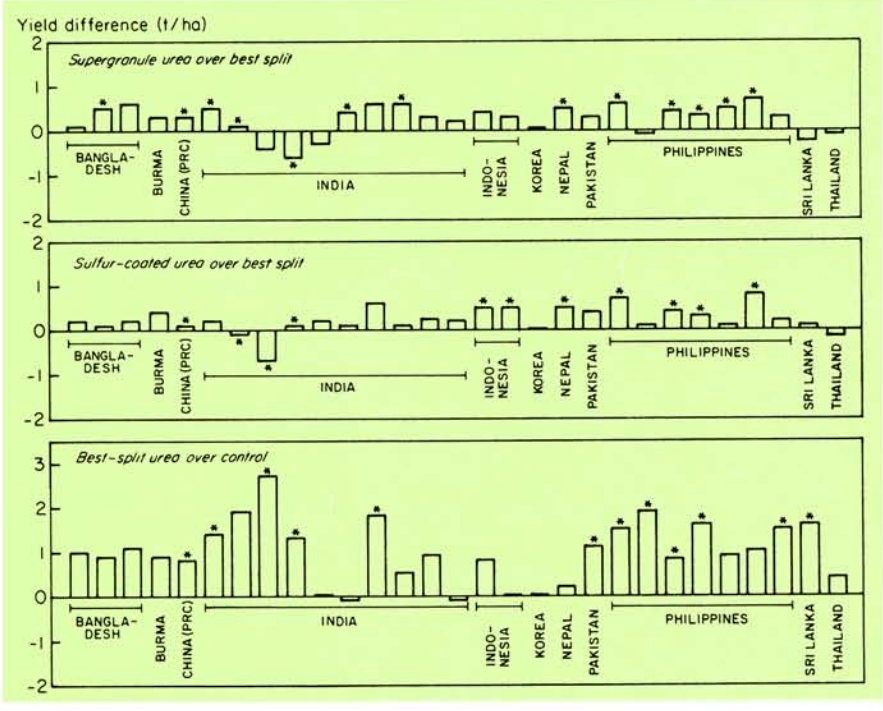
Irrigated rice. Forty-two trials on nitrogen fertilizer efficiency were conducted at 29 sites in 12 countries. Thirteen trials were conducted during the dry season and 29 during the wet. Most of the dry-season trials showed significant yield differences between the treatment with supergranule urea (SGU), point placed, or sulfur-coated urea (SCU), broadcast and incorporated, and the treatment with prilled urea, best split (Fig. 1). That comparison is based on the average yield of three nitrogen rates.

Yield differences between SGU or SCU and prilled urea treatments were observed during the wet season (Fig. 2). In some trials, yield increases with prilled urea, best split, were not significant. Yet yield differences between treatments with SGU and prilled urea or between treatments with SCU and prilled urea were significant probably because of an increase in nitrogen efficiency from SGU or SCU. The presence of sulfur in SCU also may have contributed to the yield differences, especially in the two trials in Indonesia during the wet season.

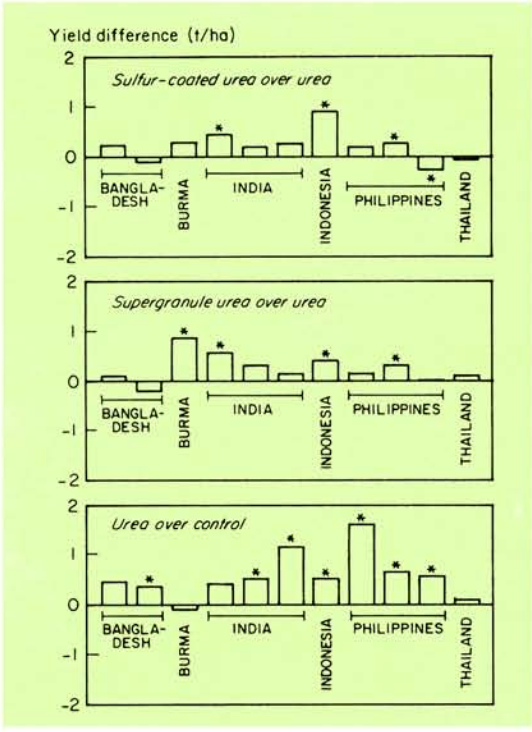
Rainfed rice. Eleven trials on nitrogen fertilizer efficiency in rainfed rice were conducted in six



1. Yield differences between treatments with supergranule urea and urea best split, between sulfur-coated urea and urea best split, and between urea best-split and the control in 13 INSFFER trials, 1979-80 dry season.



2. Yield differences between treatments with supergranule urea, and urea best split, between sulfur-coated urea and urea best split, and between urea best split and the 29 International Network on Soil Fertility and Fertilizer Evaluation for Rainfed Rice trials, 1979-80 wet season.



3. Yield differences (av of 3 rates) between treatments with sulfur-coated urea and urea broadcast and incorporated, between supergranule urea and urea broadcast and incorporated, and, between urea broadcast and incorporated and the control in 11 rainfed-rice trials. Second International Trial on Nitrogen Fertilizer Efficiency in Wetland Rice under Rainfed Conditions, International Network on Soil Fertility and Fertilizer Evaluation for Rainfed Rice, 1980 cropping season.

countries. In the seven trials where yields differed significantly between plots with urea, broadcast and incorporated, and control plots, there were no significant differences between plots with SGU or SCU and those with urea, broadcast and incorporated (Fig. 3), except in Indonesia and at one site in the Philippines.

At four sites, treatments with either SGU or SCU and those with prilled urea, broadcast and incorporated, had significant yield differences. In the trial in Burma, only SCU gave a yield difference over urea best split. It could be another case in which sulfur is limiting. The mean grain yields with the 3 materials at 3 rates of nitrogen from the 11 sites are given in Table 1. The yields from the treatment with SGU and prilled urea differed by only 0.2 t/ha at the low nitrogen rate of 27 kg/ha; they differed by 0.5 t/ha at 87 kg N/ha. The variabilities in the two sets of trials suggest that a better site characterization is needed for a meaningful interpretation of the results.

Deepwater rice. Five nitrogen fertilizer efficiency trials in deepwater rice were conducted at four sites in three countries. Nitrogen response was observed in three trials. SCU, broadcast and incorporated, gave the highest yield in two of the trials where nitrogen response was significant. However, yield differences between the broadcast and incorporated treatments with SCU and prilled urea were not significant.

Sources and rates of phosphorus. The summary of results from the 1977-1980 trials on different sources and rates of phosphorus at 10 sites in 6 countries shows greater yield response to added phosphorus in soils having a pH greater than 6.0 (Table 2). There appear to be no significant yield differences among the phosphorus sources and application rates.

Long-term fertility trial. Table 3 shows the aver-

Table 1. Mean yield of 10 treatments tested in 11 trials. Second international trial on nitrogen fertilizer efficiency in rainfed wetland rice, International Network on Soil Fertility and Fertilizer Evaluation for Rice, 1980.

Urea form	Application method	Mean yield (t/ha) at			
		0 kg N/ha	27 kg N/ha	54 kg N/ha	87 kg N/ha
Check	–	2.8	–	–	–
Urea	Broadcast and incorporated	–	3.3	3.5	3.5
SCU[a]	Broadcast and incorporated	–	3.4	3.8	4.0
SGU[b]	Placement at 10- to 12-cm soil depth	–	3.5	3.8	4.0

[a]Sulfur-coated urea. [b]Supergranule urea.

Table 2. Effects of different sources and rates of phosphorus on yield at 10 sites in 6 countries. International trial on sources of phosphorus in flooded rice, International Network on Soil Fertility and Fertilizer Evaluation for Rice, 1977-1980.

Source	Rate[a] (kg P_2O_5/ha)	Av grain yield (t/ha)	
		pH < 6.0 (29 trials)	pH > 6.0 (12 trials)
Control	–	3.3	3.7
Superphosphate	20	4.1	4.5
	40	4.1	4.8
	60	4.1	4.8
Highly reactive rock-phosphate[b]	20	3.9	4.4
	40	4.0	4.6
	60	4.0	4.5
Less reactive rock-phosphate[c]	40	4.0	4.5
	80	4.1	4.5
	120	4.1	4.7

[a]Based on total P_2O_5. [b]Phosmak was applied for soils with pH <6.0, phospal for soils with pH >6.0. [c]Local rock phosphate or Christmas Island was applied for soils with pH <6.0, local rock phosphate, Christmas Island, or guano was applied for soils with pH >6.0.

Table 3. Effects of 9 fertilizer treatments on yields at 11 sites in 7 countries. International long-term fertility trial in rice, International Network on Soil Fertility and Fertilizer Evaluation for Rice, 1976-1980.

Fertilizer treatment	Av grain yield[a] (t/ha)	
	Dry season	Wet season
Control	3.4	2.8
Nitrogen	4.5	3.9
Phosphorus	3.8	3.3
Potassium	3.7	3.1
Nitrogen + phosphorus	4.8	4.1
Phosphorus + potassium	3.9	3.3
Nitrogen + potassium	4.6	3.9
Nitrogen, phosphorus + potassium	5.2	4.3
Nitrogen, phosphorus + potassium[b]	3.7	3.8

[a]Av of 54 trials. [b]14 trials with nitrogen, phosphorus, and potassium + zinc treatment.

age grain yield of 9 treatments in 54 long-term fertility trials conducted at 11 sites in 7 countries, 1976-1980. Yields were kept higher with the continuous application of NPK complete fertilizer than with nitrogen alone or a combination of nitrogen and phosphorus (NP), or of nitrogen and potassium (NK). Average yields from NPK + zinc treatment in 14 trials were lower than those from the NPK treatment. It is not known why zinc tends to depress yield. Dry-season yields were higher than wet-season yields.

Table 4. Response of wetland rice to fertilizer nitrogen and azolla in several countries. International Network on Soil Fertility and Fertilizer Evaluation for Rice, 1981 cropping seasons.

Treatment	Rate (kg N/ha)	Av grain yield[a] (t/ha)
Control		3.0
Fertilizer nitrogen	30	3.7
	60	4.2
Azolla alone		3.7
Azolla + 30 kg fertilizer nitrogen		4.2

[a]Av of 28 sites in 8 countries.

On the basis of the average yield at 28 sites in 8 countries, one full cover crop of azolla incorporated in the soil produced yields (3.7 t/ha) equivalent to those produced with inorganic fertilizer at 30 kg N/ha (Table 4). Also, one crop of azolla plus urea at 30 kg N/ha produced yields (4.2 t/ha) equivalent to those from inorganic fertilizer at 60 kg N/ha.

CURRENT INSFFER RESEARCH TRIALS

During the 1981 cropping seasons, 5 sets of trials were conducted by collaborators of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER): 1) nitrogen fertilizer efficiency in rice, 2) phosphorus sources for flooded rice, 3) long-term fertility, 4) azolla use in wetland rice, and 5) acid sulfate soil nursery. The acid sulfate soil nursery is a new, joint undertaking with the International Rice Testing Program (IRTP). Table 5 shows the countries that received fertilizer materials and the kinds of trials they are conducting.

INSFFER TRAINING

Twenty-two participants from seven countries joined the INSFFER training course 9 February-29 May 1981. Countries represented were Burma, China, India, Indonesia, Nepal, Philippines, and Thailand. The training course includes both classroom and field activities. Lecture topics include scientific experimentation, site characterization, the rice plant — its nutrition and environment, rice breeding — genetic evaluation and utilization, soils

Table 5. Sets of fertilizers sent cooperators of the International Network on Soil Fertility and Fertilizer Evaluation for Rice during 1981.

Country	Nitrogen fertilizer efficiency trial			Phosphorus source	Acid sulfate
	Irrigated 5th	Rainfed 3rd	Deepwater 1st		
Bangladesh	6	2	2	–	–
Burma	2	1	–	3	–
China	6	–	–	–	–
Egypt	2	–	–	2	–
India	24	7	3	4	–
Indonesia	23	4	1	6	2
Malaysia	–	1	–	2	–
Mali	–	1	–	–	–
Nepal	2	2	–	2	–
Nigeria	2	1	–	–	–
Pakistan	1	–	–	–	–
Philippines	13	4	3	2	–
Senegal	10	–	–	6	–
Sierra Leone	2	–	–	–	–
Thailand	2	1	2	4	2
Vietnam	4	1	1	6	2
Total	99	15	12	37	–

and soil fertility management, fertilizers and fertilizer management, soil testing and plant analysis, soil microbiology and azolla culture, statistical design and analysis, economic analysis and interpretation, and technical report writing.

SITE VISIT TOURS

Site visit tours to Bangladesh and India were made by 11 participants from Bangladesh, India, Indonesia, Thailand, International Fertilizer Development Center, and IRRI 11-23 September 1981 to: 1) visit and characterize current INSFFER trial sites in the two countries visited, 2) observe soil fertility problems, such as sulfur and zinc, and 3) discuss current soil fertility research and develop plans for future collaborative research. One site in Bangladesh and six in India were visited.

NITROGEN FERTILIZER EFFICIENCY TRIALS AT IRRI

Irrigated rice. *Dry season.* The fourth INSFFER trial continued. Split-applied urea, SCU broadcast and incorporated, and point-placed urea supergranules were compared at four application rates. Early-maturing IR50 and medium-maturing IR48 were the test cultivars.

In both varieties, yields were 1 t/ha more than those of the control with each increase in nitrogen rate: 1 t/ha more with 29 kg N/ha, 2 t/ha more with 56 kg N/ha, and 3 t/ha more with 112 kg N/ha (Table 6). For each increment of nitrogen

Table 6. Effects of forms, rates, and methods of urea application on yield. Fourth trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (irrigated). IRRI, 1981 dry season.

Treatment	Yield[a] (t/ha)	
	IR50	IR48
No fertilizer nitrogen	2.9 e	3.8 d
29 kg N/ha		
Urea, split application[b]	3.6 d	4.4 cd
SCU[c], broadcast and incorporated	4.5 c	4.9 c
Supergranules, placement	4.3 cd	4.7 c
56 kg N/ha		
Urea, split application[b]	4.0 cd	4.7 c
Urea, broadcast and incorporated	4.1 cd	5.0 c
SCU[c], broadcast and incorporated	5.4 b	5.8 b
Supergranules, placement	5.8 b	5.7 b
112 kg N/ha		
Urea, split application[b]	6.1 b	6.0 b
Urea, broadcast and incorporated	5.9 b	5.9 b
SCU[c], broadcast and incorporated	7.3 a	7.5 a
Supergranules, placement	7.0 a	7.1 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Two-thirds broadcast and incorporated at planting, 1/3 topdressed 5-7 days before panicle initiation. [c]Sulfur-coated urea, ordinary.

Table 7. Effects of forms, rates, and methods of urea application on yield. Fifth trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (irrigated). IRRI, 1981 wet season.

Treatment	Yield[a] (t/ha)	
	IR50	IR48
No fertilizer nitrogen	3.0 d	3.7 c
29 kg N/ha		
Urea, split application[b]	3.6 d	4.2 abc
SCU[c], broadcast and incorporated	4.9 bc	4.1 bc
Supergranules, placement	4.9 bc	4.6 ab
58 kg N/ha		
Urea, split application[b]	5.2 bc	4.6 ab
SCU[c], broadcst and incorporated	5.4 ab	5.0 a
Supergranules, placement	5.5 ab	4.9 ab
87 kg N/ha		
Urea, split application[b]	5.3 abc	4.9 ab
SCU[c], broadcast and incorporated	6.1 a	4.4 abc
Supergranules, placement	5.6 ab	4.2 abc
116 kg N/ha		
Urea, split application[b]	6.1 a	4.4 abc
SCU[c], broadcast and incorporated	5.3 abc	4.2 abc
Supergranules, placement	4.6 c	4.5 ab

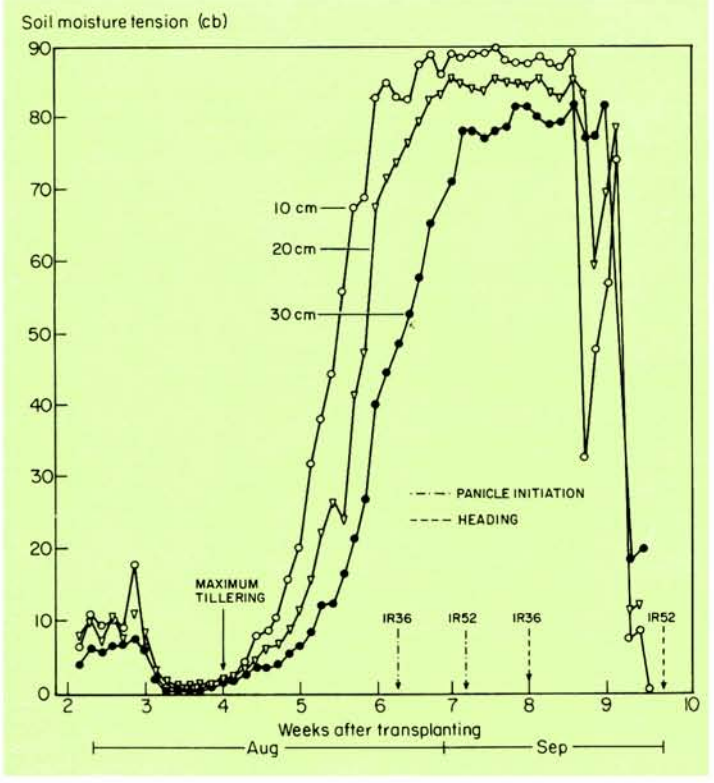
[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Two-thirds broadcast and incorporated at planting and 1/3 topdressed 5-7 days before panicle initiation. [c]Sulfur-coated urea.

applied, both varieties gave significantly higher yields with SCU broadcast and incorporated and point-placed urea supergranules than with split-applied prilled urea.

Wet season. The fifth INSFFER trial was started during the 1981 wet season. At both 29 kg N/ha and 58 kg N/ha, IR50 yielded significantly higher with SCU broadcast and incorporated and point-placed urea supergranules than with split-applied urea. Response to nitrogen beyond 58 kg/ha, was not significant (Table 7). Response of IR48 to nitrogen was erratic because of lodging caused by a typhoon that hit the crop.

Rainfed rice. *Wet season.* The third INSFFER trial on rainfed rice continued during the 1981 wet season at IRRI. Rainfed yields of IR36 and IR52 were very low. Soil moisture tension was measured by tensiometers at 10- to 30-cm depths. The rice crop suffered severe moisture stress of about 85 cb at the early reproductive stage (Fig. 4).

The average yield of IR52 was higher than that of IR36 (Table 8). Both varieties responded to nitrogen only at 87 kg/ha. IR52 yielded signifi-



4. Soil moisture tension during the growing period of IR36 and IR52. Third Trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rainfed Rice. IRRI, 1981 wet season.

Table 8. Effects of forms, rates, and methods of urea application on yield. Third trial of the International Network on Soil Fertility and Fertilizer Evaluation for Rice (rainfed). IRRI, 1981 wet season.

Treatment	Yield[a] (t/ha)	
	IR36	IR52
No fertilizer nitrogen	1.9 c	2.7 c
28 kg N/ha		
Urea, split application[b]	2.5 bc	3.1 bc
SCU[c], broadcast and incorporated	2.4 bc	3.0 bc
Supergranules, placement	2.4 bc	3.3 abc
56 kg N/ha		
Urea, split application[b]	2.5 bc	3.4 ab
SCU[c], broadcast and incorporated	2.6 b	3.1 bc
Supergranules, placement	2.5 bc	3.4 ab
87 kg N/ha		
Urea, split application[b]	2.7 ab	3.2 bc
SCU[c], broadcast and incorporated	3.3 a	3.1 bc
Supergranules, placement	2.9 ab	3.9 a

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Two-thirds broadcast and incorporated at planting; 1/3 topdressed 5-7 days before panicle initiation. [c]Sulfur-coated urea, ordinary.

cantly higher with point-placed urea supergranules than with split-applied urea and SCU broadcast and incorporated.

These results indicate that nitrogen fertilizer should be applied to rainfed rice soon after adequate rainfall.

Farmers' fields. The INSFFER trials on irrigated and rainfed rice were continued in 1981. The irrigated trials were on a clay soil in Santa Rosa, Laguna, during the dry season and in Pila, Laguna, during the wet. A rainfed trial was initiated in San Ildefonso, Bulacan.

Soil analysis before the trials started showed markedly different available phosphorus and exchangeable potassium and zinc in the irrigated sites (Table 9). Soil in the rainfed site possesses low total nitrogen and is coarser than the two other soils.

Grain yield. Response to nitrogen from all sources at all rates was generally significant (Table 10). On all soils, the response to SCU at the highest nitrogen rate was consistently the highest.

In irrigated trials, yields increased with increased rate of application for nitrogen from all sources. In the dry season, treatments with nitrogen from all sources at 29 kg N/ha gave comparable yields. In the wet season, the SCU and urea supergranule treatments gave significantly higher yields than did split application of urea. However, at 58 kg N/ha in both seasons, only SCU was superior to split-applied urea. There were no significant yield differences among sources at 87 kg N/ha. Differences among treatments were significant at 116 kg N/ha in the dry season.

Basally applied urea was as good as split-applied urea at 58 and 116 kg N/ha but inferior to point-placed urea supergranules at 58 kg N/ha and to SCU at both nitrogen rates.

In the rainfed trial, differences among sources were significant only at 87 kg N/ha. At 87 kg N/ha, SCU, with a significant response of 1.6 t/ha, was superior to split application and deep placement with urea supergranules.

Deepwater rice. Continuing experiments at the IRRI farm during the 1981 wet season used RD19

Table 9. Characteristics of soils for trials of the International Network on Soil Fertility and Fertilizer Evaluation for Rice. Farmers' fields in Santa Rosa and Pila (Laguna) and San Ildefonso (Bulacan), Philippines, 1981.

Soil property	Irrigated		Rainfed
	Santa Rosa	Pila	San Ildefonso
pH (1:1)	6.0	6.2	6.0
Cation exchange capacity (meq/100 g)	34.6	32.9	23.5
Total nitrogen (%)	0.27	0.22	0.14
Organic matter (%)	4.1	3.6	2.0
Available phosphorus (ppm, Olsen)	5.5	2.2	4.4
Exchangeable potassium (meq/100 g)	1.11	0.14	0.13
Available zinc (ppm, K and P)	0.14	nil	0.83
Texture	Clay	Clay	Silty clay
Soil series	Guadalupe	Calumpang	Buenavista
Soil order	Vertisols	Inceptisols	Alfisols

Table 10. Effects of sources and methods of nitrogen application on IR36 yield. Guadalupe clay in Santa Rosa, Laguna (4th trial), Calumpang clay in Pila, Laguna (5th trial), and Buenavista silty clay in San Ildefonso, Bulacan (3rd trial). International trials on nitrogen fertilizer efficiency in irrigated and rainfed rice. 1981.

Treatment[a]	Grain yield[b] (t/ha)		
	Irrigated		Rainfed
	Guadalupe clay (dry season)	Calumpang clay (wet season)	Buenavista silty clay
No fertilizer nitrogen	3.5 g	3.0 h	2.6 d
29 kg N/ha			
Urea, split application	4.4 f	4.0 g	4.1 c
Sulfur-coated urea	4.6 ef	4.9 ef	4.3 c
Supergranule placement	4.9 ef	4.6 f	4.1 c
58 kg N/ha			
Urea, split application	5.2 de	4.8 ef	4.8 b
Urea, basal	5.1 e	–	–
Sulfur-coated urea	5.8 c	5.3 cd	4.9 ab
Supergranule placement	5.7 cd	5.1 de	4.9 ab
87 kg N/ha			
Urea, split application	–	5.5 bcd	4.7 b
Sulfur-coated urea	–	5.5 bcd	5.2 a
Supergranule placement	–	5.5 bcd	4.8 b
116 kg N/ha			
Urea, split application	6.6 ab	4.6 abc	–
Urea, basal	6.3 bc	–	–
Sulfur-coated urea	7.0 a	5.9 a	–
Supergranule placement	6.8 ab	5.7 ab	–

[a]For split application, 2/3 urea was broadcast and incorporated at planting time, and 1/3 was top-dressed 5-7 days before panicle initiation. [b]Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 11. Effect of sources and methods of nitrogen application on RD 19 yield. Second international trial on nitrogen fertilizer efficiency in deepwater rice. IRRI, 1981 wet season.

Treatment[a]	Grain yield[b] (t/ha) at water depth of	
	50 cm	100 cm
No fertilizer nitrogen	1.6 bc	1.8 b
58 kg N		
Prilled urea, broadcast and incorporated	1.8 abc	2.2 ab
Sulfur-coated urea, broadcast and incorporated	1.9 abc	2.5 a
1/2 prilled urea + 1/2 sulfur-coated urea, broadcast and incorporated	1.9 abc	2.4 a
2/3 prilled urea, broadcast and incorporated followed by 1/3 foliar spray of urea solution 5-7 DBPI	1.4 c	2.3 a
2/3 sulfur-coated urea, broadcast and incorporated followed by 1/3 foliar spray of urea solution 5-7 DBPI	2.0 ab	2.3 a
Urea supergranule 10-12 cm deep-placement	2.3 a	2.5 a
29 kg N		
Urea supergranule 10-12 cm deep-placement	2.0 ab	2.2 ab

[a]DBPI = days before panicle initiation. [b]Separation of means in each column by Duncan's multiple range test at the 5% level.

at 50- and 100-cm water depths. The 3 sources of urea were prilled, sulfur-coated, and supergranules at 58 kg N/ha.

Phosphorus and potassium at 40 kg/ha were broadcast and incorporated during the last harrowing. The water depth was increased 5 cm/day, starting 30 days after transplanting, and maintained at either 50 or 100 cm until harvest.

At the same rate of nitrogen application (58 kg N/ha), almost all sources and application methods gave comparable yields (Table 11). Deep placement of urea supergranules gave the highest yield.

Low yield was attributed to two typhoons that occurred during flowering. As high as 40-52% unfilled spikelets were recorded in 2 experiments. Yield at 50-cm water depth was low because of early lodging.

Soil and crop management

Rice crop cultural practices

Agronomy Department

MANAGING NITROGEN IN EARLY-MATURING RICE **328**
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An experiment at the IRRI farm during the 1981 crop seasons evaluated nitrogen fertilizer management practices for 4 varieties and 10 promising early-maturing lines. Lodging resistance factor (cLr) was measured with a brass chain. Brown-rice protein content was also determined.

Dry season. The field duration and productivity (in kilograms of rice per hectare per day) in the dry season are shown in Table 1. The transplanted early-maturing lines matured 9-13 days earlier than IR36. Eight entries produced the same or higher average yields than IR36. All breeding lines tested had 5-24 kg/ha higher daily productivity than

Table 1. Field duration, productivity, and brown-rice protein of 4 rice varieties and 10 early-maturing rices, as affected by fertilizer nitrogen application. IRRI, 1981 dry season.

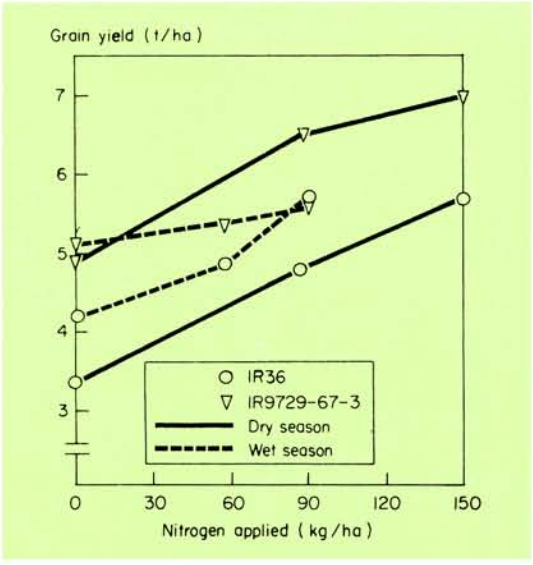
Entry	Field duration (days)	Without fertilizer nitrogen	Grain yield[a] (t/ha)				Av yield		Brown-rice protein (%)
			87 kg N/ha			150 kg N/ha	t/ha	kg/ha per day[b]	
			Urea split	SCU	Urea SG	Urea split			
IR8	101	2.2 d	2.9 e	2.7 f	3.4 g	2.8 e	2.8	28	11.1
IR36	90	3.4 c	4.8 d	5.8 bcde	5.3 def	5.7 cd	5.0	56	9.5
IR42	101	3.7 bc	5.0 cd	5.2 de	5.2 ef	5.4 cd	4.9	49	10.7
IR50	87	3.9 bc	6.0 ab	6.4 ab	6.3 bc	6.5 ab	5.8	67	8.7
IR9729-67-3	81	4.9 a	6.5 a	6.7 a	7.2 a	7.0 a	6.5	80	9.0
IR9752-71-3-2	80	3.4 c	5.2 cd	6.7 a	6.7 ab	6.7 ab	5.8	72	9.8
IR15429-268-1-2-1	81	4.3 ab	5.5 bcd	5.9 bcd	6.0 cd	6.4 ab	5.6	69	9.9
IR19728-9-3-2	80	3.3 c	4.9 d	5.4 de	5.2 ef	5.5 cd	4.9	61	10.4
IR19735-5-2-3-2-1	82	3.6 bc	5.7 bc	5.8 bcde	5.9 cde	6.5 ab	5.5	67	9.5
IR19743-25-2-2	82	3.4 c	5.1 cd	5.5 cde	5.6 cdef	5.7 cd	5.0	61	9.4
IR19743-46-2-3-3-2	77	3.9 bc	5.3 cd	5.9 bcd	5.6 cdef	6.1 bc	5.4	70	9.3
IR19746-28-2-2	80	3.7 bc	5.3 cd	6.2 abc	5.9 cde	6.9 a	5.6	70	9.0
IR19774-23-2-2-1-3	80	3.4 c	5.2 cd	5.9 bcd	5.8 cde	6.0 bc	5.3	66	10.1
IR19819-31-2-3	77	3.9 bc	4.9 d	5.1 e	5.0 f	5.1 d	4.8	62	10.1

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. Urea split = two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation; SCU = sulfur-coated urea, broadcast and incorporated; Urea SG = urea supergranules placed at 10-15 cm deep. [b]Does not include 18 days in the seedbed.

Table 2. Field duration and productivity of 4 varieties and 10 early-maturing rices as affected by fertilizer nitrogen application. IRRI, 1981 wet season.

Entry	Field duration (days)	Without fertilizer nitrogen	Grain yield[a] (t/ha)				Av yield	
			58 kg N/ha			90 kg N/ha	t/ha	kg/ha per day[b]
			Urea split	SCU	Urea SG	Urea split		
IR8	104	2.3 g	1.9 e	2.3 f	2.3 f	2.0 e	2.2	21
IR36	90	4.2 bc	4.9 ab	5.5 abc	5.3 abcd	5.7 ab	5.1	57
IR42	117	4.6 ab	5.2 ab	5.3 abcd	5.2 bcde	5.3 bc	5.1	44
IR50	87	4.6 ab	5.5 a	5.9 a	6.0 a	6.2 a	5.6	65
IR9729-67-3	84	5.1 a	5.4 a	5.7 ab	5.7 ab	5.6 ab	5.5	65
IR9752-71-3-2	81	3.2 ef	4.7 bc	4.9 cd	5.4 abc	5.6 ab	4.8	59
IR15429-268-1-2-1	80	3.9 bcde	5.0 ab	5.9 a	5.2 bcde	5.4 bc	5.1	64
IR19728-9-3-2	82	3.8 cdef	5.0 ab	5.3 abcd	5.2 bcde	5.2 bc	4.9	60
IR19735-5-2-3-2-1	82	3.8 cdef	5.1 ab	5.2 abcd	5.3 abcd	5.4 bc	5.0	61
IR19743-25-2-2	81	4.0 cd	4.9 ab	5.1 bcd	5.1 bcde	5.2 bc	4.9	60
IR19743-46-2-3-3-2	77	3.1 f	3.6 d	4.2 e	4.6 de	4.8 cd	4.1	53
IR19746-28-2-2	80	3.8 cdef	4.6 bc	5.1 bcd	5.0 bcde	5.6 ab	4.8	60
IR19774-23-2-2-1-3	80	3.2 ef	4.2 c	4.8 de	4.5 e	4.5 d	4.2	53
IR19819-31-2-3	81	3.4 def	4.2 c	4.7 de	4.8 cde	4.3 d	4.3	53

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. Urea split = two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation; SCU = sulfur-coated urea, broadcast and incorporated; Urea SG = urea supergranules placed at 10-15 cm deep. [b]Does not include 18 days in the seedbed.



1. Response to nitrogen of early-maturing IR36 and IR9729-67-3 during the 1981 dry and wet seasons.

IR36. The highest yield was produced with point placement of urea supergranules at 87 kg N/ha with IR9729-67-3 (7.2 t/ha). IR9729-67-3 also had the highest average yield (6.5 t/ha) and productivity (80 kg/ha per day). IR8 had the lowest average yield (2.8 t/ha) and daily productivity (28 kg/ha).

Wet season. The early-maturing rices matured 6-13 days earlier. Only two lines had the same or higher average grain yield than IR36. The highest yield (6.2 t/ha) was obtained with IR50 fertilized with urea in split doses at 90 kg N/ha (Table 2). IR9729-67-3 and IR50 had the highest productivity at 65 kg/ha per day.

When no fertilizer nitrogen was applied, IR9729-67-3 had the highest yields, 5.1 t/ha in the wet season and 4.9 t/ha in the dry (Fig. 1). Controlled-release SCU and deep placement of urea supergranules generally gave substantial yield increases over the tested timing of split-applied urea in both seasons. Yields generally increased with increased nitrogen rate when urea was applied in split doses. IR8 produced low yields and responded poorly to fertilizer in both seasons because of tungro and ragged stunt virus diseases.

Brown-rice protein contents of the entries during the dry season are shown in Table 3. The mean protein content of six promising lines was the same as or higher than that of IR36 and that of four was slightly lower. Brown-rice protein content increased with increasing rate of nitrogen application. At 87 kg N/ha, the treatments with controlled-release SCU or deep placement of urea supergranules

Table 3. Effect of sources of urea, application method, and application rate on brown-rice protein of 14 rice entries. IRRI, 1981 dry season.

Entry	Brown-rice protein[a] (%)					
	Without fertilizer nitrogen	87 kg N/ha			150 kg N/ha	Mean
		Urea split	SCU	Urea SG	Urea split	
IR8	11.4 a	10.8 a	11.1 a	11.4 a	10.8 a	11.1
IR36	8.4 c	8.6 c	10.7 a	9.9 b	9.8 b	9.5
IR42	9.8 b	10.6 a	10.8 a	11.1 a	11.4 a	10.7
IR50	7.7 c	8.6 b	8.9 ab	9.6 a	8.7 b	8.7
IR9729-67-3	8.2 c	8.6 bc	9.4 a	9.1 ab	9.6 a	9.0
IR9752-71-3-2	8.6 c	9.4 b	10.2 a	10.2 a	10.4 a	9.8
IR15429-268-1-2-1	8.4 b	9.0 b	10.8 a	10.4 a	10.8 a	9.9
IR19728-9-3-2	9.1 b	9.7 b	11.1 a	10.9 a	11.1 a	10.4
IR19735-5-2-3-2-1	8.4 b	9.0 b	10.1 a	9.9 a	9.9 a	9.5
IR19743-25-2-2	8.4 b	8.7 b	10.1 a	10.1 a	9.8 a	9.4
IR19743-46-2-3-3-2	8.4 b	8.8 b	9.6 a	9.9 a	9.8 a	9.3
IR19746-28-2-2	7.6 d	8.5 c	9.2 bc	9.4 b	10.2 a	9.0
IR19774-23-2-2-1-3	9.6 c	9.5 c	10.8 a	10.0 bc	10.6 ab	10.1
IR19819-31-2-3	8.7 c	9.7 b	10.8 a	10.8 a	10.6 a	10.1
Mean	8.8	9.3	10.3	10.2	10.3	

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level. Urea split = two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation; SCU = sulfur-coated urea, broadcast and incorporated; Urea SG = urea supergranules placed at 10-15 cm deep.

Table 4. Effect of fertilizer nitrogen on lodging resistance factor value (cLr) of 4 rice varieties and 10 early-maturing rices. IRRI, 1981 dry season.

Entry	cLr value[a]					
	Without fertilizer nitrogen	87 kg N/ha			150 kg N/ha	Mean
		Urea split	SCU	Urea SG	Urea split	
IR8	0.23 a	0.23 a	0.23 a	0.23 a	0.23 a	0.23
IR36	0.13 bcd	0.10 cd	0.10 bc	0.08 ef	0.09 de	0.10
IR42	0.10 ef	0.08 d	0.07 d	0.07 f	0.07 e	0.08
IR50	0.11 de	0.09 cd	0.08 cd	0.07 f	0.08 de	0.09
IR9729-67-3	0.11 de	0.09 cd	0.10 bc	0.09 def	0.08 de	0.09
IR9752-71-3-2	0.12 cde	0.15 b	0.12 b	0.15 b	0.12 bc	0.13
IR15429-268-1-2-1	0.12 cde	0.09 cd	0.09 cd	0.11 cd	0.09 de	0.10
IR19728-9-3-2	0.12 cde	0.10 cd	0.10 bc	0.09 def	0.09 de	0.10
IR19735-5-2-3-2-1	0.13 bcd	0.11 c	0.10 bc	0.11 cd	0.10 cd	0.11
IR19743-25-2-2	0.13 bcd	0.09 cd	0.09 cd	0.08 ef	0.08 de	0.09
IR19743-46-2-3-3-2	0.08 f	0.09 cd	0.09 cd	0.09 def	0.09 de	0.09
IR19746-28-2-2	0.10 ef	0.09 cd	0.10 bc	0.09 def	0.09 de	0.09
IR19774-23-2-2-1-3	0.14 bc	0.11 c	0.10 bc	0.10 de	0.10 cd	0.11
IR19819-31-2-3	0.15 b	0.14 b	0.12 b	0.13 bc	0.13 b	0.14
Mean	0.12	0.11	0.11	0.11	0.10	

[a]Av of 4 replications consisting of 4 plants each. Separation of means in a column by Duncan's multiple range test at the 5% level. $cLr = \frac{\text{Total weight of freely suspended chain links + hook (g)}}{\text{culm length (cm)}}$ Urea split = two-thirds broadcast and incorporated and one-third topdressed 5-7 days before panicle initiation; SCU = sulfur-coated urea, broadcast and incorporated; Urea SG = urea supergranules placed at 10-15 cm deep.

increased the mean brown-rice protein by at least 0.9% over the treatments with urea in split doses.

The cLr in the dry season is predictive of field lodging in the wet season. IR8 had the highest cLr mean value, 0.23, in the dry season, indicating its relatively high lodging resistance (Table 4). IR36 and all the other early-maturing lines, except two, had comparable cLr values. IR42 had a cLr of 0.08, indicating its relatively high lodging susceptibility. Not much rain fell just before or during the flowering period in the wet season, so no severe lodging occurred except in some highly lodging-susceptible entries at maturity.

The cLr values in the dry season indicated that nitrogen application generally increases susceptibility of a rice crop to lodging.

CONTINUOUS CROPPING

The continuous-cropping experiment compared transplant with broadcast crop establishment of six varieties at four nitrogen rates. Three crops were grown each year.

Crop 54 (2nd wet-season crop) was harvested December 1980; crop 55 (dry season), May 1981; and crop 56 (1st wet season), September 1981.

Table 5. Average yields of transplanted and broadcast rice at 4 nitrogen rates. Continuous cropping experiment, IRRI, 1980-81.

Fertilizer rate[a] (kg N/ha)		Yield[b] (t/ha)					
Dry season	Wet season	Crop 54		Crop 55		Crop 56	
		T	B	T	B	T	B
0	0	2.8	2.6	1.9	1.8	2.4	2.6
50	30	3.4	3.0	4.1	3.9	2.9	3.1
100	60	3.4	3.1	4.4	5.8	3.5	3.6
150	90	3.1	2.8	5.7	6.5	4.1	4.2

[a]All treatments except 0 kg N/ha included application of two-thirds N basal incorporated and one-third N topdressed a week before panicle initiation. P_2O_5 and K_2O each at 60 kg/ha were applied basally and incorporated. [b]Av of 6 varieties. T = transplanted, B = broadcast.

Table 6. Average yields of 8 rices at 4 nitrogen rates. Continuous cropping experiment. IRRI, 1980-81.

Variety or line	Yield[a] (t/ha)					
	Crop 54		Crop 55		Crop 56	
	T	B	T	B	T	B
IR8	0.9	0.8	4.2	3.8	2.5	2.6
IR36	4.0	3.7	4.7	5.1	3.1	3.6
IR50	3.3	3.6	–	–	–	–
IR52	3.8	3.0	5.1	5.1	3.4	3.6
IR54	3.5	3.2	4.8	4.7	3.8	3.9
IR4568-86-1-3-2	3.4	2.8	–	–	–	–
IR9752-71-3-2	–	–	3.6	3.8	2.4	2.8
IR15314-43-2-3-2	–	–	4.7	4.3	4.1	4.0

[a]Av of 4 replications. [b]T = transplanted, B = broadcast.

During the dry season, broadcast-seeded rice gave higher yields than transplanted rice, and the difference was significant at high nitrogen. Without added nitrogen, yields of early-maturing varieties were significantly lower than those of other varieties. In the wet season, the differences in yield between the transplanted crop and broadcast crops were slight (Table 5). Yields of the second wet-season crop responded negatively to nitrogen because of lodging.

The early-maturing rices tended to yield higher when broadcast seeded. Yields of IR8 declined because of susceptibility to ragged stunt virus diseases and hopper burn (Table 6).

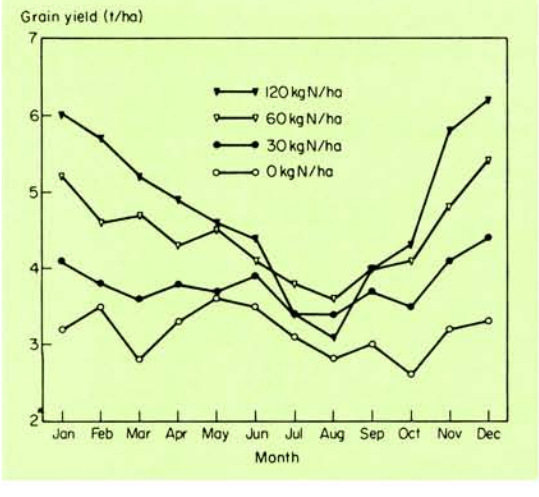
DATE OF PLANTING

In the date-of-planting trial, 20-day-old seedlings were planted the 20th day of each month. IR8, IR36, IR42, and H-4 were evaluated at 4 nitrogen levels.

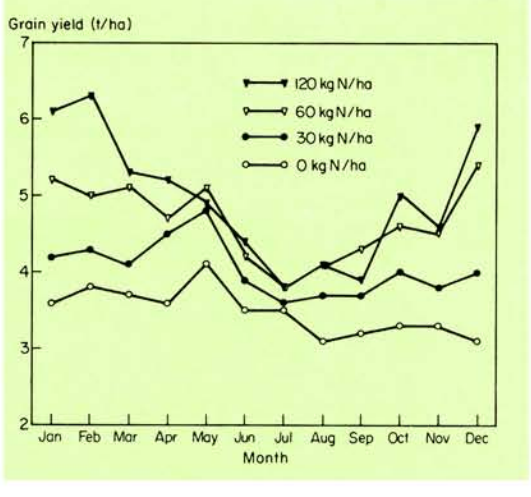
Yields of IR8 have declined for 3 years (1978-1980). In some months IR8 gave no harvest because of disease incidence and rat infestation.

H-4 had a negative nitrogen response in the wet season.

The yield response of IR36 to date of planting is shown in Figure 2. The best IR42 yield was that from the crop planted in January or February,



2. Yields of IR36 planted each month, averaged for 3 years. IRRI, 1968-80.



3. Yields of IR42 planted each month, averaged for 3 years. IRRI, 1968-80.

Table 7. Effect of azolla as a complementary nitrogen fertilizer source at 50-cm water depth on IR42 yield. IRRI, 1981 dry season.

Rate (kg N/ha)	Grain yield[a] (t/ha)		
	Prilled urea	Sulfur-coated urea	Urea supergranules
	No azolla		
0	3.5 a	3.9 a	3.5 b
58	3.8 a	4.6 a	4.4 a
116	4.4 a	4.4 a	4.6 a
	Plus azolla		
0	3.2 b	4.5 a	4.2 b
58	4.4 a	4.3 a	4.8 a
116	3.7 ab	4.7 a	4.5 ab

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

Table 8. Effect of nitrogen rate (average of 3 replications of 2 azolla treatments and 3 sources of urea) on agronomic characteristics of IR42 at 50-cm water depth.[a] IRRI, 1981 dry season.

Characteristic	0 kg N/ha	58 kg N/ha	116 kg N/ha
Grain yield (t/ha)	3.8 b	4.4 a	4.4 a
Plant ht at harvest (cm)	117 b	122 a	123 a
Tillers at harvest (no./m^2)	354 b	376 ab	413 a
Panicles at harvest (no./m^2)	322 b	342 ab	366 a
Panicle length (cm)	26 a	25 a	25 a
Unfilled spikelets (%)	1.7 a	12 b	12 b
100-grain wt (g)	1.8 a	1.8 a	1.8 a
Grain nitrogen content (%)	1.3 b	1.4 ab	1,5 a
Straw nitrogen content (%)	0.6 a	0.7 a	0.8 a
Grain nitrogen uptake (kg N/ha)	50 b	62 a	67 a
Straw nitrogen uptake (kg N/ha)	26 b	110 a	121 a

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

followed by that in May or December (Fig. 3).

USING AZOLLA IN DEEPWATER RICE

Experimental trials to determine the complementary effect of azolla used with inorganic fertilizer sources (prilled urea, sulfur-coated urea, and urea supergranules) were conducted at 50- and 100-cm water depths. IR42 and RD 17 were used in the dry season and RD 19 in the wet. *Azolla pinnata,* an organic nitrogen fertilizer source with 4.24% N analysis (dry weight basis), was inoculated at 500 g/m^2 1 day after transplanting (DT) and incorporated 30 DT. Water level was increased 5 cm/day beginning at 30 DT.

Dry season. Yields of IR42 were affected significantly by nitrogen rates (Table 7). Yield increased 0.6 t/ha with 58 kg N/ha application. Azolla alone gave an 8.0% lower yield than azolla combined with inorganic fertilizer at 58 kg N/ha.

Plant height, tiller and panicle number, and percentage of unfilled spikelets were influenced by nitrogen rates (Table 8). Nitrogen content and plant nitrogen uptake increased proportionately with level of inorganic fertilizers. The values were slightly higher when inorganic fertilizer was combined with azolla.

RD 17 at 100-cm depth was highly susceptible to virus (probably tungro) disease and no grain was harvested.

Wet season. At two water depths and three nitrogen rates, almost all the treatments with inorganic nitrogen sources, with and without azolla

Table 9. Effect of azolla as a complementary nitrogen fertilizer source at 50- and 100-cm water depths on RD 19 yield. IRRI, 1981 wet season.

Rate (kg N/ha)	Grain yield[a] (t/ha)					
	50-cm depth			100-cm depth		
	Prilled urea	Sulfur-coated urea	Urea supergranules	Prilled urea	Sulfur-coated urea	Urea supergranules
			No azolla			
0	2.3 a	3.2 a	2.8 b	2.2 a	2.1 a	2.2 a
29	3.1 a	3.6 a	2.2 b	2.3 a	2.2 a	2.6 a
58	3.0 a	3.5 a	3.6 a	2.2 a	2.2 a	2.5 a
			Plus azolla			
0	2.5 a	2.2 a	2.9 a	2.2 a	2.4 a	2.3 a
29	2.6 a	2.0 a	3.0 a	2.8 a	2.3 a	2.3 a
58	2.5 a	2.6 a	3.4 a	2.7 a	2.5 a	2.3 a

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

Soil and crop management

Tillage and management of soil physical conditions

Agronomy Department

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RESPONSE OF DRYLAND CROPS TO SOIL ENVIRONMENT AFTER WETLAND RICE

Under rainfed conditions, growth of dryland crops in a soil previously puddled for rice is governed by the soil physical environment and the soil water availability to the crop. The effect of complete seedbed tillage and no tillage on sorghum and mungbean grown in the field with shallow (75 cm ± 25 cm), intermediate (100 ± 25 cm), and deep (125 ± 25 cm) ground water tables was studied in the dry season. Because rainfall during crop growth was only 14 mm, the crop depended primarily on soil water availability.

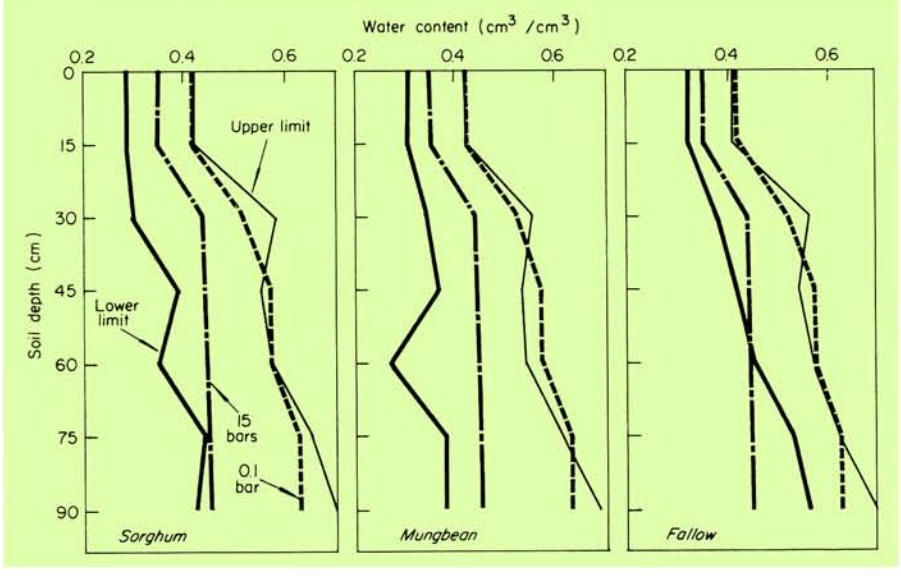
The experimental field was irrigated in January to simulate soil moisture storage at the end of the wet season. In no-tillage plots, weed growth was controlled with herbicides. Sorghum variety Cosor-3 and mungbean variety CES-55 were seeded in 50-cm-wide rows and thinned to 430,000 plants/ha for sorghum and 370,000 plants/ha for mungbean 2 weeks after germination. Sorghum received as basal fertilizer 60 kg N/ha, 22 kg P/ha, and 42 kg K/ha, followed by a second topdressing of 40 kg N/ha 6 weeks after seeding. Mungbean received as basal fertilizer 30 kg N/ha, 26 kg P/ha, and 50 kg K/ha.

Soil water extraction by sorghum and mungbean. Figure 1 compares seasonal soil water depletion by sorghum, mungbean, and fallow from the crop root zone of 0- to 90-cm depth at the deep water table site. Upper limit represents the initial soil moisture storage and lower limit, the residual soil moisture at harvest. Traditionally defined available soil moisture is shown by the 0.1-bar and 15-bar moisture limits determined on soil core samples in the laboratory.

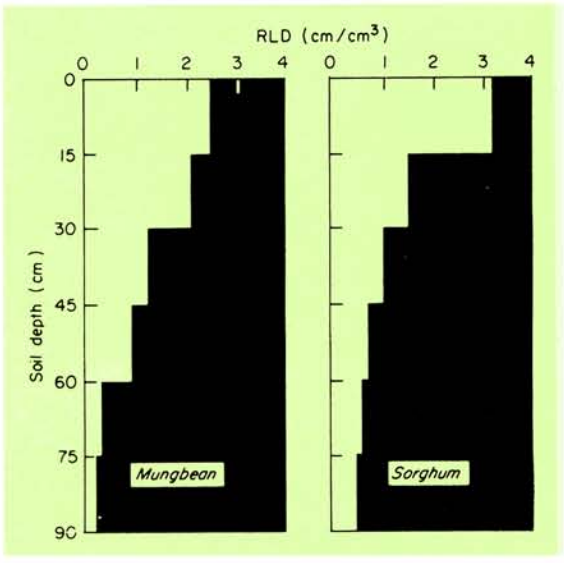
Both crops extracted soil moisture in excess of the traditionally accepted available soil moisture (11.4 cm for the soil). Seasonal soil moisture depletion amounted to 17.4 cm for sorghum, 19.0 cm for mungbean, and 11.6 cm for fallow.

Rooting depth of sorghum and mungbean in a previously puddled soil. Roots of both sorghum and mungbean extended to 90-cm depth (Fig. 2). Root length density (RLD) of sorghum was greater than that of mungbean at depths of 0-15 cm and 60-90 cm. Root density of mungbean exceeded that of sorghum at the 15- to 60-cm depth zone. Root densities of both crops were adequate in the previously puddled soil and comparable to those previously reported for nonpuddled soil at the IRRI dryland farm.

Root distribution of sorghum and mungbean. Mungbean roots were relatively uniform at shallow depths but with an increase in soil depth, rooting density was distinctly greater below the plant



1. Soil water content profiles showing lower and upper limits of water available to sorghum and mungbean grown after wetland rice. IRRI, 1981 dry season.



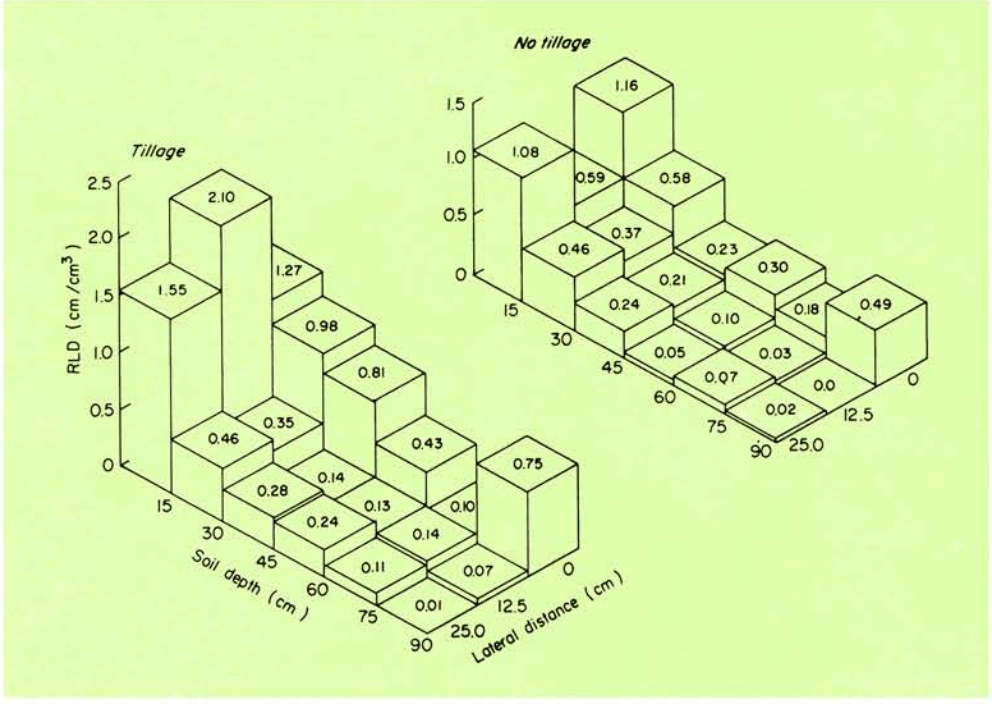
2. Root length density (RLD) of mungbean and sorghum grown after wetland rice. IRRI, 1981 dry season.

center than at lateral distances (Fig. 3). About 30% of the RLD in mungbean was concentrated at 0-10 cm. A similar concentration occurred in sorghum at 0-15 cm (Table 1). About 90% of the RLD was found within the 75-cm depth for both mungbean and sorghum.

Effects of tillage on rooting depth. Tillage for seedbed preparation increased the depth of root penetration for sorghum over the no-tillage treatment during the first 40 days after sowing (Fig. 4). However, the maximum rooting depths were similar in both tillage treatments. Tillage did not influence root penetration rate and depth in mungbean. On the average, sorghum and mungbean showed root extension rates of about 2 cm/day.

Effects of tillage on root density. In sorghum, RLD at the 0- to 30-cm depth was greater in the untilled plots than in the tilled plots but no differences were found at greater depths (Fig. 5). In mungbean, tillage produced slightly greater RLD than no tillage (Fig. 6).

Effects of water table on rooting density. RLD values above the shallow water table (75 ± 25 cm) were much greater than those at the deep water table (125 ± 25 cm) level (Fig. 7, 8). Favorable soil moisture conditions for the shallow water table



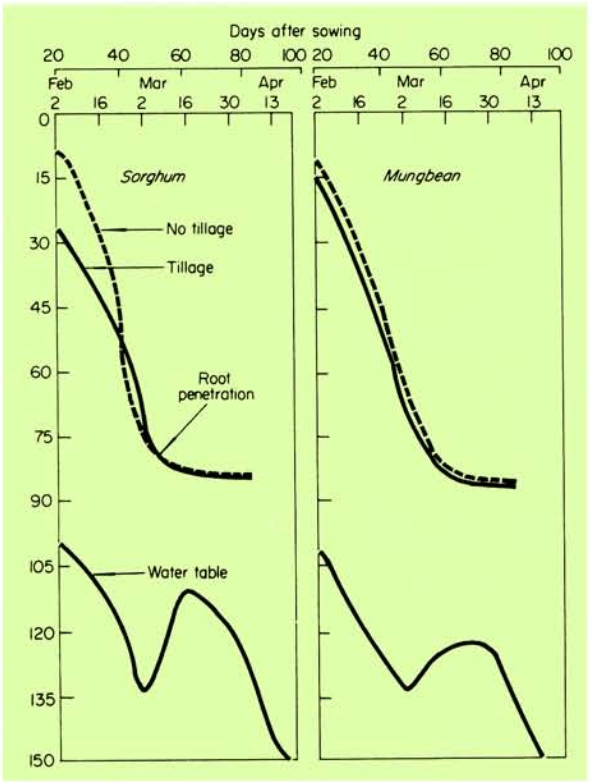
3. Root length density (RLD) of mungbean as a function of soil depth and lateral distance from the plant, deepwater-table plots. IRRI, 1981 dry season.

Table 1. Distribution of root density at the deep water table position in mungbean and sorghum grown with and without tillage. IRRI, 1981.

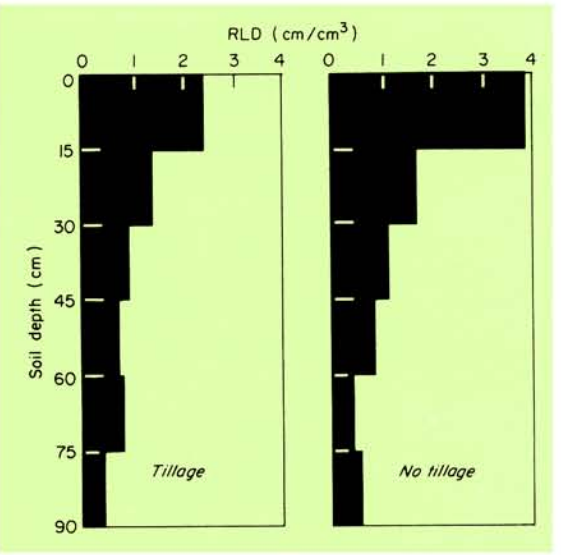
Root length density (% of total)	Soil depth (cm)			
	Mungbean		Sorghum	
	Tillage	No tillage	Tillage	No tillage
30	10	10	11	14
60	22	25	30	39
90	60	67	75	71

treatment encouraged prolific root development while insufficient soil moisture availability was primarily responsible for less root extension in the deeper water table treatment. An inadequate oxygen supply at the 75-cm depth restricted further root penetration in the shallow water table plots. Favorable aeration promoted deeper root penetration in the deep water table treatment.

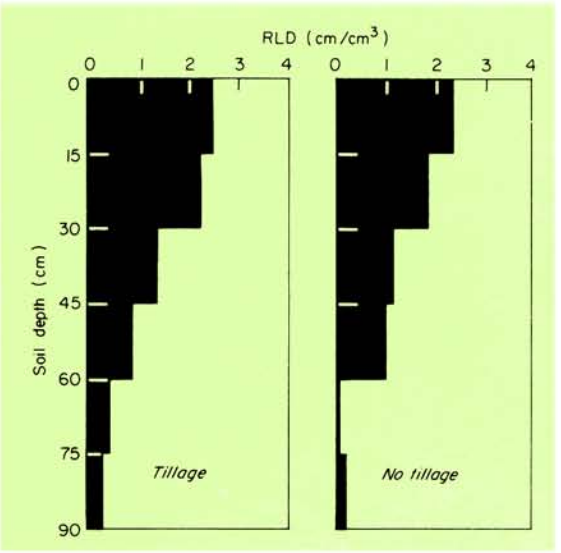
Soil water balance components for dryland crops. Soil water losses resulting from evapotranspiration and deep drainage below the root zone, and moisture gains resulting from the upward movement of water from the water table into the root zone were characterized during the crop-growing season. Even in the absence of rain, downward drainage from the root zone occurred in sorghum during the first 15 days (Fig. 9), in mung-



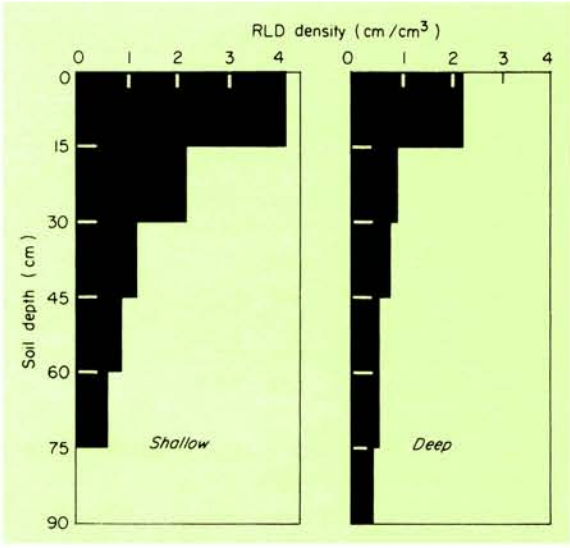
4. Root penetration of sorghum and mungbean grown after wetland rice and water table depth during the post-rainy season. IRRI, 1981 dry season.



5. Effect of tillage treatment on root length density (RLD) of sorghum grown after wetland rice. IRRI, 1981 dry season.

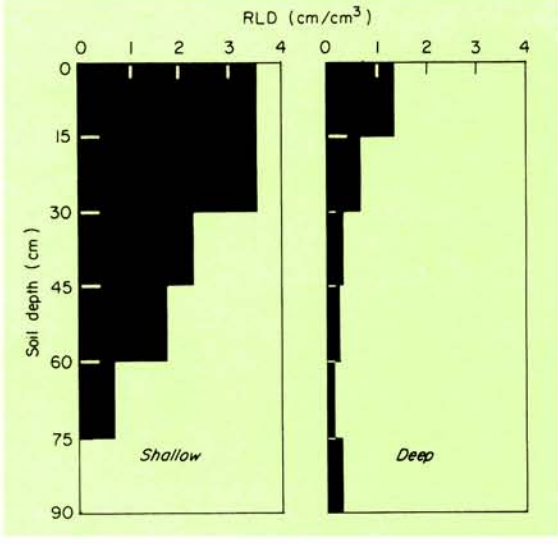


6. Effect of tillage treatment on root length density (RLD) of mungbean grown after wetland rice. IRRI, 1981 dry season.

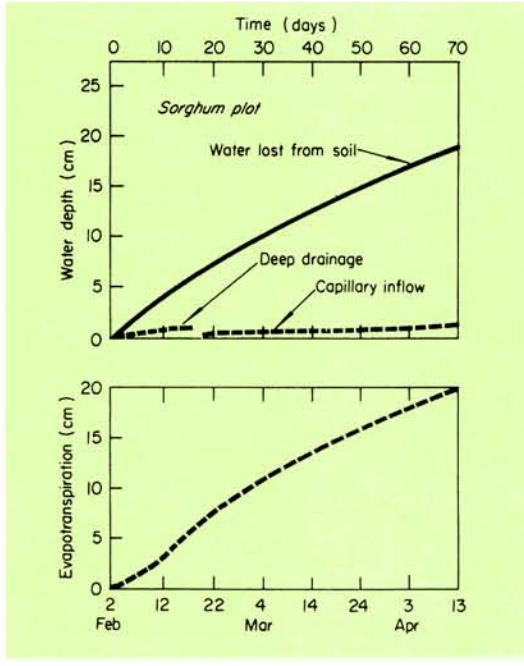


7. Effect of water table level on root length density (RLD) of sorghum grown after wetland rice. IRRI, 1981 dry season.

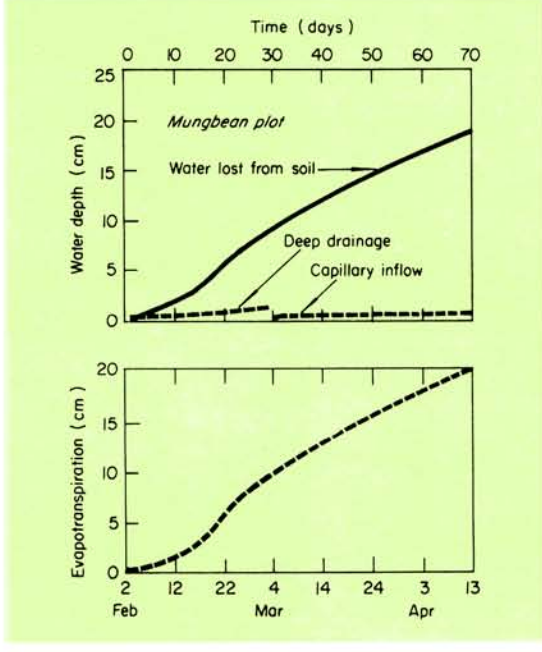
bean during the first 28 days (Fig. 10), and in fallow during the first 42 days (Fig. 11). After drainage, water moved upward and capillary inflow occurred for the remaining period. Capillary inflow was generally low because of very low capillary conductivities in the soil. Actual evapotranspiration losses were obtained by subtracting the deep drainage or



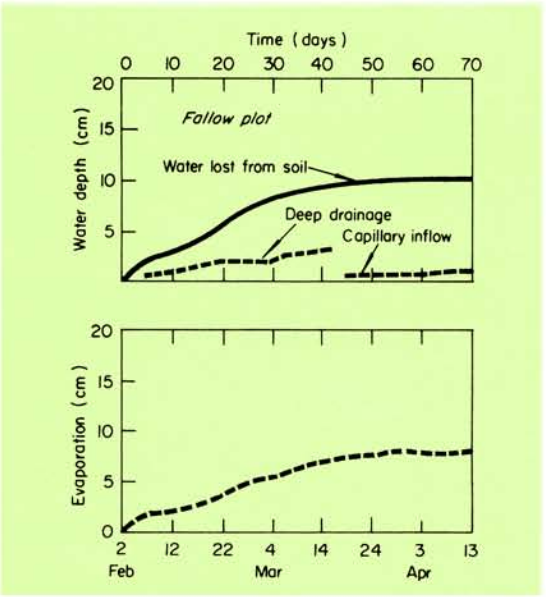
8. Effect of water table level on root length density (RLD) of mungbean grown after wetland rice. IRRI, 1981 dry season.



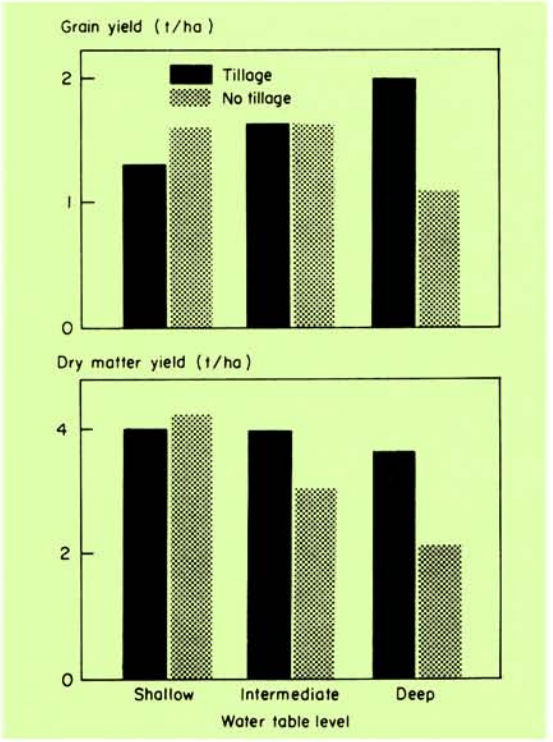
9. Deep drainage, upward capillary contribution, total soil water loss, and net evapotranspiration losses as a function of time, from the 0- to 90-cm rooting depth of sorghum, deep water table plot. IRRI, 1981 dry season.



10. Deep drainage, upward capillary contribution, total soil water loss, and net evapotranspiration losses as a function of time, from the 0- to 90-cm rooting depth of mungbean, deep water table plot. IRRI, 1981 dry season.



11. Deep drainage, upward capillary contribution, total soil water loss, and net evaporation losses as a function of time, from the 0- to 90-cm soil depth in fallow, deep water table plot. IRRI, 1981 dry season.



12. Effect of tillage and water table level on grain and straw dry matter yields of sorghum grown after wetland rice. IRRI, 1981 dry season.

by adding the capillary inflow to the curve representing water lost from the soil, as measured by the neutron-moderation technique.

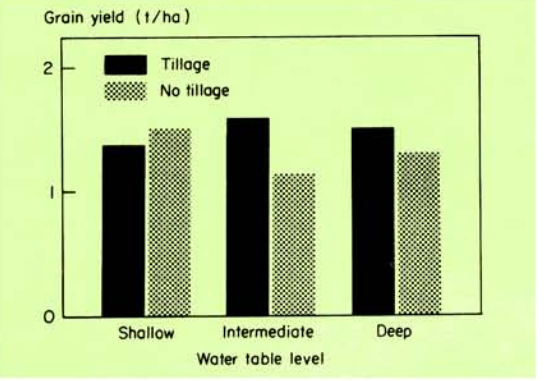
Sorghum yield response to tillage and water table depth. Grain and dry-matter yields of dry-season rainfed sorghum, obtained on reserve soil moisture at the end of the wet season, are shown in Figure 12. The crop extracted about 18 cm soil water in the growing season (Fig. 1) and suffered from soil moisture stress during later growth stages. In the absence of rain, sorghum yields were low, an average 1.5 t grain and 3.5 t stalk/ha. To yield better, the crop must have supplementary irrigation or be planted earlier in the transition from the wet season to the dry.

Sorghum yield response showed an interaction between tillage and water table. When the water table was deep, the tilled plots gave higher grain yields than the untilled plots. When the water table was shallow, untilled plots gave higher yields than the tilled plots.

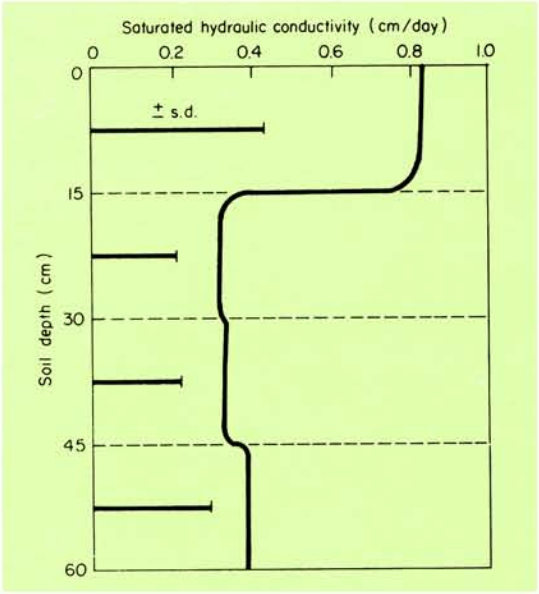
Mungbean yield response to tillage and water table depth. Mungbean also extracted nearly 20 cm of soil water but produced near-optimum yields, averaging about 1.4 t/ha (Fig. 13). The shorter growth duration of mungbean favored its effective use of available soil moisture and resulted in adequate grain yields. Tillage or water table levels showed no consistent trend of influence on yield.

HYDRAULIC CONDUCTIVITY PROFILES OF IRRI FARM SOIL

Figure 14 shows the vertical saturated hydraulic conductivity of soil with depth in a wetland rice



13. Effect of tillage and water table level on grain yield of mungbean grown after wetland rice. IRRI, 1981 dry season.



14. Saturated vertical hydraulic conductivity profile measured in situ in a wetland puddled paddy field. IRRI, 1981 wet season.

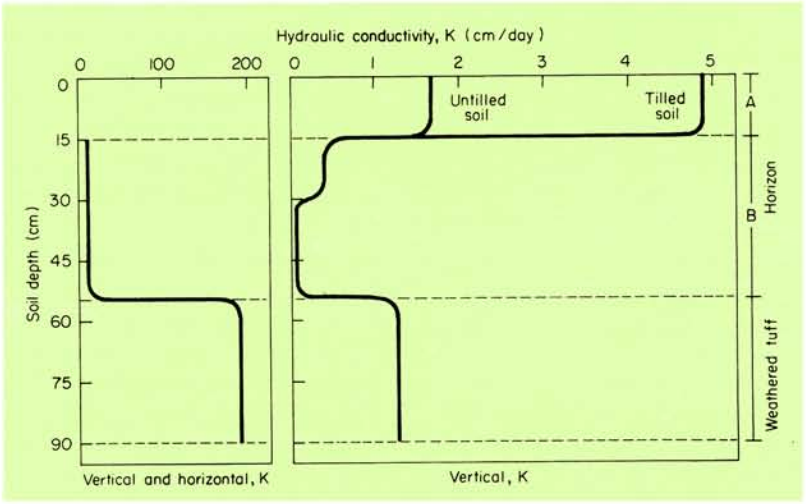
field. In situ measurements were made on piezometric soil water pressures and vertical percolation rates. The soil profile was saturated to all measurement depths, as indicated by the positive hydrostatic pressures.

Even though the 0- to 15-cm surface depth was puddled for rice culture, its hydraulic conductivity was still greater than that of the undisturbed subsoil. The hydraulic conductivity of subsoil depths was essentially constant, about 0.4 cm/day. Hydraulic gradients in the 0- to 15-cm depth were always less than unity, indicating that hydraulic conductivity exceeded the vertical percolation rates. Hydraulic gradients were close to unity for subsoil depths of 15-60 cm, indicating that vertical percolation equalled the hydraulic conductivity.

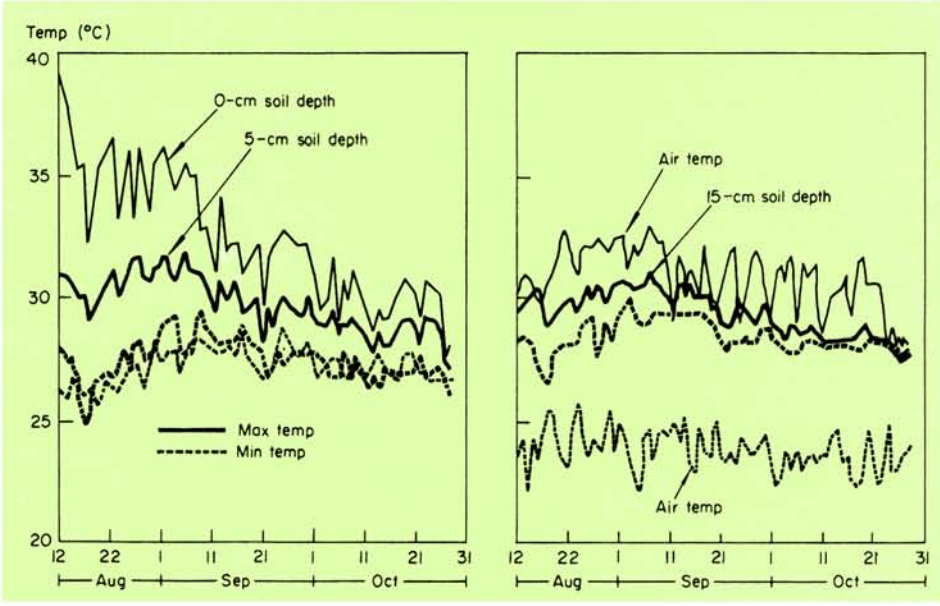
Figure 15 shows vertical and horizontal hydraulic conductivities measured in the area of the IRRI wetland farm in the rice-dryland crop rotation. Vertical hydraulic conductivity was measured on soil core samples in the laboratory. Combined horizontal and vertical hydraulic conductivity was obtained by field auger hole technique. Greater horizontal than vertical hydraulic conductivities indicate the anisotropic nature of the volcanic soil. The hydraulic conductivities in the 0- to 60-cm depth showed the same general trend as that seen in Figure 14. Below 60-cm soil depth, hydraulic conductivity was higher because of a porous tuff layer at this site.

WET- AND DRY-SEASON SOIL TEMPERATURES

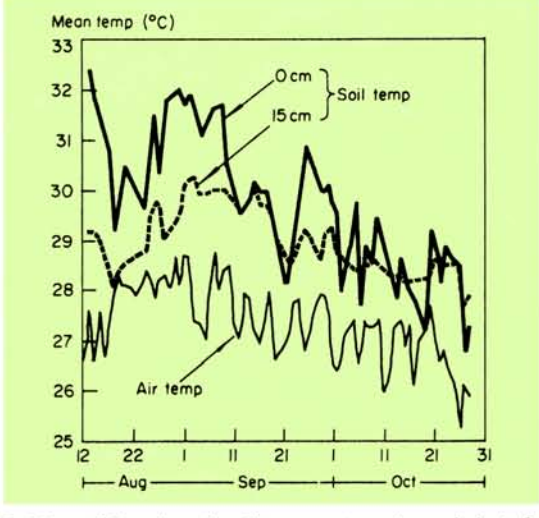
Wetland rice culture, wet season. The variation and magnitude of soil temperatures affect the physiology of rice roots, activity of microorganisms,



15. Saturated hydraulic conductivities in vertical and horizontal directions of a field under a wetland rice - upland crop cropping pattern. IRRI, 1980-81.



16. Daily maximum and minimum soil temperatures, by soil depth, in an irrigated wetland field. IRRI, 1981 wet season.

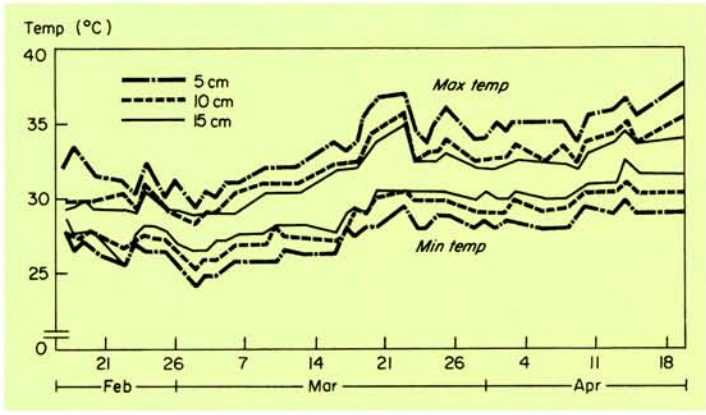


17. Mean daily air and soil temperatures in an irrigated wetland field. IRRI, 1981 wet season.

and kinetics of chemical reactions. Soil temperatures in a rice crop were measured at 0-cm (soil-floodwater interface), 5-cm, 15-cm, and 30-cm soil depths at the IRRI wetland farm August-October 1981. Figure 16 shows the daily maximum and minimum soil temperatures. Air temperatures are included for comparison. Large variations were observed only in the maximum temperature at shallow depths of 0 and 5 cm. Maximum and minimum soil temperatures at 15- and 30-cm depths were essentially the same, within 1° C. The difference between maximum and minimum temperatures (amplitude) decreased sharply with depth, rarely exceeding 1° C at 15 cm or deeper. Differences as high as 12° C were found at the 0-cm depth during rainless periods in August when the maximum temperatures reached 35°-38° C.

Mean daily air and soil temperatures are shown in Figure 17. Soil temperatures at 5- and 30-cm depths are not plotted but were usually within 1° C of those recorded at the 15-cm depth. Soil temperatures usually remained within 28°-30° C, but the 0-cm depth showed temperatures as high as 30°-32° C during rainless, cloud-free periods. Soil temperatures were consistently higher than mean air temperatures, with differences of 1°-3° C.

Dryland crop culture, dry season. The highest soil temperatures occur during the dry season. Figure 18 shows fallow soil temperatures at 5-, 10-,



18. Daily maximum and minimum soil temperatures at 5-cm depths in a fallow plot. IRRI, 1981 dry season.

and 15-cm depths at the IRRI farm. Maximum temperatures at all 3 depths were usually greater than 30° C. Soil temperatures at the 5-cm depth were highest, reaching 37° C in March and April. The minimum temperatures at all 3 depths generally ranged from 26° to 30° C.

Climatic environment and rice

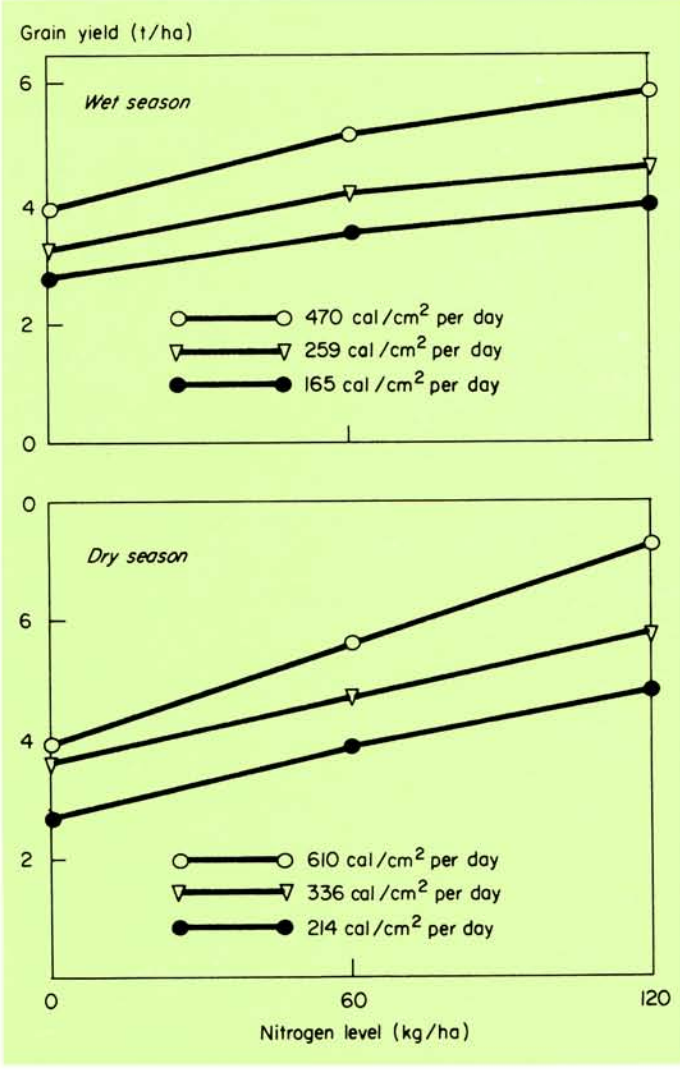
Plant Physiology Department

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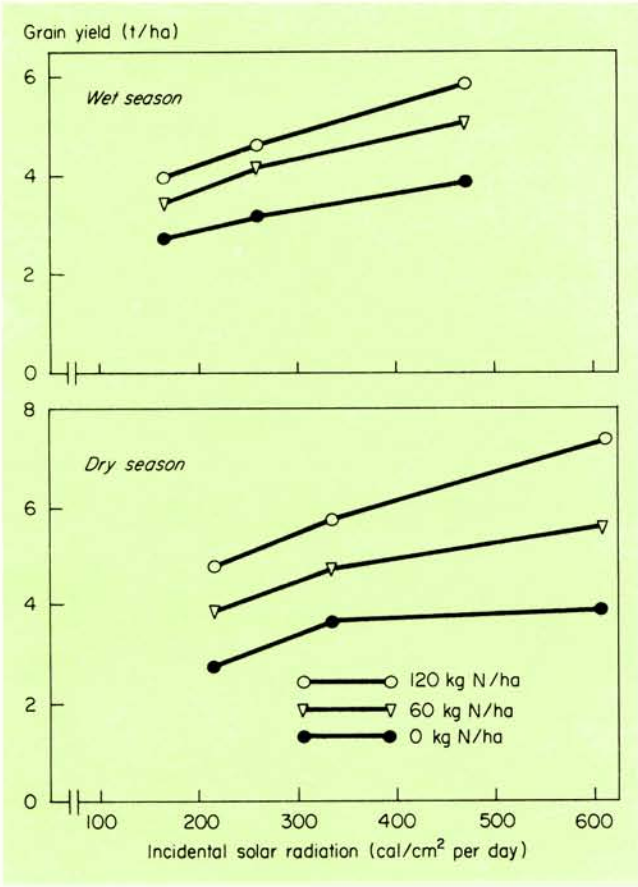
Sunlight-nitrogen interactions. When the effect of sunlight on grain yield was studied in the past, the other factors — including nitrogen level — were maintained at optimal levels. But in farmers' fields, the amount of nitrogen applied to rice varies from one farmer to another. If variation in farmers' yields is to be explained in terms of sunlight effect, it is important to understand how nitrogen interacts with sunlight in the formation of yield.

Wet- and dry-season crops of IR36 were grown at three levels of nitrogen, with three levels of shading during the ripening stage. At the same level of nitrogen, grain yields were higher with increased solar radiation (Fig. 1). At each level of solar radiation, yield increased with an increase in the application of nitrogen. At 0 kg N/ha, yields in the wet and dry seasons were about the same. The yield increase with increasing levels of nitrogen is steeper in the dry season than in the wet. At 120 kg N/ha yields did not decline, even under very low solar radiation. In a similar condition, traditional tall varieties would have lodged and yields would have decreased.

At the same level of solar radiation, yields were larger at higher levels of nitrogen (Fig. 2). At each level of nitrogen, yield increased with increased solar radiation. The rate of yield increase with higher solar radiation was steeper at higher nitro-



1. Effect of nitrogen level and 3 levels of solar radiation during ripening on IR36 yield. IRRI, 1981.



2. Effect of solar radiation and 3 levels of nitrogen during ripening on IR36 yield. IRRI, 1981.

Table 1. Effect of phosphorus on spikelet sterility induced by low temperature at booting. IRRI, 1981.

Duration	Day/night temp (°C)	Phosphorus level (ppm)	Spikelet sterility (%)	
			Fujisaka 5	IR36
Control	29/21	0.5	3.3	12.4
		2.0	7.2	11.9
		5.0	7.0	12.6
3 days	15/15	0.5	9.4	28.5
		2.0	14.1	24.4
		5.0	14.0	27.5
5 days	15/15	0.5	21.4	43.5
		2.0	25.5	46.7
		5.0	30.7	47.4

gen levels. In other words, under higher levels of solar radiation, greater effects are expected from applications of nitrogen.

Low-temperature-induced sterility and phosphorus nutrition. The effect of phosphorus level on spikelet sterility induced by low temperature at the booting stage was studied using solution culture technique. Low temperature-tolerant Fujisaka 5 and susceptible IR36 were grown at 3 levels of phosphorus (0.5, 2, 5 ppm) in culture solution in a glasshouse room maintained at 29° / 21° C (day/night) to the booting stage. Plants were subjected to low temperatures (15° / 15° C) in a growth chamber for 3-5 days, then transferred back to the glasshouse room.

Spikelet sterility was much lower in Fujisaka 5 than in IR36 at both low and normal temperatures (Table 1). In Fujisaka 5, increasing the phosphorus appeared to slightly increase spikelet sterility. In IR36, the effect of phosporus on spikelet sterility was negligible. In both varieties, phosphorus content in leaves indicated that phosphorus was defi-

cient at 0.5 ppm P, but normal at 2 ppm P and 5 ppm P. These results somewhat contradict those reported previously.

High temperature-induced sterility and phosphorus nutrition. The effect of phosphorus level on spikelet sterility induced by high temperature at flowering was studied, using solution culture technique. High temperature-tolerant N22 and susceptible BKN6624-46-2 were grown at 3 levels of phosphorus (0.5, 2, 5 ppm) in culture solution in a glasshouse room maintained at 29° / 21° C to a few days before flowering. Plants were subjected to high temperature (35° / 27° C) in a glasshouse room until flowering of tagged panicles was completed, then transferred back to the glasshouse room. High temperature induced lower spikelet sterility in N22 than in BKN6624-46-2 (Table 2). Increasing the phosphorus increased spikelet sterility of both varieties at 29° / 21° C, but affected spikelet sterility only slightly at 35° / 27° C. Varietal differences had a much more pronounced effect than amount of phosphorus.

Nitrogen-potassium interaction in low temperature-induced sterility. Because increasing the nitrogen supply increases spikelet sterility induced by low temperature, and increasing the potassium supply alleviates the spikelet sterility (Annual report for 1980), the interaction between nitrogen and potassium in low temperature-induced sterility at the booting stage was examined, using solution culture technique. Low temperature-tolerant Fujisaka 5 and susceptible IR36 were grown at 3 nitrogen × 3 potassium levels in culture solution in a glasshouse maintained at 29° / 21° C. At the booting stage, plants were subjected to 15° / 15° C in a growth chamber for 3 and 5 days, then transferred back to the glasshouse. There was a clear interaction between nitrogen and potassium (Table 3).

Increasing the nitrogen supply increased spikelet sterility in both varieties. Increasing the potassium supply counteracted the nitrogen effect by decreasing spikelet sterility. In a 3-day low-temperature treatment, spikelet sterility of Fujisaka 5 ranged from 7.5% for 10 ppm N × 40 ppm K to 49.8% for 80 ppm N × 2 ppm K. Spikelet sterility of IR36 varied from 17.2% for 10 ppm N × 40 ppm K to 76.5% for 80 ppm N × 2 ppm K. At the highest level of nitrogen (80 ppm), spikelet sterility of Fujisaka 5 decreased with increasing potassium, from 49.8% at 2 ppm K to 14.2% at 40 ppm K. In IR36, the trend was the same. Increasing the potassium supply significantly decreased the number of degenerated spikelets per panicle.

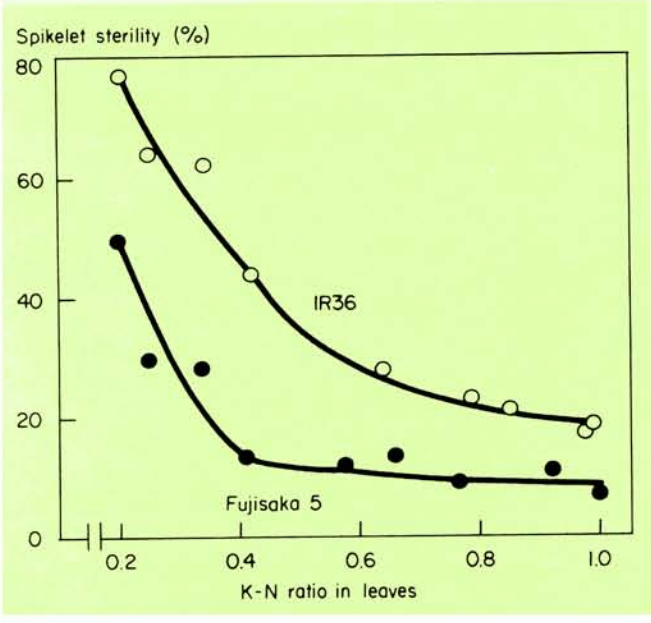
In the 5-day low-temperature treatments, low-temperature damage was severe and the effect of potassium was less pronounced than in the 3-day treatment.

Table 2. Effect of phosphorus on spikelet sterility induced by high temperature at heading. IRRI, 1981.

Day/night temp (°C)	Phosphorus level (ppm)	Spikelet sterility (%)	
		N22	BKN6624-46-2
29/21 (control)	0.5	9.4	8.6
	2.0	12.6	9.6
	5.0	16.1	11.9
35/26 (high)	0.5	20.2	89.6
	2.0	23.3	87.1
	5.0	25.1	84.6

Table 3. Effect of nitrogen and potassium on spikelet sterility induced by low temperature at booting. IRRI, 1981.

Duration	Day/night temp (°C)	Nitrogen x potassium levels (ppm)	Spikelet sterility (%)	
			Fujisaka 5	IR36
Control	29/21	10 x 2	2.8	8.5
		10 x 10	2.8	7.6
		10 x 40	2.2	7.9
		40 x 2	15.2	24.3
		40 x 10	2.2	14.6
		40 x 40	2.3	11.3
		80 x 2	27.0	36.3
		80 x 10	9.7	28.7
		80 x 40	4.9	17.1
3 days	15/15	10 x 2	11.9	21.1
		10 x 10	10.8	18.7
		10 x 40	7.5	17.2
		40 x 2	30.1	64.1
		40 x 10	14.3	43.9
		40 x 40	9.4	22.7
		80 x 2	49.8	76.5
		80 x 10	28.9	62.0
		80 x 40	14.2	28.4
5 days	15/15	10 x 2	36.0	66.8
		10 x 10	34.8	62.1
		10 x 40	28.4	56.4
		40 x 2	69.8	92.3
		40 x 10	39.9	89.1
		40 x 40	37.0	67.3
		80 x 2	62.3	94.9
		80 x 10	59.1	96.1
		80 x 40	51.1	73.3



3. Relationship between spikelet sterility and K-N ratio in leaves of plants subjected to 15° / 15° C (day/ night) for 3 days at booting. IRRI, 1981.

Potassium content in leaves and spikelet sterility correlated loosely. But when K-N ratio in leaves was plotted against spikelet sterility, the correlation improved (Fig. 3). In both varieties, spikelet sterility correlated inversely with K-N ratio in leaves. In Fujisaka 5, a K-N ratio of 0.4 is considered critical; below 0.4 spikelet sterility increases with a decrease in the K-N ratio. However, in IR36, a K-N ratio of 0.8 appears to be necessary to maintain low spikelet sterility. To tolerate low-temperature damage, IR36 requires more potassium than Fujisaka 5.

Mineral nutrition and growth duration. Day length and temperature largely control the length of time required from germination to flowering. But the plant's nutritional status to some extent modifies growth duration, perhaps because mineral nutrition affects date of flowering by affecting the growth rate.

Four varieties were grown with natural day length in a glasshouse maintained at 29° / 21° C. Varying levels of nutrient were supplied in the culture solution. To a limited extent, mineral nutrition modified date of flowering (Table 4). Nutrient supply and variety appeared to have some influence. With phosphorus, BKN6624-46-2 took 100 days (at high P) to 119 days (at low P) to flower; IR36 took from 80 days (at high P) to 83 days (at low P). With nitrogen, the flowering date of BKN6624-46-2 varied from 91 days (at high N) to 112 days after germination (low N). That of IR36 varied from 71 days (at high N) to 77 days (at low N). Potassium had very little effect on flowering in BKN6624-46-2. Flowering in Fujisaka 5 and N22 was only slightly affected by mineral nutrition. Thus, the effect of mineral nutrition on flowering is both variety and nutrient specific.

CALCIUM PEROXIDE AS AN OXYGEN SUPPLIER

Soil pH and seedling emergence. The rate of oxygen release from calcium peroxide-coated seed is dependent upon the pH of the medium surrounding the seed. When a medium is acid, the rate of oxygen release is fast; when alkaline, it is slow. Such differences may eventually affect seedling emergence. However, in soil the rate of diffusion may prevent such a reaction from proceeding as expected. Two soils with different pH values — Malinao (pH 3.2) and Maahas (pH 6.3) — were used to test the effect of soil pH on seedling emergence. Seeds were planted 1 cm deep in soil submerged in 5 cm water.

Seedling emergence from coated seeds was equally good in both soils (Fig. 4). In the first week after seeding, seedlings emerged faster in acid

Table 4. Effect of mineral nutrition on plant's flowering.

Nutrient level	Days to flowering			
	IR36	Fujisaka 5	N22	BKN6624-46-2
Low N	77	57	61	113
Medium N	72	55	64	93
High N	71	58	65	91
Low P	83	58	72	119
Medium P	81	60	66	102
High P	80	60	65	100
Low K	78	60	75	91
Medium K	76	59	66	93
High K	74	61	65	94

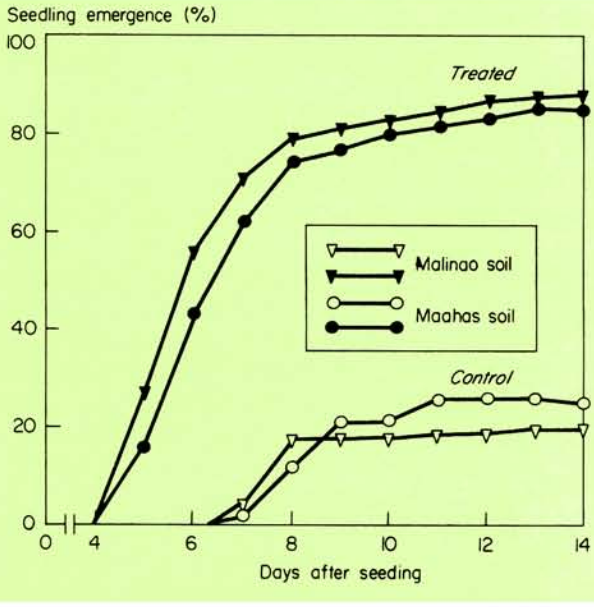
Malinao soil than in the neutral Maahas soil, suggesting that the oxygen release from calcium peroxide was faster in Malinao soil. Differences in seedling emergence became smaller over time. Two weeks after seeding, seedling emergence was about the same in both soils.

Seed-calcium peroxide ratio. Rice seeds normally are coated with calcium peroxide at 1:1 by weight. To test if it is possible to reduce the amount of calcium peroxide, calcium peroxide-seed ratios were varied from 0.2:1 to 1:1. Seedling emergence was highest at 1:1. However, at 0.5:1, seedling emergence was about 80% that at 1:1.

Seeding rates, weeds, and yield. Broadcast seeding rates usually range from 120 to 150 kg seeds/ha. Such traditionally high seeding rates are perhaps aimed at compensating for seed losses to rats and birds and for poor seedling emergence from undrained portions of a field. Field drainage at seeding also stimulates vigorous weed growth. In wet seeding, planting about 1 cm deep in the soil minimizes seed losses to rats and birds, and flooding the field at seeding time minimizes weed growth. It seems that use of calcium peroxide-coated seeds makes much lower seeding rates possible in wet-seeded rice.

Seeding rates were varied from 10 to 50 kg/ha to study the effects of seeding rate on stand establishment and weed population in the field. The field was not weeded. Emerged seedlings ranged from 51/m^2 for 10 kg seed/ha to 132/m^2 for 50 kg seed/ha with traditional broadcast seeding, and from 36/m^2 for 10 kg seed/ha to 125/m^2 for 50 kg seed/ha with wet seeding (Table 5). In transplanted rice, the number of hills is 25/m^2 at 20- × 20-cm spacing.

If seedlings are evenly distributed, 36 and 51 emerged seedlings/m^2 should be sufficient. At 40 days after seeding, the number of shoots ranged from 535 to 874/m^2 with traditional broadcast seeding and from 571 to 1,093/m^2 with wet seeding.



4. Seedling emergence of calcium peroxide-coated IR36 seeds from flooded Malinao and Maahas soils (seeding depth, 1 cm; water depth, 5 cm). IRRI greenhouse, 1981.

Table 5. Number of rice plants and shoots and weight of weeds 40 days after rice was seeded at different rates by the traditional broadcast method. IRRI, 1980 wet season.

Treatment[a]	Seeding rate (kg/ha)	Emerged plants (no./m²)	Shoots (no./m²)	Weed fresh wt (g/m²)		
				Broad-leaves	Grasses	Sedges
Uncoated (drained)	10	51	535	215	977	15
	20	93	745	165	620	28
	30	123	702	155	502	6
	50	132	874	108	376	0
Calcium peroxide-coated (flooded)	10	36	571	63	14	0
	20	64	845	116	25	0
	30	89	954	158	0	0
	50	125	1095	115	19	0

[a]Paddy was drained or flooded at broadcast seeding.

These numbers of tillers and main shoots are considered sufficient to achieve reasonably high yields.

There was a marked difference in population of weeds, particularly grasses, between the two direct seeding methods. Drainage stimulated growth of grasses in the traditional broadcast method; submergence curtailed it remarkably in the wet-seeded method.

Table 6. Yield of calcium peroxide-coated IR36 seeds broadcast at different rates. IRRI, 1981 dry season.

Seeding rate (kg/ha)	Grain yield[a] (t/ha)
10	5.13 b
20	5.62 ab
30	5.50 ab
50	6.22 a

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

A separate experiment of similar design in dry season examined how seeding density affects grain yield. Yields ranged from 5.13 t/ha with 10 kg seed/ha to 6.22 t/ha with 50 kg seed/ha (Table 6). Yield differences between seeding rates were not statistically significant. Even at 10 kg seed/ha, a yield of 5.13 t/ha is considered quite satisfactory.

It appears that seeding rates can be reduced to 20 kg/ha without reducing yield. When seeding rates are low, three practices are important: use of a high-tillering variety, even distribution of seeds, and adequate weed control.

Collaborative experiment. A collaborative experiment in Cagayan Integrated Agricultural Development Project, Philippines, compared several seeding methods in the field. Seedling emergence was as good with calcium peroxide-coated seeds sown in submerged soil as with traditional broad-

Table 7. Seedling emergence and yields under different seeding methods of IR36 with and without calcium peroxide seed coating. Cagayan Integrated Agricultural Development Project, Iguig, Cagayan, Philippines, 1981.

Paddy condition	Seed treatment	Planting method	Seedling emergence (no./m²)	Grain yield[a] (t/ha)
Submerged	Coated	Machine seeding	191	7.06 a
		Row seeding	187	6.55 a
		Broadcast	175	5.97 a
	Uncoated	Machine seeding	5	1.69 b
		Row seeding	13	1.88 b
		Broadcast	3	2.39 b
	–	Transplanting[b]	–	6.18 a
Drained	Uncoated	Broadcast	182	5.80 a

[a]Separation of means by Duncan's multiple range test at the 5% level. [b]20-day-old seedlings planted at 20- x 20-cm spacing.

cast seeding in drained field (Table 7). Yields differed between coated and uncoated seeds sown into submerged soils. With coated seeds, yields were comparable to or higher than yields with traditional broadcasting methods.

The result implies that using calcium peroxide-coated seeds permits the maintenance of water in the field, thereby minimizing undesirable weed growth and damage by birds and rats without reducing yield. In addition, seeding can be done even when it is raining or after the rainy season has started, providing greater operating flexibility in crop establishment.

Constraints on rice yields

Agricultural Economics and Agronomy Departments

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RAINFED RICE PRODUCTION

Agricultural Economics Department

Intensive study of the constraints to increased rainfed rice yields started in 1980-81 in Camarines Sur, Bicol, Philippines. Tarlac Province in Central Luzon was added in 1981-82. Two rainfed rice crops a year are possible in Bicol. Only one rainfed rice crop a year can be grown in Tarlac.

Two crops a year. The rainfed rice areas of Camarines Sur in Bicol was chosen for concentrated study because farmers there already grow two modern-variety crops a year and recommendations are available for rainfed rice production in the region. Although Bicol is one of the major rainfed rice-growing regions of the Philippines, yields are low — reported as 1.7 t/ha. The Bicol River Basin Development Authority, among others, coordinates the agricultural activities of government agencies in the region, so that an institution is in place to extend any benefits emerging from the research.

The study was located in three rainfed villages of Camarines Sur Province during the first and second crop seasons of 1980-81. The data were gathered through farm management record keeping-field surveys and yield-constraints experiments.

Characteristics of villages and survey respondents. Almost half (47%) of the rice area in Bicol is lowland rainfed. Camarines Sur produces almost 30% of the region's total rice output. About two-thirds of the Bicol River Basin area, which is being developed by the Bicol River Basin Development Authority, is in Camarines Sur. Pending full implementation of that project, a sizable proportion of the river basin remains rainfed, with 37% wetland and 15% dryland rice.

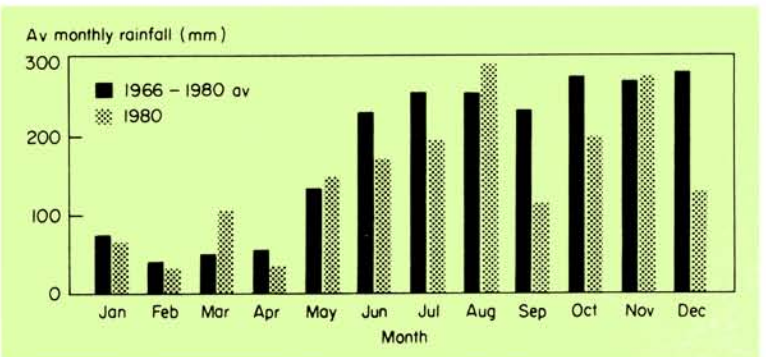
The municipality of San Fernando north of Naga, the provincial capital, was selected as the field site. Three villages — Planza, Beberon, and Lupi — were chosen for farm surveys and field experiments. A random sample of 42 owners and 42 tenants was selected from the 3 villages.

The 84 farmer cooperators were visited weekly to record input use, cultivation practices, and rice output data related to each respondent's largest rice parcel, termed the intensive data parcel (IDP). As many farmers only farm one parcel of land, the IDP usually was synonymous with a rice farm as a whole.

Single-visit surveys recorded farm inventories, farmer prices, yield constraints perceived by farmers, and credit use. Four barangay assistants acted as enumerators for both surveys. They also were responsible for recording work undertaken and moisture status of each sample IDP every 2 days.

During the second crop season (October-January), 24 constraints experiments were located in the 3 villages — 12 in Planza and 6 each in Beberon and Lupi. Half the experiments in each village were located on plateau-upper slopes and half on lowland plains.

Rainfall. The province has a mean annual rainfall of 1,812 mm (Fig. 1). The wet season usually begins in late May and ends in late December-early January. On the average, rainfall is evenly distributed June through December, providing 7 months of rainfall above 200 mm/month and farmers can plant 2 rainfed rice crops each year.



1. Average monthly rainfall at Pili, Camarines Sur, Philippines. Based on rainfall data for 15 years (1966-80).

Rainfall in 1980 was 1,470 mm, 340 mm below the 15-year average. Lower-than-average rainfall in September and October caused some moisture stress in second-season rice crops; lower-than-normal December rainfall stressed many crops approaching maturity. Late December-early January (1981) rainfall was above normal.

Land use. Information from barangay officials and the census survey is summarized in Table 1. All rice land in the villages was rainfed. A few farmers who had used pumpsets in the past no longer did so because of the high cost of pumping or because their wells had dried up.

Land area and land use. Official land surveys of the towns listed the total farm area of the villages as 203 ha for Planza, 187 ha for Beberon, and 137 ha for Lupi. In Planza, 80% of the farm area is planted to rice. In Beberon, 40% is under rice, 30% under coconut, and the remainder under sugarcane and other crops. In Lupi, 58% of the area is under rice and about 40% under coconut. Planza is predominantly a rice village because it is located entirely on rainfed rice lands; substantial portions of Beberon and Lupi are dryland.

The 3 barangays contained almost the same number of households, ranging from 143 in Beberon to 154 in Lupi. Beberon had the highest proportion of farm households (87%), Lupi the lowest (73%). The number of rice-farming households was somewhat larger in Planza (115) than in Beberon (94) or Lupi (90), reflecting the dominance of rice in Planza over the area under dryland crops in Beberon and Lupi. As a result, the average operational rice holding was somewhat larger in Planza (1.3 ha/household) than in Beberon or Lupi (0.8-0.9 ha/household).

Land tenure. Owner-operators and tenant-operators, the dominant land-tenure groups in the study area, account for more than 75% of all farm households. The proportion of owner-operators ranged from 36% in Lupi to 46% in Planza, that of tenant-cultivators was also one-third to one-half. Numbers of part-owners and mixed cultivators (tenants cum leaseholders) were similar in each barangay.

The most common sharing arrangement between tenant and landlord on tenanted rice farms is two-thirds:one-third. The tenant pays all production costs and is free to choose his production technology. Rice output is shared 2:1 between tenant and landlord after harvesters' shares have been deducted. Harvester shares range from one-ninth to one-eleventh, depending on kinship ties between harvester and farmer or landlord.

Rice area per farm. Rice farms in the study area are small by Philippine standards. Modal size was 0.60 ha. Only 4 farms in the sample cultivated more than 2 ha of rice and 75% of the farms were less than 1 ha. The distribution of farm owners was positively skewed, with a mode of 0.5 ha and a

Table 1. General characteristics of sample villages, San Fernando, Camarines Sur, Philippines, 1980-81.[a]

Item	Planza	Beberon	Lupi
Source of irrigation	Rainfed	Rainfed	Rainfed
Total area cultivated land (ha)	203.0	187.0	136.8
Estimated rice area (ha)	151.0	75.0	80.8
Estimated coconut area (ha)	10.0	62.0	55.0
Other crop area (ha)	32.0	50.4	26.0
Total no. of farm households	119.0	124.0	113.0
No. of rice farming households	115 (100)	94 (100)	90 (100)
Owner-cultivator	53 (46)	39 (41)	32 (36)
Tenant-cultivator	38 (33)	46 (49)	31 (34)
Part-owner	13 (11)	2 (2)	13 (14)
Others	11 (10)	7 (7)	14 (16)
Nonfarm households	30.0	19.0	41.0
Av size of operational holding per farm (ha)	1.7	1.5	1.2
Av size of operational holding for rice (ha)	1.3	0.8	0.9
No. of hand tractors	13.0	6.0	9.0
No. of small threshers	6.0	2.0	2.0
No. of small rice mills	2.0	2.0	3.0

[a]Source: Census conducted by IRRI Agricultural Economics Department Staff, July 1980.

mean of 0.78 ha. Distribution of tenanted land was normal, with a mode of 0.75 ha and a mean of 0.8 ha. The comparatively smaller modal farm size of owners than of tenants may reflect the relatively easier subdivision of owned than of tenanted land. Landlords probably prefer to deal with as few tenants as possible.

Dominant cropping patterns. The dominant cropping patterns in the three survey villages are sketched in Figure 2. Rice was wet seeded from late May; transplanting commenced in late June. Of the first-season rice crop, 53% was wet seeded. Most of the second-season crop was planted November to early December.

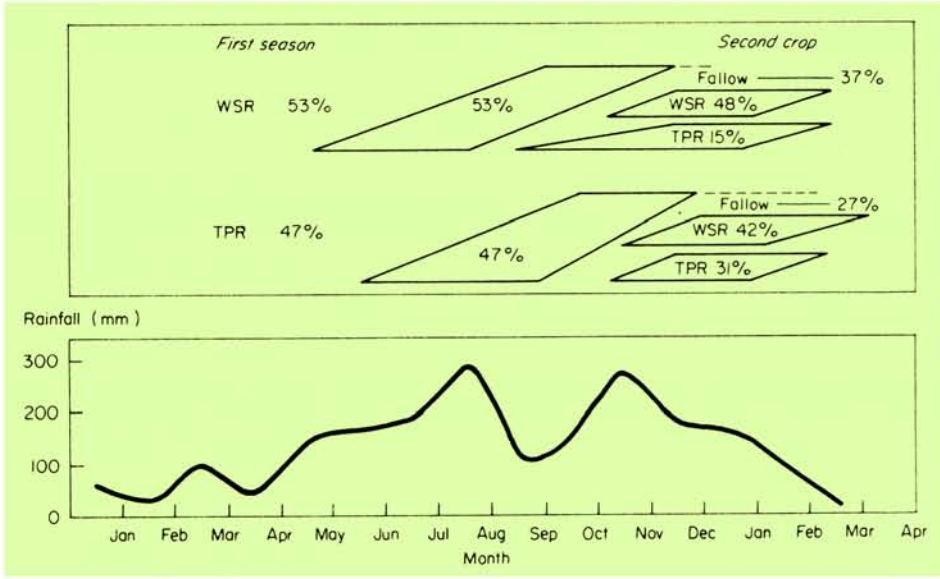
Over all, 68% of the area was double cropped. Most of the second crop was planted November through early December. Wet-seeded rice (WSR) was dominant, particularly on those fields that were in WSR in the first season. In the second season, 37% of WSR land was left fallow; in the first season, 27%.

Rice varieties. The use of modern varieties is widespread among all tenure groups (Table 2). For the first crop, over 70% of farmers planted only IR varieties. IR36 was dominant, followed by IR42 and IR747. A further 28% planted modern varieties and local varieties such as Malagkit, Benargais, and Javanese. The local varieties were grown primarily for home consumption and were planted on only a small portion of the farm.

For the second crop, all farmers planted at least one IR variety. Unlike in the first season, a number of farmers mixed varieties in the same paddy. One reason advanced for this management strategy was to reduce the risk of complete failure of the second-season crop. Sufficient information was not available to test this rationale.

Mechanized land preparation. A significantly higher proportion of part-owners than of owners or tenants used tractors for land cultivation (Table 3). More time was spent on mechanized land preparation in the second season (average 4.5 days/ha) than in the first (av 2.9 days/ha). All farms used carabao for land preparation, particularly for harrowing and final rolling of the field before seeding or transplanting.

Crop establishment. In general, about half of the first-season rice crop was direct seeded and half transplanted (Fig. 2). In the first season, a significantly larger proportion of owners and part-owners than of tenants wet seeded their rice crop. Method of establishing the second crop did not



2. Dominant cropping pattern at Camarines Sur field site (Jan 1980-Feb 1981). WSR = wet-seeded rice, TPR = transplanted rice.

Table 2. Use of modern and local varieties by farmers of different tenure groups, Camarines Sur, Philippines, 1980-81.

Variety	Farmers (%)			
	Owner	Tenant	Part-owner/ mixed	All
	First crop			
IR only	71	73	70	71
IR and local	27	27	30	28
Local only	2	0	0	1
	Second crop			
IR only	91	74	79	81
IR and local	9	26	21	19
Local only	0	0	0	0

differ significantly by land tenure.

In discussion with farmers, it appeared that the decision to wet seed or transplant was influenced by the water status of the paddy, whether or not the farmer had seedlings when a paddy was ready for transplanting, and the farmer's expectation of whether the crop might need to be replanted because of loss to drought or flooding. Those farmers who planted earliest (frequently the owners) also tended to direct seed because of the water status of the paddies and the risk of drought.

For the second crop, the method of crop establishment tended to be determined by the water status of paddies, which varied considerably, even between adjacent paddies. The incidence of wet seeding in Bicol is not a recent response to shortages of labor or higher labor cost. It has been practiced since pre-Hispanic times. The decision to wet seed or transplant, given current circumstances, probably is determined by biophysical, not economic, parameters.

Agrochemical inputs. Fertilizer use did not differ between tenure groups (Table 4). On the average, 12% of the sampled farmers applied fertilizer to the first crop, but only 5% to the second. The quantity of fertilizer applied by users (measured in terms of nitrogen + phosphorus + potassium) was low, on the average, 19 kg/ha for the first crop and 15 kg/ha for the second. The actual use of fertilizer is substantially below the inter-agency fertilizer recommendations for rainfed conditions (60-30-0 kg/ha).

Insecticides and herbicides are more widely used than fertilizer, and are used on the first crop more frequently than on the second. Insect control was commonly one foliar spray, costing an average $3.33-$3.72/ha. This implies an application of active ingredient at 0.2 kg/ha, well below the recommended 0.75 kg/ha. The most common herbicide used was liquid 2,4-D; butachlor is becoming more widely used.

Labor. Although more owners and part-owners than tenants used power tillers for land preparation and wet seeded their crop, the variation in the pattern of labor use among the three tenure classes was not significant (Fig. 3). Labor use for the first-season TPR was 103 days/ha. Significantly less labor (55 days/ha), was used for WSR (Table 5). Family labor provided over half the labor used to grow the crop.

Three operations — land preparation, transplanting, and harvesting and threshing — accounted for over 80% of labor use. Minimal labor was used for crop maintenance. Significantly more labor was used to prepare land for the DSR (47 days/ha) than for TPR (37 days/ha). However, significantly more labor was used to transplant than to wet seed the crop. It also took significantly longer to harvest WSR than TPR.

A similar pattern of labor use emerges for the second-season crop (Table 6). Labor inputs tend to be lower for the second crop — 43 days/ha for a

Table 3. Use of mechanized land preparation by tenure category, Camarines Sur, Philippines, 1980-81.

Crop	Owner	Tenant	Part-owner	All	X^2
		Adoption (%)			
First	41.0	30.0	90.0	50.0	11.13*
Second	35.0	34.0	84.0	42.0	9.97*
		Use by adopters (days/ha)			
First	3.2	2.2	1.8	2.9	–
Second	6.0	3.3	3.9	4.5	–

* = X^2 values significant at 5% level.

Table 4. Farmers' adoption and use of agrochemicals by tenure group and season, Camarines Sur, Philippines, 1980-81.

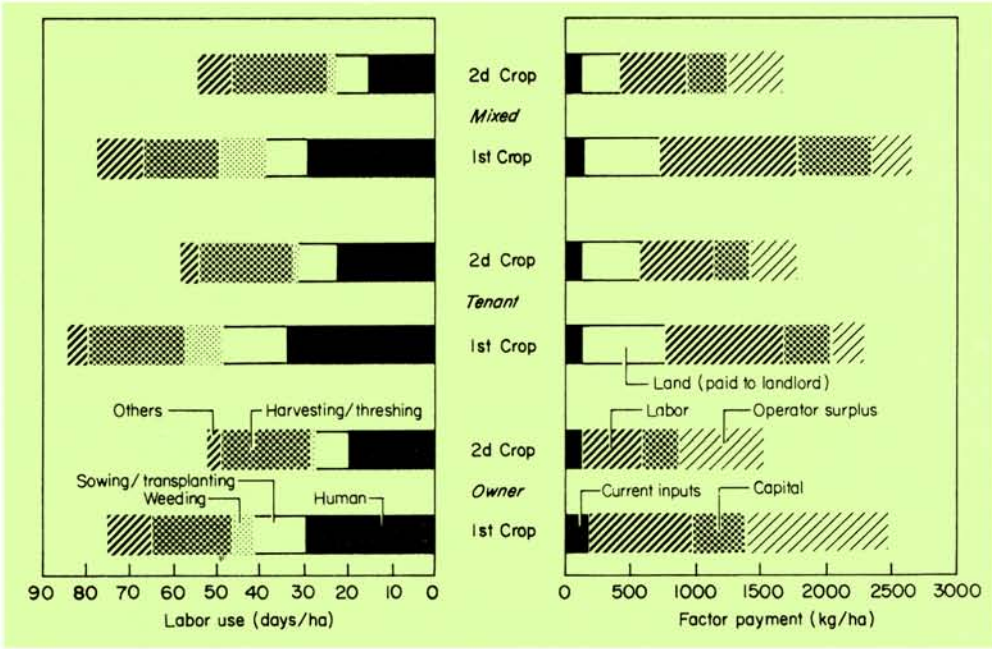
Tenure group	Adoption[a] (%)			Level of use		
	Fertilizer	Insecticide	Herbicide	Fertilizer (kg/ha)	Insecticide[b] ($/ha)	Herbicide[b] ($/ha)
			First season			
Owner	17	83	93	16	3.86	2.8
Tenant	6	70	91	29	3.20	3.33
Part-owner	10	100	100	24	4.66	4.4
All	12	80	93	19	3.86	3.2
X^2	2.11[ns]	4.79[ns]	1.12[ns]	–	–	–
			Second season			
Owner	3	42	48	6	3.60	2.00
Tenant	6	56	50	23	3.86	2.26
Part-owner	8	75	75	11	2.93	2.26
All	5	52	52	15	3.46	2.13
X^2	3.44[ns]	4.16[ns]	2.87[ns]	–	–	–

[a]ns = not significant at the 5% level. [b]US$1 = ₱7.50.

WSR crop and 79 days/ha for a transplanted crop — mainly because less time was spent on land preparation.

Rice yields. Mean rice yields did not differ by tenure groups in either season, but they did differ by method of crop establishment (Table 7). For the first crop, the average yield of tenant cultivators was 2.3 t/ha; owners obtained 2.5 t/ha and mixed-cultivators 2.7 t/ha. In general, second-crop yields averaged 1.6 t/ha, significantly lower than first-crop yields.

Mean yields differed significantly by crop estab-



3. Labor-use and cost-return structure by tenure and season, Camarines Sur, 1980-81.

Table 5. Labor inputs per hectare for direct-seeded and transplanted rice of farmers in 3 villages, Camarines Sur, Philippines. First crop, 1980-81.

Task	Direct seeded		Transplanted		Difference
	Days	%	Days	%	
Land preparation[a]					
Libmanan	25.7	47	38.0	37	12.3*
(Machine)	(1.4)		(0.8)		(-0.6)
(Animal)	(19.3)		(28.2)		(8.9)*
Sowing, transplanting	1.5	3	22.8	22	21.3*
Weeding	4.4	8	9.6	9	5.2
Harvesting and threshing	16.3	30	24.4	24	8.1*
Fertilizer and chemical application	0.6	1	1.1	1	0.5*
Others[b]	6.0	11	7.5	7	1.5
Total	54.5	100	103.4	100	48.9*
(Family)	(32.4)	(59)	(53.7)	(52)	(21.30)*
(Hired)	(22.1)	(41)	(49.7)	(48)	(27.60)*

[a] Includes clearing and repairing dikes. [b] Includes cleaning and hauling operations.

lishment under owner and tenant areas. For owners, the mean yield differences between WSR and transplanted rice (TPR) were 0.5 t/ha for the first crop and 0.6 t/ha for the second. About the same yield differences were obtained on share-tenanted farms. Therefore, the economic analysis focuses on the production systems for owners and tenants, the two dominant forms of tenure, and WSR and TPR crops.

An important issue is whether the method of crop establishment is the real reason for the significant difference in yields between WSR and TPR. An analysis of paddy water status (paddies with less than 20 days of stress were categorized low stress and those with more than 20 days of stress, high stress) versus method of crop establishment showed that wet seeding was most frequently used on fields with higher levels of moisture stress (Table 8). Thus, it was moisture stress rather than method of crop establishment that accounted for the significant yield difference.

Credit practices. Currently, rainfed areas in Bicol are excluded from the Masagana 99 credit program. Over half the owners and 37% of the tenants interviewed claimed they did not borrow money for farming purposes. The most frequent

Table 6. Labor inputs per hectare for direct seeded and transplanted rice of sampled farmers in 3 villages, Camarines Sur, Philippines, second crop, 1980-81.

Task	Direct seeded		Transplanted		Difference
	Days	%	Days	%	
Land preparation[a]					
Libmanan	17.1	40	24.5	31	7.4*
(Machine)	(2.4)		(1.9)		(-0.5)
(Animal	(12.8)		(18.3)		(5.5)*
Sowing, transplanting	1.3	3	20.8	26	19.5*
Weeding	1.0	2	0.5	1	-0.5
Harvesting and threshing	20.4	47	26.6	33	6.2*
Fertilizer and chemical application	0.7	2	0.8	1	0.1
Others[b]	2.6	6	6.5	8	3.9
Total	43.1	100	79.7	100	36.6*
(Family)	(22.2)	(52)	(40.4)	(51)	(18.2)*
(Hired)	(20.9)	(48)	(39.3)	(49)	(18.4)*

[a] Includes clearing and repairing dikes. [b] Includes cleaning and hauling operations.

Table 7. Mean rice yields by tenure, method of crop establishment and season, Camarines Sur, Philippines, 1980-81.[a]

Crop establishment method	Rice yield (t/ha)			All tenure groups
	Owner	Tenant	Part-owner	
	First crop			
Wet seeded	2.3	2.0	2.5	2.2
Transplanted	2.8	2.5	2.9	2.6
Difference	0.5*	0.5*	0.4	0.4*
	Second crop			
Wet seeded	1.4	1.5	1.6	1.5
Transplanted	2.0	2.2	2.0	2.1
Difference	0.6*	0.7*	0.4	0.6*

Table 8. Wet seeded rice (WSR) and water stress in paddy, first and second season, Camarines Sur, Philippines, 1980-81.

	Wet seeded crop (%)		X^2
	Low stress	High stress[a]	
First crop	42	78	7.07**
Second crop	48	84	23.77**

[a] Low moisture stress sites had less than 20 days of stress, high stress sites had more than 20 days.

sources of borrowing by owners were relatives and friends. Effective interest rates averaged 71% per year from relatives and 13% per year from friends.

Tenants and part-owners also most frequently borrowed money from relatives and friends, but at higher interest rates (108-116% a year). The different rates for owners and tenants suggest that possibly owners are given preferential rates because their status as land owners has a higher social position in the community.

The average credit level for all farmers was $97.69/ha in 1981. Yet the average cash outlay for two rice crops was $38.46/ha. This suggests that most of the loans reported were not being used for rice or, for that matter, for agricultural practices.

Economic analysis of rice production systems. The economic performance of WSR and TPR was evaluated by comparing input and output values for two tenure systems: owner and tenant-operator. The results are shown in Table 9 for the first crop, in Table 10 for the second. The tables show how per-hectare output was distributed among the factors used in growing the rice crop and what surplus (net profit) remained for the farm-operator after costs had been paid. In spite of the higher labor use for TPR, net profits were similar to those of WSR during the first crop and greater during the second. Even if profits were not higher with a transplanted first crop, the farm-operator benefited from increased return to farm-family labor.

The cost-return structure indicates in terms of factor shares that the share to capital was low and did not differ among farmers following either crop establishment method. Operator surplus ranged from 41-48% of total output for owner-cultivators to 8-27% for tenant-cultivators.

The economic advantages of TPR over WSR are shown more clearly when income shares to various factors of rice production are calculated. The income (value added) from rice production over two crops (1 year) and its distribution among various earners for the two planting methods are compared in Table 11. The income of $602.56/year from TPR was almost $166.66 higher than income from WSR. Operator's surplus increased absolutely for both owner-cultivators and tenants.

The increased income resulted from more intensive use of both farm family labor and hired labor for TPR. From the standpoint of the labor employment problem and welfare to society, transplanting may be the preferable practice. Weighted against it must be the trade-off of early crop establishment through wet seeding, which in turn increased the probability of a higher yielding, second-season rice crop.

One crop a year. A survey of 86 farmers provided information on existing systems of rice production in Tarlac.

Tarlac farmers regarded 1981 as a good-weather year. Early rains in May allowed land preparation and transplanting to be done by late June (Fig. 4). Rainfall was steady, with infrequent water stress. No major typhoons struck Tarlac while the crop was in the ground.

The majority (87%) of the farmers surveyed were leaseholders farming an average 1.9 ha of rainfed rice land each. The most widely grown rice variety was IR36 (54% of area surveyed), followed by IR50. Farmers do not grow a dryland crop before or after rice.

Production technology. Some 80% of the farmers used only carabao (which they owned) for land preparation; 13% used hand tractors; the remainder

Table 9. Cost-return structure of wet-seeded vs transplanted rice, by tenure, in 3 villages, Camarines Sur, Philippines, first crop, 1980-81.

	Factor payments[a] (kg/ha)		Factor shares (% of output)	
	Owner-cultivator	Tenant-cultivator	Owner-cultivator	Tenant-cultivator
	Wet-seeded rice			
Output rough rice	2259	2038	100	100
Factor payments:				
Current inputs	146	162	6	8
Land (paid to landlord)	–	598	–	29
Capital[b]	392	377	17	18
Labor: Total	647	704	29	35
(Hired)	(356)	(463)	(16)	(23)
(Family)	(291)	(241)	(13)	(12)
Operator surplus	1074	197	48	10
(Sample size)	(24)	(13)		
	Transplanted rice			
Output rough rice	2768	2465	100	100
Factor payments:				
Current inputs	183	114	7	5
Land (paid to landlord)	–	724	–	29
Capital[b]	399	361	14	15
Labor: Total	1053	1059	38	43
(Hired)	(577)	(641)	(21)	(26)
(Family)	(476)	(418)	(17)	(17)
Operator surplus	1133	207	41	8
(Sample size)	(17)	(20)		

[a]Measured in rice equivalents. [b]Sum of paid or imputed rentals of carabao, tractor, and other machines.

Table 10. Cost-return structure of wet-seeded vs transplanted rice, by tenure, in 3 villages, Camarines Sur, second crop, 1980-81.

	Factor payments[a] (kg/ha)		Factor shares (% of output)	
	Owner-cultivator	Tenant-cultivator	Owner-cultivator	Tenant-cultivator
	Wet-seeded rice			
Output rough rice	1354	1457	100	100
Factor payments:				
Current inputs	121	145	9	10
Land (paid to landlord)	–	355	–	24
Capital[b]	266	298	20	20
Labor: Total	363	494	27	34
(Hired)	(356)	(463)	(26)	(32)
(Family)	(7)	(31)	(1)	(2)
Operator surplus	604	165	44	10
(Sample size)	(29)	(18)		
	Transplanted rice			
Output rough rice	2007	2182	100	100
Factor payments:				
Current inputs	132	105	7	5
Land (paid to landlord)	–	558	–	26
Capital[b]	333	259	17	12
Labor: Total	711	650	35	30
(Hired)	(384)	(457)	(19)	(21)
(Family)	(327)	(193)	(16)	(9)
Operator surplus	831	610	41	27
(Sample size)	(11)	(14)		

[a]Measured in rice equivalents. [b]Sum of paid or imputed rentals of carabao, tractor, and other machines.

Table 11. Comparison of income per hectare per year and its share among earners by crop establishment and tenure, 3 villages, Camarines Sur, Philippines, 1980-81.

	Owner-cultivators		Tenant-cultivators	
	$/ha[a]	%	$/ha[a]	%
	Wet-seeded rice			
Value added[b]	494.53	100	453.73	100
Earners:				
Landlord	–		136.93	30
Farmer	393.73	83	225.07	50
(Capital[c])	(93.07)	(20)	(95.87)	(21)
(Labor)	(61.06)	(13)	(61.73)	(14)
(Operator surplus)	(227.63)	(50)	(67.47)	(15)
Hired laborer	808.00	17	(91.73)	20
	Transplanted rice			
Value added[b]	636.27	100	626.80	100
Earners:				
Landlord	–		182.00	29
Farmer	499.20	78	276.27	44
(Capital)	(104.67)	(16)	(93.20)	(15)
(Labor)	(113.87)	(18)	(89.87)	(14)
(Operator surplus)	(280.67)	(44)	(93.20)	(15)
Hired laborer	136.80	22	159.60	25

[a]US$1 = ₱7.50. [b]Output value less current input costs. [c]Return to hired capital included.

used a combination of animal and tractor power. Transplanting was mainly with hired labor (87%) or a combination of hired and family labor. The majority of farmers (84%) applied fertilizer at the 24 kg N/ha typical for the Philippines (Table 12). About 30% applied fertilizer basally, usually some 2 weeks after transplanting in the floodwater. Over a third of the sample surveyed did not weed their rice. Of those who did, hand and mechanical weeding were the dominant forms of weed control (22-27%). Few farmers used herbicides. Insecticides were applied by 92% of the farmers, about one-third the recommended level of 0.75 kg a.i./ha.

Mean yield was 3.5 t/ha. The yields obtained from crop cuts did not differ significantly from the 3.3 t/ha estimated by farmers during a postharvest survey.

Factors influencing rice yields. One paddy belonging to each survey farmer was monitored to assess the importance of managed and nonmanaged variables as yield determinants. The most prevalent insects were whorl maggot, armyworm, and leaffolder; the most prevalent diseases, bacterial leaf streak and bacterial leaf blight. Most paddies were weedy, rated over 6 on a 1-9 weed infestation scale.

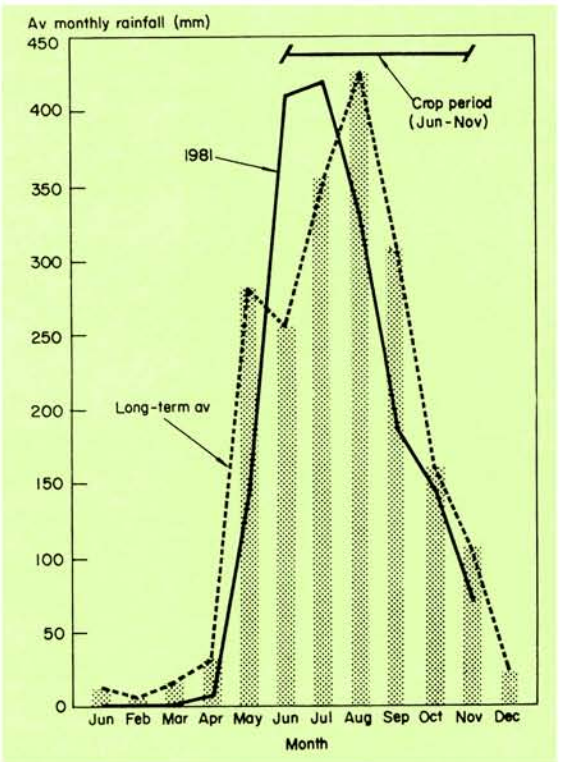
The important yield-limiting constraints identified by farmers are listed in Table 13. Twenty-six percent of the respondents perceived no major constraint for their 1981 rainfed rice crop. Fertilizer and weeds were mentioned as the dominant constraints. Most of the respondents did not think insects had reduced yields, but more than half of them identified weeds as a yield-limiting factor.

A response function estimate related on-farm rice yields to managed and site-related factors (Table 14). Although the model only explained 36% of the variability between paddy yields, significant factors included whether or not fertilizer was basally applied (this practice seemed to increase yields by 0.5 t/ha), land form position (yields on the upper land form were 0.3 t/ha lower than those on the lower slopes and valley bottom), soil test phosphorus, and level of weed infestation.

RETURNS TO CROPPING INPUTS

Agronomy and Agricultural Economics Departments

Farmers' practices in applying urea. Field evaluations of methods of applying three forms of urea continued.



4. Average monthly rainfall at Tarlac, Tarlac, Philippines. Based on rainfall data for 7 years (1975-81).

Table 12. Resource use in rainfed rice production, Tarlac crop year 1981.

Input	Unit	Level
Seedlings – age	days	28
– density	hills/m^2	33
Fertilizer – nitrogen (N)	kg/ha	24
– phosphorus (P_2O_5)	kg/ha	14
– potassium (K_2O)	kg/ha	5
Weed control – none	%	35
– hand	%	22
– mechanical	%	27
– chemical	%	10
– combination of above	%	6
Insect control – none	%	8
– 1 application	%	11
– 2 applications	%	32
– 3 applications	%	37
– over 4	%	20

Table 13. Constraints limiting rainfed rice yields identified by farmers, Tarlac 1981.

Most important constraint	Farmers reporting	
	No.	%
No problem	22	26
Low fertilizer rates	25	29
Weeds	20	23
Diseases, insects	4	5
Other	15	17

Table 14. Relationship between rainfed rice yields, site, and managed factors in Tarlac, 1981.

Variable	Partial regression coefficient[a]
Basal application of fertilizer	498.66*
Dummy for lower landscape position	315.46+
Available phosphorus (ppm Bray no. 2)	154.55**
Weed infestation score	-145.20*
Days of moisture stress	-31.17+
R^2	0.36
F-ratio	8.27**

[a] **, *, and + imply significance at 1, 5, and 10% level, respectively.

Nueva Ecija sites, 1981 dry season. In six irrigated trials, yields increased significantly with applied nitrogen (Table 15). Farmers' timing of nitrogen application (10 days after transplanting and 1 week after panicle initiation) resulted in significantly lower yields than researchers' timing (3 equal split doses).

Application methods were compared at 87 kg N/ha. Urea application in researchers' 2 and 3 splits and with a plowsole applicator gave yields comparable to those from point-placement (10- to 12-cm soil depth) of urea supergranules and of SCU broadcast and incorporated. Application of 116 kg N/ha as urea in 3 split doses did not give yields higher than application of 87 kg N/ha by all the other methods except the farmers' split.

In a separate experiment, farmers' timing of nitrogen application was compared with researchers' timing at three levels of nitrogen, using farmers' cultural practices and high cultural practices. Researchers' timing gave yields about 1 t/ha more than did farmers' timing at farmers', intermediate, and high levels of nitrogen, under both farmers' and high cultural practices levels (Table 16).

Laguna sites, 1981 dry season. Evaluation of forms of urea and methods of application continued on three irrigated farms. Treatments and

Table 15. Effect of sources and methods of nitrogen application on grain yield of rice in irrigated farms in 3 Philippine provinces, 1981 dry season.

Treatment	Grain yield[a] (t/ha)		
	Nueva Ecija	Laguna	Camarines Sur
No fertilizer nitrogen	4.6 d	4.4 b	4.2 d
Farmers' nitrogen level[b]			
Farmers' split[c] application	6.0 c	5.3 ab	6.3 c
Researchers' 3 equal split applications[d]	6.6 b	5.9 a	7.1 abc
87 kg N[e]/ha			
Farmers' split[c] application	5.9 c	5.5 a	6.2 c
Researchers' 3 equal split applications[d]	6.9 ab	5.6 a	6.9 bc
Researchers' 2 split applications[f]	7.0 ab	5.5 a	7.0 bc
Plowsole application	6.8 ab	5.6 a	6.8 bc
Supergranule point placement	6.8 ab	5.4 ab	7.2 ab
SCU broadcast and incorporated	7.2 ab	5.9 a	7.8 a
116 kg N[e]/ha			
Researchers' 3 equal split applications[d]	7.3 a	5.6 a	7.4 ab

[a]Av of 6 farms in Nueva Ecija, 3 farms in Laguna, and 4 farms in Camarines Sur. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]For Nueva Ecija sites – 80 kg N/ha; for Laguna – 90 kg N/ha; for Camarines Sur – 86 kg N/ha. [c]For Nueva Ecija – 10 days after transplanting (DT) and 5-7 days after panicle initiation; for Laguna – 18 and 57 DT; for Camarines Sur – 10 and 40 DT. [d]Basal broadcast and incorporated (BI), 20-30 DT, and 5-7 days before panicle initiation (DBPI). [e]As urea. [f]Two-thirds BI, and one-third at 5-7 DBPI.

Table 16. Effect on grain yields of farmers' and researchers' timing of nitrogen application at farmers', intermediate, and high levels of fertilizer nitrogen and at farmers' and high levels of cultural practices in experiments in irrigated farms, Philippines, 1981 dry season.

Sites (no.)	Cultural practices	Nitrogen applied (farmers' level)		Yield[a] (t/ha)					
		Rate (kg/ha)	Timing (DT)	Farmers' level		Intermediate		High	
				F	R	F	R	F	R
			Nueva Ecija						
6	Farmers'	90	10, 7[b]	4.8	5.8	4.5	5.3	5.2	6.1
6	High	90	10, 7[b]	5.5	6.4	5.1	6.0	5.9	6.7
			Laguna						
4	Farmers'	66	18, 57	5.9	6.2	6.0	6.3	6.3	6.8
4	High	66	18, 57	6.4	6.4	6.6	6.4	6.8	6.7
			Camarines Sur						
2	Farmers'	81	10, 40	5.2	5.2	5.1	5.0	5.3	5.3
2	High	81	10, 40	5.4	5.2	5.3	5.2	5.5	5.2

[a]Test rates of nitrogen: intermediate level – 60 kg N/ha, high level – 120 kg N/ha. F – farmers' timing of N application; R – researchers' timing – 3 equal split applications: basal broadcast and incorporated, 20-30 days after transplanting (DT), and 5-7 days before panicle initiation (DBPI). [b]Days after panicle initiation.

experimental procedures basically were the same as those used at the Nueva Ecija sites.

Researchers' 3 equal split applications at farmers' nitrogen level yielded 5.9 t/ha, farmers' split application (18 and 57 DT) yielded 5.3 t/ha (Table 15). At 87 kg N/ha, sulfur-coated urea (SCU) broadcast and incorporated produced 5.9 t/ha; researchers' 3 equal split applications and plowsole application yielded 5.6 t/ha. Farmers' timing of fertilizer application produced 5.5 t/ha, similar to the yield from researchers' 2 unequal split applications. Supergranule point placement produced 5.4 t/ha. Researchers' 3 equal split applications at 116 kg N/ha yielded 5.6 t/ha, equal to the yield at 87 kg

N/ha. Yield was 4.4 t/ha when no fertilizer nitrogen was applied. In general, yields were low because the crops were harvested in July, at the beginning of the wet season.

In a separate experiment, researchers' timing of fertilizer application yielded more than farmers' timing at all nitrogen levels (using farmers' cultural practices), with the difference larger at the high nitrogen rate (Table 16). With high cultural practices, both farmers' and researchers' timing produced similar yields.

Camarines Sur sites, 1981 dry season. Field trials on 4 irrigated farms used different forms and application methods of urea.

Without nitrogen, yields ranged from 3.6 to 5.3 t/ha, averaging 4.2 t/ha (Table 15). Researchers' 3 equal split nitrogen applications had a yield advantage of 0.8 t/ha over farmers' traditional timing.

Urea applied with the plowsole fertilizer applicator produced yields that ranged from 6.0 to 7.5 t/ha and averaged 6.8 t/ha. Urea supergranules placed in the root zone 4 DT produced an average yield of 7.2 t/ha. Basal application of SCU gave the highest average yield in all sites, 7.8 t/ha. Yields with 116 kg N/ha applied in 3 equal splits did not differ significantly from yields with 87 kg N/ha applied by all other methods except the farmers' split.

In a separate experiment, farmers' timing of nitrogen was further compared with researchers' timing at three levels of nitrogen. On two irrigated farms, yields were similar under the three nitrogen levels for both farmers' and researchers' timing and under farmers' and high cultural practices (Table 16).

Yield response to major farm inputs. *Nueva Ecija sites, 1981 dry season.* Dry-season experiments on six farmers' fields evaluated responses of wetland rice to type of fertilizer (N, P, K, and NPK), nitrogen level, insect control strategies, zinc, and fungicide treatment. The levels of inputs used by the six cooperating farmers are in Table 17.

Average yields at 80 kg N/ha were comparable to those at 120 kg N/ha and farmers' fertilizer level (83 kg N/ha) (Table 18). Of the three fertilizer nutrients studied in the test sites, only nitrogen appeared to be limiting (Table 19). Plots that did not receive nitrogen produced the lowest yields; those that did not receive phosphorus or potassium and those receiving complete fertilizer at 120-45-45 kg NPK/ha gave comparable yields. Dipping seedling roots in 2% ZnO suspension in water before transplanting gave no added yield advantage over untreated seedlings (Table 20), indicating that the test sites were not zinc deficient for rice (soil pH levels varied from 5.2 to 6.5).

Plots with high-level insect control significantly outyielded both the plots with the pest management strategy and those with farmers' insect control level (Table 21). There were no serious disease incidences at the test sites during the dry season and both untreated plots and plots with disease protection gave similar yields (Table 22). The yield gap between farmers' inputs and high inputs was 1.0 t/ha (Fig. 5, Table 23).

Laguna sites, 1981 dry season. Levels of inputs in dry-season experiments on 4 irrigated farms are shown in Table 17.

Yields with farmers' level of fertilizer were comparable to yields with 80 and 120 kg N/ha (Table 18). Applying NPK at 120-45-45 kg/ha produced 6.5 t/ha, similar to the yields of the no-phosphorus and no-potassium treatments (Table 19). Without nitrogen fertilizer, yield was 2.2 t/ha lower. Dipping seedling roots in 2% ZnO suspension before transplanting resulted in a 0.5 t/ha reduction in yield (Table 20). However, the yield reduction was not significant. Yield with the application of a fungicide to control diseases was similar to that without (Table 22). High-level insect control produced 6.2 t/ha, farmers' level 6.0 t/ha (Table 21).

Camarines Sur sites, 1981 dry season. Experiments on three irrigated farms evaluated the response of transplanted rice to nitrogen, phosphorus, and potassium; three insect control strategies; and zinc and fungicide treatments. Farmers' levels of fertilizer averaged 87 kg N/ha, 8 kg P_2O_5/ha, and 8 kg K_2O/ha (Table 17). Farmers' insect control consisted mainly of foliar sprays, with an average of 1.6 applications.

Yields at farmers' and test levels of nitrogen are given in Table 18. Complete fertilizer (NPK at 120-45-45 kg/ha) produced the highest yields (6.1-8.0 t/ha), with an average of 7.2 t/ha. Without fertilizer nitrogen, yields decreased by 3.3 t/ha. Without phosphorus in the fertilizer package yields decreased by 0.3 t/ha; without potassium yields decreased by 0.1 t/ha (Table 19).

Dipping seedlings in 2% ZnO suspension before

Table 17. Levels of inputs used in yield response trials in farmers' fields in 4 Philippine provinces, 1981.

Province	Input level	Sites (no.)		Fertilizer[a] (kg/ha)			Insect control[b] applications (no.)	
		Irrigated	Rainfed	N	P_2O_5	K_2O	F	G
			Dry season					
Nueva Ecija	Farmers'	6	0	83	36	29	1.7	0.5
Nueva Ecija	Intermediate	6	0	80	45	45	1.7	0.7
Nueva Ecija	High	6	0	120	45	45	2.3	2.0
Laguna	Farmers'	4	0	84	5	5	1.5	0.0
Laguna	Intermediate	4	0	80	45	45	0.0	2.0
Laguna	High	4	0	120	45	45	2.0	3.0
Camarines Sur	Farmers'	3	0	87	8	8	1.6	0.0
Camarines Sur	Intermediate	3	0	80	45	45	1.3	0.0
Camarines Sur	High	3	0	120	45	45	2.0	2.0
			Wet season					
Tarlac	Farmers'	0	10	13	8	3	1.2	0.0
Tarlac	Intermediate	0	10	40	30	30	0.0	2.0
Tarlac	High	0	10	80	30	30	2.0	3.0
Camarines Sur								
Libmanan	Farmers'	11	3	20	5	5	1.3	0.1
Libmanan	Intermediate	11	3	34	30	30	1.1	0.0
Libmanan	High	11	3	69	30	30	2.6	2.0
San Fernando	Farmers'	0	13	12	7	0	2.0	0.0
San Fernando	Intermediate	0	13	40	30	30	2.3	0.0
San Fernando	High	0	13	80	30	30	2.2	1.9

[a]Time of N application for intermediate and high levels: dry season – 3 equal split doses: basal broadcast and incorporated (BI), 20-30 days after transplanting (DT), and 5-7 days before panicle initiation (DBPI); wet season – 2 equal split doses: BI and 5-7 DBPI. Phosphorus and potassium were applied basally. [b]Data show average number of foliar (F) sprays (azodrin, gusathion, parapest, etc.) or of granular (G) applications (lindane, furadan, diazinon, etc.) to paddy water. The main field crop was treated and in some cases, seedbeds also.

Table 18. Average grain yields at varying nitrogen levels from experiments in farmers' fields in 4 Philippine provinces, 1981.

Province	Sites (no.)		Grain yield (t/ha)				
	Irrigated	Rainfed	Farmers' level	0 N	40 kg N/ha	80 kg N/ha	120 kg N/ha
			Dry season				
Nueva Ecija	6	0	6.3 b	4.7 c	–	6.6 ab	7.0 a
Laguna	4	0	6.3 a	4.3 a	–	6.4 a	6.5 a
Camarines Sur	3	0	5.8 b	3.9 c	–	6.6 ab	7.2 a
			Wet season				
Tarlac	0	10	5.3 b	5.5 b	6.1 a	6.2 a	–
Camarines Sur							
Libmanan	11	3	4.3 b	4.4 b	5.0 a	5.2 a	–
San Fernando	0	13	4.3 b	4.1 b	4.9 a	5.2 a	–

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. Data are averages of 3 levels of insect control. The corresponding input levels are given in Table 17. In Libmanan sites, N rate for intermediate level was 34 kg/ha, that for high level 69 kg/ha.

transplanting did not significantly increase yield (Table 20), indicating that the test sites were not zinc deficient for rice. The high-level insect control gave significantly higher yields than both the farmers' insect control and pest management strategy levels (Table 21).

Because there was no serious incidence of rice diseases during the dry season, fungicide application resulted in no significant yield increase (Table 22). The yield gap for 3 farms varied from 1.4 to 2.5 t/ha, with an average 2.0 t/ha (Fig. 5, Table 23).

Tarlac sites, 1981 wet season. Studies from 1974 to 1980 on constraints to high rice yields in farmers' fields primarily focused on irrigated farms. Begin-

Table 19. Yield response to nitrogen, phosphorus, and potassium at 3 levels of insect control in farmers' fields in 4 Philippine provinces, 1981.

Province	Sites (no.)		Grain yield[a] (t/ha)			
	Irrigated	Rainfed	NPK	PK	NK	NP
			Dry season			
Nueva Ecija	6	0	7.0 a	4.6 b	6.9 a	6.9 a
Laguna	4	0	6.5 a	4.3 b	6.6 a	6.4 a
Camarines Sur	3	0	7.2 a	3.9 b	6.9 a	7.1 a
			Wet season			
Tarlac	0	10	6.2 a	5.5 b	6.0 a	6.0 a
Camarines Sur						
Libmanan	11	3	5.2 a	4.4 c	4.7 b	5.0 a
San Fernando	0	13	5.2 a	4.1 c	4.6 b	5.0 a

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. Fertilizer levels: dry season – 120 kg N/ha, 45 kg P_2O_5/ha, and 45 kg K_2O/ha; wet season – 80 kg N/ha, 30 kg P_2O_5/ha, and 30 kg K_2O/ha. N rate for Libmanan sites was 69 kg/ha.

Table 20. Effect of zinc-treated seedlings (seedling dip in 2% ZnO suspension) on the grain yield of rice at 3 levels of insect control. Philippines, 1981.

Province	Sites (no.)		Grain yield (t/ha)		
	Irrigated	Rainfed	Untreated control	Zinc-treated seedlings	Difference[a]
			Dry season		
Nueva Ecija	6	0	7.0	7.1	0.1^{ns}
Laguna	4	0	6.5	6.0	-0.5^{ns}
Camarines Sur	3	0	7.2	7.3	0.1^{ns}
			Wet season		
Tarlac	0	10	6.2	6.2	0.0^{ns}
Camarines Sur					
Libmanan	11	3	5.2	5.2	0.0^{ns}
San Fernando	0	13	5.2	5.1	-0.1^{ns}

[a]ns = not significant.

Table 21. Average grain yield at 3 levels of insect control from yield-constraints experiments in farmers' fields in 4 Philippine provinces, 1981.

Province	Sites (no.)		Grain yield[a] (t/ha)		
	Irrigated	Rainfed	Farmers' level	Pest management strategy	High level
			Dry season		
Nueva Ecija	6	0	6.5 b	6.3 b	6.9 a
Laguna	4	0	6.0 b	6.1 ab	6.2 a
Camarines Sur	3	0	6.3 b	6.4 b	6.8 a
			Wet season		
Tarlac	0	10	5.8 b	5.8 b	6.1 a
Camarines Sur					
Libmanan	11	3	4.8 b	4.8 b	5.1 a
San Fernando	0	13	4.7 b	4.7 b	5.0 a

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

Table 22. Effect of fungicide applications on grain yields at 3 levels of insect control in experiments in farmers' fields in 4 Philippine provinces, 1981.

Province	Sites (no.)		Grain yield (t/ha)		
	Irrigated	Rainfed	Untreated control	With fungicide application	Difference[a]
		Dry season			
Nueva Ecija	6	0	7.0	7.1	0.1[ns]
Laguna	4	0	6.5	6.4	-0.1[ns]
Camarines Sur	3	0	7.2	7.1	-0.1[ns]
		Wet season			
Tarlac	0	10	6.2	6.1	-0.1[ns]
Camarines Sur					
Libmanan	11	3	5.2	5.2	0.0[ns]
San Fernando	0	13	5.2	5.1	-0.1[ns]

[a]ns = not significant.

Table 23. Yields at farmers', intermediate, and high levels of inputs in yield-constraints experiments in farmers' fields in 4 Philippine provinces, 1981.

Province	Sites (no.)		Grain yield[a] (t/ha)			
	Irrigated	Rainfed	Farmers' inputs	Intermediate inputs	High inputs	Yield gap
		Dry season				
Nueva Ecija	6	0	6.3	6.4	7.3	1.0
Laguna	4	0	6.1	6.4	6.7	0.6
Camarines Sur	3	0	5.6	6.7	7.6	2.0
		Wet season				
Tarlac	0	12	5.1	6.1	6.6	1.5
Camarines Sur						
Libmanan	13	3	4.1	4.8	5.4	1.3
San Fernando	3	13	4.3	4.9	5.5	1.2

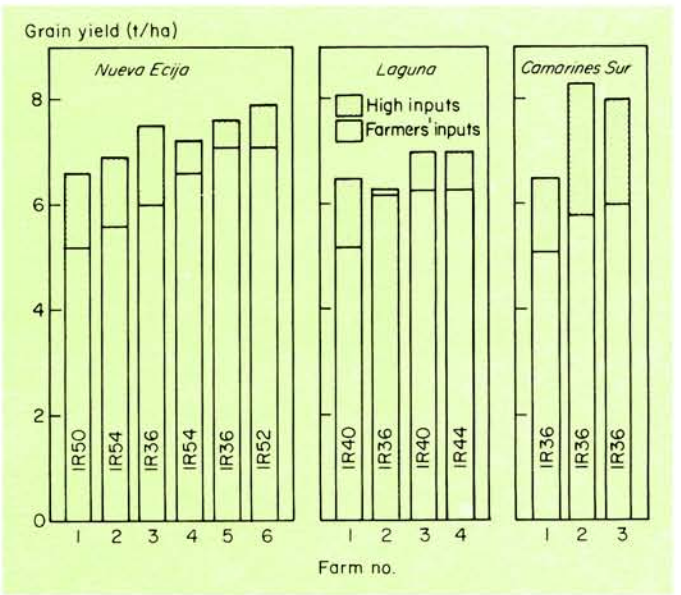
[a]The corresponding levels of inputs are given in Tables 17 and 25 for dry- and wet-season trials, respectively.

ning in 1981, emphasis during the wet season shifted to rainfed areas.

Wet-season experiments on 10 farms evaluated complete fertilizer application, removal of one major nutrient element at a time, fungicide treatment, and 3 insect control strategies. The average amount of nitrogen applied was 13 kg/ha (Table 17), with 50% of the farmers not applying any. Four out of five farmers did not apply fertilizer because animal manure from a nearby piggery farm was carried to their farms by flowing rain water. Insecticide applications averaged one foliar spray. No farmer applied granular insecticide.

Yields from farmers' application of fertilizer were not significantly different from yields without fertilizer N, but were significantly lower than yields with 40 and 80 kg N/ha (Table 18). Application of NPK at 80-30-30 kg/ha produced the highest grain yield, 6.2 t/ha (average of 3 insect control levels) (Table 19).

No-phosphorus and no-potassium treatments had lower yields, 6.0 t/ha, but the differences were not significant. Removal of nitrogen fertilizer significantly reduced grain yields by 0.7 t/ha. Dipping the seedlings in 2% ZnO suspension before transplanting did not increase grain yields (Table 20). Application of a fungicide did not affect grain yield (Table 22). Bacterial leaf streak and sheath blight



5. Yield gap differences among farmers' fields. Yield-constraints studies in 3 Philippine provinces, 1981 dry season. (Each bar represents 1 farm.)

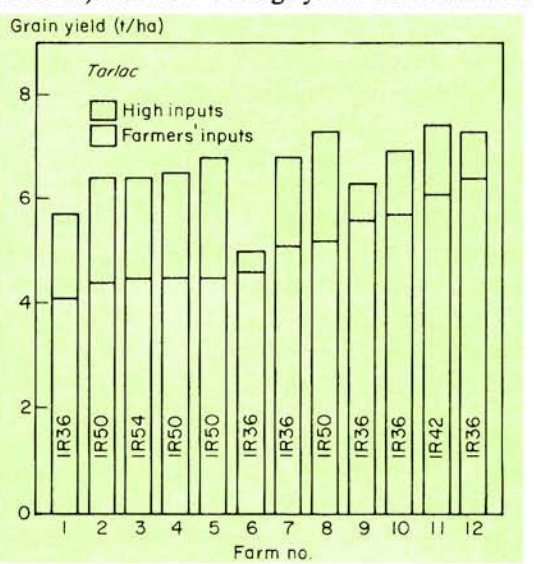
were the diseases observed in the area. High-level insect control significantly increased yield over farmers' insect control (Table 21). Yields with farmers' insect control and pest management strategy were similar. The average yield gap in the test sites was 1.5 t/ha (Table 23).

In a separate experiment, the average yield gap in the test sites was 2.1 t/ha (Fig. 6, Table 24). High fertilizer levels contributed 1.0 t/ha to the gap; high weed control, 0.6 t/ha; and high insect control, 0.3 t/ha.

Camarines Sur (Libmanan) sites, 1981 wet season. In the Libmanan area, 19 wet-season trials on yield response to major farm inputs were installed under 4 water regimes — 5 in rainfed, 2 in flood-prone, 6 in old-irrigated, and 6 in newly irrigated areas. Yield data were collected from only 14 sites. Two rainfed and one old irrigated trials were abandoned because of acute water shortage. Severe lodging resulting in submerged panicles destroyed one trial each in the flood-prone and new-irrigated areas.

Average levels of inputs, particularly fertilizer, applied by cooperating farmers were extremely low (Table 17). Six of 14 farmers (3 rainfed, 2 newly irrigated, and 1 old irrigated) did not apply any fertilizer at all. Most farmers controlled weeds by spraying herbicides. Twelve of 14 farmers used foliar insecticides to control insects. Granular insecticide use was not common.

Yields at varying levels of nitrogen are shown in Table 18). Farmers' average yields were similar to



6. Yield gap differences among farmers' fields. Farm yield constraints studies in rainfed sites, Tarlac, Philippines, 1981 wet season. (Each bar represents 1 farm.)

Table 24. Relative contributions of 3 inputs (fertilizer, insect control, and weed control) toward the improvement of rice yields in farmers' fields in 3 project areas in the Philippines, 1981 wet season.

Province	Sites (no.)		Grain yield (t/ha)			Contribution[a] (t/ha) of			
	Irrigated	Rainfed	Farmers' inputs	High inputs	Difference	Fertilizer	Weed control	Insect control	Residual
Tarlac	0	2	4.5	6.6	2.1	1.0	0.6	0.3	0.2
Camarines Sur									
Libmanan	8	1	4.1	5.5	1.4	0.8	0.2	0.5	-0.1
San Fernando	3	0	4.9	6.1	1.2	0.8	0.1	0.4	-0.1

[a]Measured as yield decrease from high input due to a reduction from high to farmers' level of each input.

the yields of plots that received no nitrogen. The yield increase (0.6 t/ha) from applied nitrogen was significant. Increasing the rate of nitrogen to 69 kg/ha did not substantially increase yield. Among the fertilizer combinations tested, NPK at 69-30-30 kg/ha gave an average yield of 5.2 t/ha (Table 19). Yield response to phosphorus application was significant but that to potassium was not. Without nitrogen, yields were reduced by as much as 0.8 t/ha. Yield of zinc-treated seedlings (seedling root dip in 2% ZnO suspension before transplanting) were not any higher than that of untreated seedlings, indicating that zinc deficiency is not a constraint to high rice yields at the test sites (Table 20).

High-level insect control produced an average yield of 5.1 t/ha, significantly higher than did farmers' level and pest management strategy (Table 21). Such rice diseases as Helminthosporium leaf spot, bacterial leaf streak, and leaf blight were observed on some farms during the late reproductive stage. However, the average yield from plots with one fungicide treatment was similar to that from the untreated check (Table 22).

RD 19, a newly developed, photoperiod-sensitive variety for deepwater areas, was planted in two flood-prone sites to compare its performance with that of the farmers' variety at high fertilizer levels. RD 19 was completely destroyed at the milk stage when the crop lodged and was submerged in more than 1 m of floodwater from a strong typhoon.

A minifactorial trial also was conducted in the new study area to determine the magnitude of the yield gap and the relative contribution of test factors (fertilizer, insect control, and weed control) to the yield gap. The yield gap was identified from 16 trials — 9 from minifactorial and 7 from yield response to major farm inputs. Three sites were in the rainfed area, six in the old irrigated area, six in the new irrigated area, and one in a flood-prone area. Of 16 cooperating farmers, 8 did not apply any fertilizer. Most farmers controlled weeds by at least one herbicide application. Others did hand weeding. Farmers sprayed their crop with foliar insecticides at least once. Only one farmer applied additional granular insecticide. Input levels are given in Table 25.

Farmers' yields ranged from 1.5 t/ha to 6.3 t/ha (Fig. 7), averaging 4.1 t/ha (Table 23). With high inputs, yields varied from 2.7 t/ha to 6.9 t/ha, with an average of 5.4 t/ha. Yields with intermediate inputs ranged from 2.3 t/ha to 6.9 t/ha, averaging 4.8 t/ha. The average yield gap was 1.3 t/ha.

The two lowest yields from each of the three input levels were from rainfed trials (Fig. 7). Low yields from the rainfed sites were associated with insufficient moisture during the vegetative and reproductive stages.

Two sites (farms 3 and 4) from the newly irrigated area gave the next two lowest yields with farmers' inputs because farmer-cooperators did not apply any fertilizer. Other farmers who applied low levels of fertilizer or no fertilizer produced high yields, suggesting that the soils were quite fertile.

The contribution of separate inputs to the yield gap was determined from nine minifactorial trials: five in newly irrigated area, three in old-irrigated area, and one in rainfed area. Of the nine farmer-cooperators, only four applied fertilizer and eight applied both weed and insect control measures. The rainfed farmer did not apply any fertilizer or control weeds and insects. Average input levels are summarized in Table 26.

On the average, high inputs outyielded farmers' inputs by 1.4 t/ha (Table 24). Of this yield differ-

Table 25. Levels of inputs used in yield-constraints experiments in farmers' fields in 3 project areas in the Philippines, 1981 wet season.

Province	Input level	Sites (no.)		Fertilizer[a] (kg/ha)			Weed control[b]		Insect control[c]	
		Irrigated	Rainfed	N	P_2O_5	K_2O	M	C	F	G
Tarlac	Farmers'	0	12	17	9	5	0.1	0.2	1.3	0.0
Tarlac	Intermediate	0	12	40	30	30	1.0	1.0	0.0	2.0
Tarlac	High	0	12	80	30	30	1.0	1.0	2.0	3.0
Camarines Sur										
Libmanan	Farmers'	13	3	18	5	5	0.4	0.9	1.2	0.1
Libmanan	Intermediate	13	3	35	30	30	1.0	1.0	1.2	0.0
Libmanan	High	13	3	70	30	30	1.0	1.0	2.6	2.0
San Fernando	Farmers'	3	13	13	7	0.8	0.1	1.2	2.0	0.0
San Fernando	Intermediate	3	13	40	30	30	0.1	1.0	2.1	0.0
San Fernando	High	3	13	80	30	30	0.1	1.0	2.4	1.9

[a]Time of N application for intermediate and high levels: 2 equal split doses – broadcast and incorporated and 5-7 days before panicle initiation. Phosphorus and potassium were applied basally. [b]Av number of mechanical (M) weeding, either by handweeding or by rotary weeder, and chemical (C) herbicide applications. [c]Average number of foliar (F) sprays (azodrin, gusathion, parapest, etc.) or of granular (G) applications (lindane, furadan, diazinon, etc.) to paddy water. The main field crop was treated and in some cases, seedbeds also.

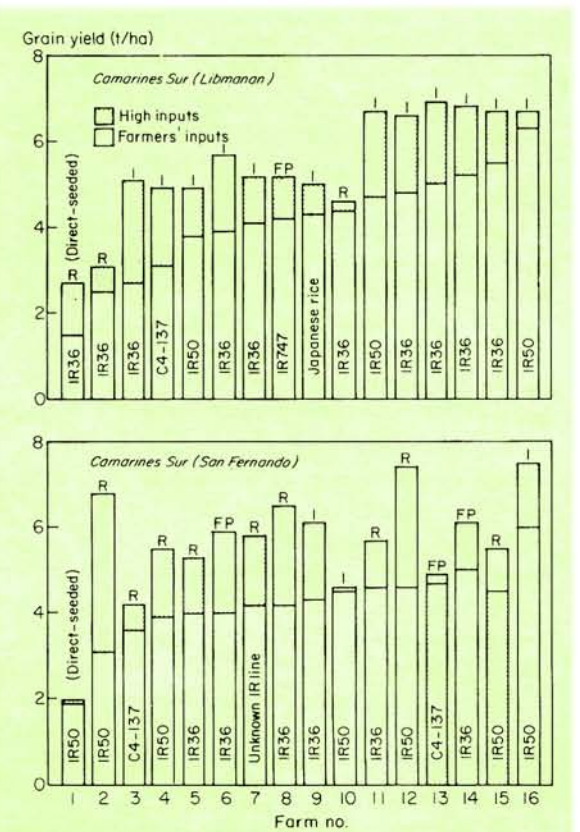
ence, improved fertilizer application contributed 0.8 t/ha (53%) and improved insect control accounted for 0.5 t/ha (34%) (Fig. 8). Improved weed control made only a modest contribution to the yield gap.

Camarines Sur (San Fernando) sites, 1981 wet season. Experiments in San Fernando, Camarines Sur, were conducted in three water regimes — rainfed drought prone, rainfed flood prone, and intermediate. Treatments and methodology were basically the same as in the dry season, except for an additional treatment in flood-prone sites to test the performance of RD 19.

Because most farmers did not apply fertilizers, the average rate of fertilizer application was low, 12 kg N/ha and 7 kg P_2O_5/ha (Table 17). None of the 13 farmers applied potassium fertilizer. Crops were protected from insect pests by an average of two foliar sprays. Farmers applied preemergence herbicide to control weeds.

Yields at farmers' and test levels of nitrogen are given in Table 18. Yields under farmers' nitrogen level averaged 4.3 t/ha. Without fertilizer nitrogen, yields averaged 4.1 t/ha; at 40 kg N/ha, 4.9 t/ha. Increasing nitrogen to 80 kg N/ha produced yields similar to those obtained at 40 kg N/ha.

Response to the fertilizer combinations are given in Table 19. Application of complete fertilizer (NPK at 80-30-30 kg/ha) produced the highest yield (5.2 t/ha). Without fertilizer nitrogen, yields were 1.1 t/ha lower. Without phosphorus yields



7. Yield gap differences among farmers' fields. Farm yield constraints studies in 2 project areas in Camarines Sur, Philippines, 1981 wet season. (Each bar represents 1 farm.) R = rainfed, I = irrigated, FP = flood prone.

Table 26. Farmers' and high levels of inputs used in minifactorial trials in farmers' fields in 3 project areas in the Philippines, 1981 wet season.

Province	Input level	Sites (no.)		Fertilizer[a] (kg/ha)			Weed control[b]		Insect control[c]	
		Irrigated	Rainfed	N	P_2O_5	K_2O	M	C	F	G
Tarlac	Farmers'	0	2	36	17	14	0.0	0.5	2.0	0.0
Tarlac	High	0	2	80	30	30	1.0	1.0	2.0	3.0
Camarines Sur										
Libmanan	Farmers'	8	1	18	7	7	0.3	1.2	1.4	0.1
Libmanan	High	8	1	71	30	30	1.0	1.0	2.8	2.0
San Fernando	Farmers'	3	0	18	4	4	0.0	1.0	2.0	0.0
San Fernando	High	3	0	80	30	30	0.0	1.0	3.0	2.0

[a]Time of nitrogen application for intermediate and high levels: 2 equal split doses — broadcast and incorporated and 5-7 days before panicle initiation. Phosphorus and potassium were applied basally. [b]Average number of mechanical (M) weedings, either by hand or by rotary weeder, and chemical (C) herbicide applications. [c]Average number of foliar (F) sprays (azodrin, gusathion, parapest, etc.) or of granular (G) applications (lindane, furadan, diazinon, etc.) to paddy water. The main field crop was treated, and in some cases, seedbeds also.

were 0.6 t/ha lower. Yield differences attributable to potassium fertilizer were not significant.

The effect of zinc on yield is given in Table 20. Dipping seedlings in 2% zinc suspension in water produced yields similar to those obtained from untreated plots. Farmers' insect control and pest management strategy gave similar yields (4.7 t/ha). However, when insect control was high, yields were 0.3 t/ha higher (Table 21).

Helminthosporium leaf spot, rice blast, and leaf blight were among the rice diseases observed during the wet season. Fungicide application did not significantly increase yields (Table 22).

RD 19 lodged and was submerged in floodwater during the dough stage. Farmer's variety, early-maturing IR36, escaped flood damage.

To determine the magnitude of the yield gap and relative contributions of test factors (fertilizer, insect control, and weed control) to the yield gap, minifactorial trials were conducted at three irrigated sites. The yield gap was identified from 16 trials — 3 minifactorial and 13 yield responses to major farm inputs. Input levels for the 16 trials are given in Table 25.

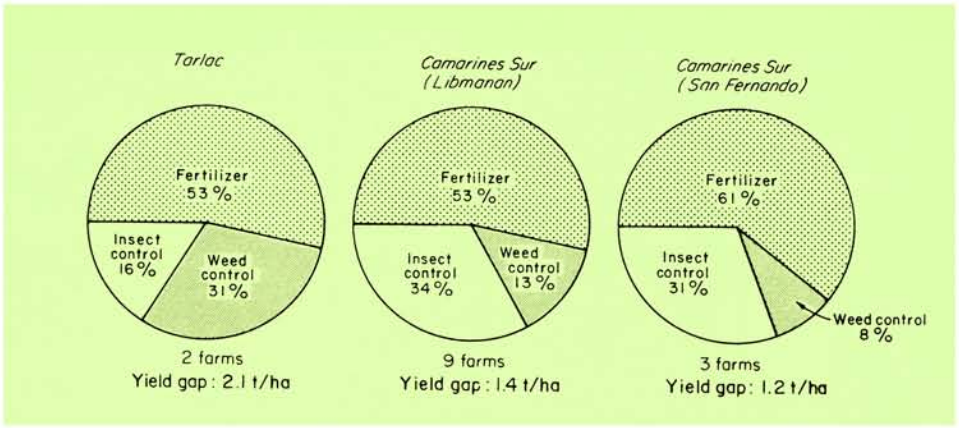
The average levels of fertilizers applied by the farmer were 13 kg N/ha, 7 kg P_2O_5/ha, and 0.8 kg K_2O/ha. Farmers' insect control averaged 2 foliar sprays; weed control, 1 application of preemergence herbicides. The yield gap from 3 irrigated minifactorial trials and 13 yield-response trials was 1.2 t/ha (Table 23).

The contribution of separate inputs to the yield gap was determined from the three minifactorial trials. Farmers' and high levels of inputs are given in Table 26. One out of three farmers did not apply fertilizer. Weed control consisted of an average of one application of preemergence herbicide; insect control, two foliar applications. Average yield with farmers' input levels was 4.9 t/ha; with high-level inputs it was 6.1 t/ha, resulting in a yield gap of 1.2 t/ha (Table 24). High fertilizer levels contributed 0.8 t/ha (61%) to the yield gap; improved insect control contributed 0.4 t/ha (31%), and improved weed control contributed 0.1 t/ha (8%) (Fig. 8).

Profitability of researchers' practices. *Reducing the yield gap.* The constraints experiments (see Table 26) were budget analyzed to assess the profitability of increasing inputs from farmers' level to the researcher's level in Libmanan, San Fernando, and Tarlac (Table 27). The incremental cost of researchers' practice over farmers' practice ranged from $149/ha in Tarlac to $175 in San Fernando. Only at Tarlac did researcher's practice appear substantially more profitable than the farmers'.

The profitability of each technological component (fertilizer and insect and weed control) was evaluated from the yield data in Table 24. At each site, researchers' fertilizer practice was more profitable than farmers' (at San Fernando, only marginally so). At the Tarlac site, researchers' fertilizer input (80-30-30) was considerably more profitable than farmers' (36-17-14).

The incremental cost of researchers' insect control ($70-$84/ha) was the same as that of fertilizer. However, the extra output generated from the researcher's insect control did not cover the extra



8. Relative contribution of fertilizer, insect control, and weed control to the improvement of rice yields in farmers' fields, 3 project areas in the Philippines, 1981 wet season.

Table 27. Economic performance of anticipated high-level combination of 3 inputs and farmers' levels of those inputs in constraints experiments in farmers' fields, Philippines, 1981 wet season.

Location	Sites[a] (no.)	Increase (decrease) ($/ha) over farmers' level		
		Output value[b]	Input cost[c]	Net return
Libmanan, Camarines Sur	8 I	176.00	167.33	8.67
	1 RF	146.67	167.33	(20.67)
San Fernando, Camarines Sur	3 I	146.67	182.00	(35.33)
Tarlac, Tarlac	2 RF	343.20	155.33	187.87

[a] I is irrigated; RF is rainfed. [b] At palay price of $0.15/kg in Camarines Sur and $0.19/kg in Tarlac. US$1 = ₱7.50. [c] At input prices prevailing in the study areas during the study.

material costs. Improved weed control was profitable at Libmanan (both irrigated and rainfed) and Tarlac, but not at San Fernando.

Over the three sites, increasing fertilizer use appears profitable in Tarlac and Libmanan, but only marginally so in San Fernando. In general, increased insect control was not profitable. Nor was weed control, except in San Fernando. Explanation of the unsatisfactory performance of researcher's technology at the San Fernando rainfed site is being explored.

N response. The profitability of alternative nitrogen rates in the 1981 wet-season trials (see Table 18) was evaluated through partial budget analysis. The results (Table 28) are consistent with those of the yield-gap analysis reported in Table 29. In Tarlac, both 40 and 80 kg N/ha were considerably more profitable than farmers' level of nitrogen input. However, the incremental gain in profit of increasing nitrogen from 40 to 80 kg N/ha suggests that 40 kg N/ha would remain more attractive to farmers. Over the 13 rainfed sites in San Fernando, 40 kg N/ha was considerably more profitable than either the low rate used by farmers (less than 15 kg N/ha) or the highest (80 kg N/ha) used by the researcher. However, increasing nitrogen input to 80 kg/ha in Libmanan was clearly profitable.

In the rainfed sites, 40 kg N/ha is probably profitable from a farmer's viewpoint. In the irrigated environment, a high nitrogen rate — possibly up to 80 kg N/ha — is profitable.

Other factors included in the crop management trials were phosphorus, potassium, and zinc, as well as alternative insect control practices and disease control. In general, these practices were not

Table 28. Economic performance of various nitrogen levels in constraints experiments in the Philippines, 1981 wet season.

Location	Sites[a] (no.)	Increase[b] (decrease) ($/ha) over zero N								
		Farmer's level[c]			40 kg N/ha			80 kg N/ha[f]		
		Output value[d]	Input cost[c]	Net return	Output value	Input cost	Net return	Output value	Input cost	Net return
Libmanan, Camarines Sur	11 I	0	15.73	(15.73)	87.20	32.13	55.06	124.66	56.40	68.26
San Fernando, Camarines Sur	13 RF	12.53	12.00	0.53	87.20	32.13	55.06	112.13	63.20	48.93
Tarlac, Tarlac	10 RF	(14.66)	13.86	(28.53)	113.33	29.73	83.63	145.73	58.40	87.33

[a]I is irrigated; RF is rainfed. [b]US$1 = ₱7.50. [c]Nitrogen use by farmers in Libmanan: I = 18 kg/ha, RF = 0; San Fernando = 13 kg/ha; Tarlac = 17 kg/ha. [d]At palay price of $0.15/kg in Camarines Sur and $0.19/kg in Tarlac. [e]At $0.75/kg N in Camarines Sur and $0.19/kg N in Tarlac. [f]Actual N level in Libmanan was 71 kg/ha.

Table 29. Economic performance of anticipated high levels of 3 separate inputs and farmers' current practices in yield constraints experiments in farmers' fields, Philippines, 1981 wet season.

Location	Sites[a] (no.)	Increase (decrease)[b] ($/ha) over farmer's level								
		Fertilizer			Insect control			Weed control		
		Output value	Input cost	Net return	Output value[c]	Input cost[d]	Net return	Output value	Input cost	Net return
Libmanan, Camarines Sur	8 I	102.67	79.47	23.20	58.66	13.33	(13.33)	44.00	15.87	28.13
	1 RF	117.33	79.47	37.89	29.33	13.33	(42.67)	132.00	15.87	116.13
San Fernando, Camarines Sur	3 I	90.40	83.33	7.07	78.27	79.20	(0.93)	3.73	19.47	(15.73)
Tarlac, Tarlac	2 RF	209.73	53.46	156.27	57.20	87.33	(30.13)	76.27	14.67	61.60

[a]I is irrigated; RF is rainfed. [b]US$1 = ₱7.50. [c]At palay price of $0.15/kg in Camarines Sur and $0.19/kg in Tarlac. [d]At input prices prevailing in the study areas during the study.

Table 30. Number of nonflooded days, average fertilizer use, and grain yield of rice. Constraints study, Libmanan, Camarines Sur, 1981 wet season.

Name of farmer	Nonflooded days (no.)		Paddy water below surface (cm)	Yield (t/ha)		Fertilizer used (kg/ha)		
	Vegetative	Reproductive		Farmers' inputs	CP[a]	N	P_2O_5	K_2O
Old irrigated area								
B. Moran	0	35	25.0	6.3	5.9	14	14	14
S. Rasonable	0	0		3.9	4.0	37	0	0
R. Sandagon	9	13	27.0	4.7	4.6	60	0	0
J. Jimenez	0	0		4.8	4.8	38	22	22
V. San Esteban	0	29	17.0	3.8	3.8	0	0	0
Newly irrigated area								
S. Adan	0	0		5.2	4.5	36	0	0
S. Traballo	0	0		5.5	4.8	0	0	0
M. Soriano	3	14	6.0	4.3	4.8	46	22	22
S. Curioso	0	0		2.7	2.7	0	0	0
E. Bisuña	0	0		5.0	4.6	40	15	15
F. Toriente	7	15	7.0	3.1	2.7	0	0	0
Flood-prone area								
A. Oliva	0	5		4.2	–	11	0	0

[a]Comparable paddy.

Table 31. Chemical and physical properties of soils in 2 test sites, Libmanan, Camarines Sur, 1981 wet season.

Soil property	Moran site	Sandagon site
pH (1:1 w/v H_2O)	5.4	5.2
Organic C (%)	2.6	2.1
Total N (%)	0.31	0.25
Exchangeable cations (meq/100 g)		
Na	2.42	1.52
K	0.56	0.22
Mg	7.53	7.28
Ca	14.9	13.1
CEC (meq/100 g)	28	22
Available p (ppm) Olsen	36	9
Available Zn (ppm)	2.4	1.3
Particle size analysis (%)		
Clay	39	40
Silt	47	44
Sand	14	16

more profitable than recommended or current farmer practices.

Water control and site characterization. Water control in farmers' fields often is not good, even with irrigation, because the irrigation water supply is not properly coordinated with the critical water requirements of rice. At Libmanan project site in Camarines Sur, 3 of 5 farmers' fields in the old irrigated area were without standing water for 22-35 days. As a result, the water level gradually dropped to 17-27 cm below the soil surface (Table 30).

The situation was similar in newly irrigated and flood-prone, irrigated areas.

However, yield reductions did not quite reflect the apparent water shortage (number of non-flooded days). The high yields were possible because soils in most sites were extremely fertile. In 2 sites in the old irrigated area, total nitrogen ranged from 0.25 to 0.31% (Table 31). Organic carbon, CEC, and soil texture also show the favorable soil, nutrition, and water regime in those sites, suggesting that data on nonflooded days should be evaluated against supportive soil data.

Consequences of new rice technology

Agricultural Economics and Agricultural Engineering Departments

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SOCIAL AND ECONOMIC CONSEQUENCES

Agricultural Economics Department

Changes in two areas of the Philippines. The impact of new rice technology on farmers in 2 areas of the Philippines was monitored for 15 years. During that time, modern varieties and related technologies were introduced and changes occurred in land tenure, irrigation, mechanization, and labor practices. Surveys covered farmer practices on wet-season crops, in Laguna Province in 1966, 1970, 1975, and 1978, and in Central Luzon in 1966, 1970, 1974, and 1979.

The Laguna Province surveys were of a sample of farmers in the towns of Calamba, Cabuyao, Biñan, Bay, and Pila; the Central Luzon surveys were of a sample of farmers in 14 towns along the main highway loop north of Manila, in Bulacan, Nueva Ecija, Pangasinan, Tarlac, and Pampanga provinces (Fig. 1).

In the 1966 Laguna survey, 155 rice farmers in Calamba, Cabuyao, and Biñan were interviewed.



1. Areas in which the impact of new rice technology was measured in a 15-year longitudinal survey.

By 1978, only 45 of them could be located — an attrition traced partly to rapid urbanization, which converted many rice fields to industrial and residential areas, and partly to the inability of interviewers to locate the original farmers or the unwillingness of such farmers to be reinterviewed. To increase sample representativeness, an additional 51 farmers from Bay and Pila were added in 1978.

The original Central Luzon sample included farmers in villages south and north of Manila. To increase sample homogeneity and to eliminate overlap with the Laguna survey, farmers south of Manila were dropped in 1979 and an additional 91 were selected from within the sample villages north of Manila. The Central Luzon data reported here includes only farmers in villages north of Manila — 92 interviewed in 1966, 62 in 1970, 58 in 1974, and 149 in 1979 (Table 1). The group is a somewhat more homogeneous sample of Central Luzon farmers than that reported on earlier but is more heterogenous than the Laguna sample.

Each farm operator was interviewed once or twice each season. In years of single interviews, the interview followed harvest. In years of two interviews, one interview followed transplanting and another followed harvest. Two interviews appeared to provide more accurate data on timing of operations, but it was unlikely that only one interview gave significantly different estimates of the amount of inputs or of production. For this report, annual data are judged to be equally reliable.

Land tenure. Share tenancy was the most common form of land tenure of rice land in the Philippines before 1973. That year, a land reform converted many rice farmers from sharecroppers to leaseholders paying a fixed rent in kind. A second land-reform stage converted leaseholders into land owners amortizing the costs of their farms over 15 years. The amortization is essentially the same amount as the rent was, but the farmer becomes owner of the land upon final payment.

In 1966, a somewhat smaller proportion of the farmers in Central Luzon than in Laguna were share tenants. Between 1966 and 1970, 20% of the farmers in Central Luzon became leaseholders, compared with only 10% in Laguna. During the next 5 years, more than half of the farmers in both areas became leaseholders. By 1978, only 6% of the Laguna farmers remained share tenants. By 1979,

Table 1. Sample size and land tenure of farmers in 2 areas of Luzon, Philippines, 1966-79.

Year	Farmers interviewed (no.)	Tenure (% of sample)			
		Owner-operators	Lease-holders	Share-tenants	Mixed tenure
		Central Luzon			
1966	92	14	13	73	0
1970	62	10	35	55	0
1974	58	19	57	24	0
1979	149	7	79[a]	7	7
		Laguna			
1966	155	3	5	42	0
1970	151	4	12	82[b]	2
1975	67	6	57	36	1
1978	96	3	85	6	6

[a] Includes amortizing owners. [b] Includes 3 subtenants.

Table 2. Biochemical production technology used by 2 samples of rice farmers, Luzon, Philippines, 1966-79.

Sample year	Modern varieties		Fertilizer		Insecticide		Herbicide	
	Farmers growing (%)	Area planted (%)	Farmers applying (%)	Expenditure ($/ha)	Farmers applying (%)	Expenditure ($/ha)	Farmers applying (%)	Expenditure ($/ha)
Central Luzon rice farmers								
1966	0	0	62	7.70	33	0.51	8	0.26
1970	68	67	92	10.33	61	1.80	32	0.16
1974	78	69	93	34.00	83	5.57	56	3.14
1979	95	94	95	43.81	90	12.23	56	4.35
Laguna rice farmers								
1966	0	0	75	6.15	52	0.51	84	0.77
1970	95	94	98	11.97	88	1.97	96	1.31
1975	100	97	98	49.86	88	9.86	88	3.86
1978	100	100	100	51.78	99	12.74	86	4.80

only 7% of Central Luzon farmers were share tenants. Each sample had an equal number of mixed-tenure farmers.

Production technology. Significant changes occurred in the biochemical technology used by farmers in both samples (Table 2). Most dramatic was the rapid adoption of modern varieties between 1966 and 1970. While a significant proportion of farmers had been applying fertilizer even before the adoption of modern varieties, in 1966 the amount spent on fertilizer was only enough to purchase an average of 20 kg nutrients/ha.

A significant number of farmers also had been using insecticides before the adoption of modern varieties, but also at low rates. Use of both insecticide and herbicide spread gradually in both areas and by the late 1970s, almost all farmers were applying some insecticides and more than half were using herbicides.

Mechanical technologies for land preparation and crop harvest also predate the introduction of modern rice varieties in Central Luzon (Table 3). Four-wheel 35- to 40-hp tractors had been introduced in the early 1960s. A large threshing machine, known locally as *tilyadora*, had been the most common means of threshing rice since the 1930s. Landlords required their tenants to use the threshing machines to control division of the crop into the shares through which the landlords received rents. Reduced use of the tilyadora during the 1970s coincided with the shift to leaseholding, which made it unnecessary for landlords to supervise threshing. Also, the increased availability of irrigation water, which made double cropping pos-

Table 3. Cropping intensity and mechanical technology used by 2 samples of rice farmers, Luzon, Philippines, 1966-79.

Sample year	Area (%) with 2 crops/year	Farmers (%) using			
		Power tillers	4-wheel tractors[a]	Large threshers	Portable threshers
Central Luzon rice farmers					
1966	19	0	13	76	0
1970	25	2	35	71	0
1974	32	10	43	50	0
1979	54	48	27	29	22
Laguna rice farmers					
1966	68	38	0	0	0
1970	66	76	0	0	0
1975	87	87	0	0	0
1978	93[b]	96	0	0	72

[a] Animals were also used in most cases. [b] 2% planted to water melon during the dry season.

sible, made delays caused by waiting for the tilyadora extremely costly when rapid manual threshing could clear fields for a second crop.

A small portable thresher compatible with double cropping introduced in the 1970s found rapid acceptance in Central Luzon as well as in the intensively cultivated areas of Laguna, where the tilyadora had never been used.

Use of two-wheel power tillers for land preparation predates the adoption of modern varieties in Laguna. Farmers also use them to pull the small trailers that transport inputs. Power tillers were unknown in Central Luzon before the late 1970s.

Power tillers and four-wheel tractors are technologies different enough to be technically and economically suitable in one area but not in another. In 1966, 68% of the rice fields in Laguna, but only 19% in Central Luzon, were double-cropped. Fields in Laguna seldom were dry after the first crop, so that land could be prepared for the second crop only by using lightweight two-wheel power tillers or carabao. In Central Luzon, however, where most fields grew only one crop, fields were thoroughly dry before land preparation began. The heavier four-wheel tractors could be used effectively in the few inches of water that collected after early rainfall. Secondary tillage (harrowing and leveling) was carried out with carabao in Central Luzon and, to a certain extent, in Laguna. The four-wheel tractor services were almost always availed of on a custom hire basis from the landlord or businessman owner. Many Laguna farmers owned their power tillers. This pattern continues into the 1980s.

As two-wheel power tillers became more suitable for land preparation with increased irrigation and increased double cropping in Central Luzon in the 1970s, the number of farmers using them increased to nearly half the number interviewed in 1979. By that time, almost all the Laguna farmers also were using power tillers.

Labor use. Patterns of labor use for rice production have changed along with uses of other inputs and technology (Table 4). In Laguna, the 93 days of labor/ha used for production in 1966 decreased to 88 in 1970, increased to 103 in 1975, and dropped to 93 in 1978. In Central Luzon, labor input was slightly lower — 61 days/ha in 1966, 64 days in 1970, 66 days in 1974, and 83 days in 1979. Task allocation between family and hired labor is quite clear. Most land preparation was done by family labor, transplanting mainly by hired labor. Crop-care activities involving the application of inputs were done mainly by family labor; harvesting, threshing, and associated tasks were carried out by hired labor.

The changes in labor use, whether hired or family, are less dramatic than the changes in crop composition or cropping intensity. A distinct association between the use of hired labor for land preparation and the use of power tillers seems to emerge in Laguna. In 1966, 38% of the farmers surveyed used power tillers, with the family contributing 80% of the land-preparation labor. In 1978,

Table 4. Labor used for rice production by 2 samples of rice farmers, Luzon, Philippines, 1966-79.

Operation	Source of labor	Labor (days/ha)							
		Central Luzon rice farmers				Laguna rice farmers			
		1966	1970	1974	1979	1966	1970	1975	1978
Land preparation[a]	Family	16.5	10.7	8.4	11.2	19.3	9.5	7.1	6.6
	Hired	3.6	2.3	4.1	3.5	4.6	5.4	6.4	8.2
Crop establishment[b]	Family	2.5	2.1	2.2	4.7	3.6	2.0	2.6	2.3
	Hired	16.2	16.4	19.2	21.0	9.3	10.1	10.7	10.9
Weeding	Family	3.7	7.2	6.4	3.5	11.2	6.1	4.2	3.0
	Hired	2.1	1.7	1.7	1.5	2.5	11.0	21.6	18.2
Crop care[c]	Family	1.1	3.5	6.6	8.5	7.8	5.1	8.4	12.2
	Hired	0.1	0.5	1.6	0.8	0.1	1.9	7.4	2.1
Total of above	Family	23.8	23.5	23.6	27.9	41.9	22.7	22.3	24.1
	Hired	22.0	20.9	26.6	26.8	16.5	28.4	46.1	39.4
Harvest and post harvest[d]	Family	0.9	3.1	1.6	4.0	1.7	1.4	1.5	1.6
	Hired	13.9	16.7	13.7	24.5	32.7	35.2	32.8	27.5
Total	Family	24.7	26.6	25.2	31.9	43.6	24.1	23.8	25.7
	Hired	35.9	37.6	40.3	51.3	49.2	63.6	78.9	66.9
Grand total		60.6	64.2	65.5	83.2	92.8	87.7	102.7	92.6
					Family labor (%)				
		40.8	41.4	38.6	38.3	50.0	27.5	23.2	27.8

[a] Includes plowing, harrowing, and repair of dikes. [b] Includes seeding, transplanting, pulling and bundling seedlings, and distributing seedlings. [c] Includes application of insecticides, herbicides and fertilizer, irrigation and draining, replanting, and supervision. [d] Includes harvesting, threshing, hauling, weighing, and drying.

Table 5. Cash costs and returns for wet-season rice production by 2 samples of rice farmers, Luzon, Philippines, 1966-79.

Sample, year	Returns			Costs ($/ha)					Net return
	Yield (t/ha)	Price ($/kg)	Revenue ($/ha)	Material input	Hired labor	Hired capital	Land rent	Total	
Central Luzon rice farmers									
1966	2.18	0.11	237.95	15.38	28.46	10.26	64.87	118.97	118.98
1970	2.45	0.08	191.31	17.70	30.65	7.54	43.93	99.82	91.49
1974	2.08	0.15	321.86	54.71	76.28	16.28	64.86	212.13	109.73
1979	3.38	0.14	492.52	90.20	111.43	34.69	65.31	301.63	190.89
Laguna rice farmers									
1966	2.24	0.10	231.28	14.36	48.97	5.90	87.95	157.18	74.10
1970	3.12	0.07	236.23	24.10	60.16	8.69	78.20	171.15	65.08
1975	3.39	0.16	526.00	81.71	144.57	20.86	126.14	373.28	152.72
1978	3.70	0.14	506.57	130.14	144.11	30.55	87.53	392.33	114.24

98% used power tillers and the family contribution had decreased to 46% of the total labor used. Farmers in the Laguna sample also used more labor for weeding than farmers in the Central Luzon sample.

The adoption of small mechanical threshers by 78% of the Laguna farmers had surprisingly little impact on harvest and postharvest labor use.

Costs and returns. From 1966 to 1979, yields increased 55% on the Central Luzon farms studied and 65% on the Laguna farms (Table 5). Yield increase was steady, except in Central Luzon, where severe typhoons caused losses in 1974.

Increases in the farmers' selling price of rice resulted in about a fourfold increase in revenue. But costs increased by about the same factor. Land rent was the only cash cost that did not increase by a factor of 4. Land reform, by transforming many

farmers from share renters to leaseholders, kept land rent increases to a minimum.

However, cash accounting gives a somewhat misleading picture of trends because of the sharp changes in prices from 1966 to 1970. One way to eliminate the price effect is to compute costs and returns in rice equivalences — in kilograms rice per hectare. Table 6 shows this data transformation. Land rents in rice equivalences declined while real payments to hired labor and hired capital increased by 20% in Central Luzon and 16% in Laguna. The amount left as farmer profit also increased by 20%. In addition, the proportion of farmers increasing their incomes by growing two crops per year in both areas nearly doubled.

Accounting by factor shares is another way to eliminate the impact of price changes. In Central Luzon, the factor share for land declined steadily and the share for hired labor nearly doubled, from 12 to 23% of output (Fig. 2). The share for capital nearly doubled and that for current inputs increased threefold. In Laguna, the share for land continues to be slightly higher than in Central Luzon, although it dropped from 39 to 18%. More labor-intensive production is reflected in a higher share for labor in Laguna than in Central Luzon. In Laguna, the share for hired labor increased from 21 to 28% of output. Shares for capital and for current inputs increased substantially. The residual left as farmers' profit declined to 13% of output in Central Luzon and to 5% in Laguna.

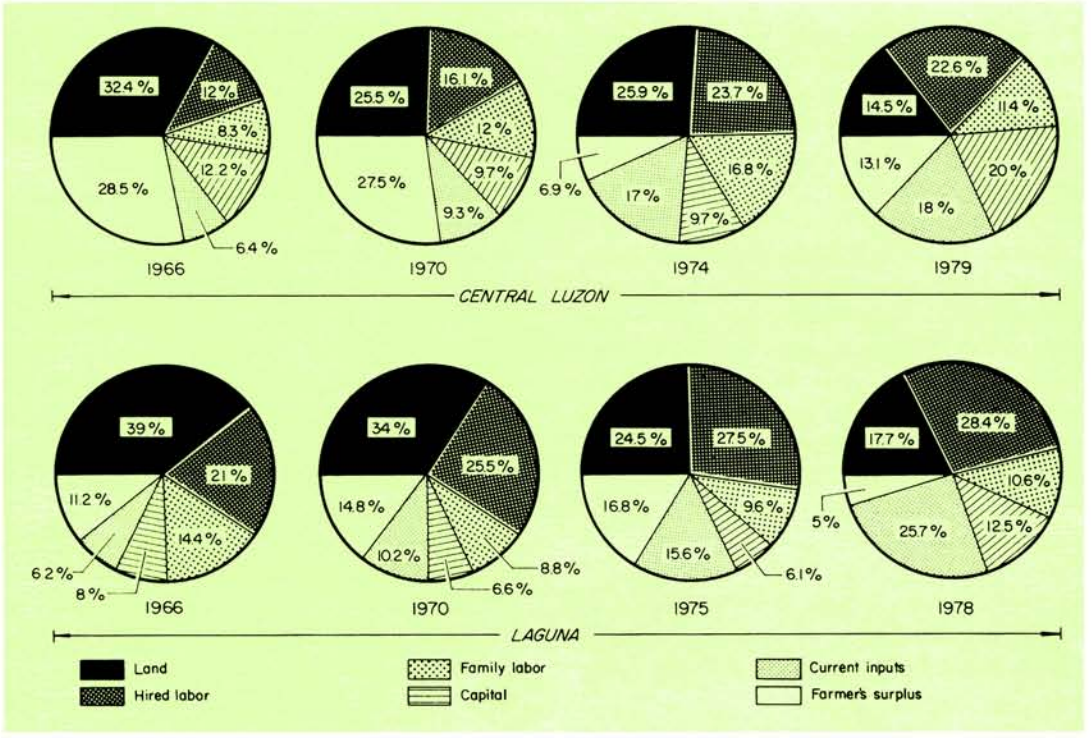
Impact of development on a rice village. To better understand the impact of new rice technology on facets of the rural economy, one village in Pila, Laguna, was studied in greater detail. The barrio is in a rice monoculture area south of Manila, along Laguna de Bay. An integrated household record-keeping study conducted in 1975 and repeated in 1980 included both farmer and landless-worker households.

Population. The village population increased from 387 persons in 1966 to 528 persons in 1974, jumped to 636 in 1976, and increased to 708 in 1980 (Table 7). Annual growth rates were 4% for 1966-1974, 9.8% for 1974-1976, and 2.7% for 1976-1980.

The structural change in village population is shown in Table 8. From 1966 to 1976, 25% of the population increase was social — there were more in-migrants than out-migrants. From 1976 to 1980, there was a net social decrease in population, although the total population grew because of a high net rate of natural increase — more births

Table 6. Rice equivalent costs and returns and specified production factor shares in 2 samples of rice farmers, Luzon, Philippines, 1966-79.

	Central Luzon				Laguna			
	1966	1970	1974	1979	1966	1970	1975	1978
				Kg rice/ha				
Paid-out								
Land rent	595	561	419	449	852	1035	814	640
Hired labor	263	393	493	765	473	796	933	1052
Hired capital	95	97	105	238	58	115	135	223
Material inputs	141	227	354	619	140	320	528	950
Left with farmer	1091	1169	709	1311	715	858	984	833
Land	114	62	119	40	15	27	16	15
Family labor	182	293	349	388	324	276	326	392
Personal capital	172	140	97	439	124	92	73	241
Management inputs	622	674	144	444	252	463	569	185
				Factor share (%)				
Land	32.4	25.5	25.9	14.5	39.0	34.0	24.5	17.7
Labor (total)	20.4	28.0	40.5	34.1	35.5	34.3	39.1	39.0
Hired labor	12.0	16.1	23.7	22.6	21.0	25.5	27.5	28.4
Family labor	8.3	12.0	16.8	11.4	14.4	8.8	9.6	10.6
Capital	12.2	9.7	9.7	20.0	8.0	6.6	6.1	12.5
Current inputs	6.4	9.3	17.0	18.3	6.2	10.2	15.6	25.7
Farmer's surplus	28.5	27.5	6.9	13.1	11.2	14.8	16.8	5.0



2. Allocation of rice output to production factors by 2 samples of rice farmers, Luzon, Philippines, 1966-79.

than deaths.

Households. Growth in number of households paralleled growth in population (Table 7). Households in the barrio increased from 64 in 1966, to 95 in 1974, to 126 in 1980. Dramatic changes also occurred in the composition of farmer and landless-worker households. (A farmer is defined as one who cultivates rice fields, either as an owner or as a tenant; a landless worker is one with no rice farm to operate, either owned or rented.) While the number of farmer households increased slowly to 1976, then declined, the number of landless-worker households increased very rapidly, 9-11% a year. As a result, the proportion of landless households

Table 7. Population and households in an intensively studied village, Laguna, Philippines, 1966-80.

	Population	Households[a] (no.)		
		Total	Farmer	Landless worker
1966	387	64	44	20
		(100)	(69)	(31)
1974	528	95	54	41
		(100)	(57)	(43)
1976	636	109	55	54
		(100)	(50)	(50)
1980	708	126	47	79
		(100)	(37)	(63)
	Annual compound growth rate (%)			
1966-1974	4.0	5.1	2.6	9.4
1974-1976	9.8	7.1	0.9	14.8
1976-1980	2.7	3.7	-3.6	10.0

[a] Numbers in parentheses = %.

Table 8. Social and natural increases in population in an intensively studied village, Laguna, Philippines, 1966-1980.

	Male	Female	Total
1966 population	201	186	387
Increases from 1966 to 1976			
Net social increase[a]	+ 31	+ 32	+ 63
Net natural increase[b]	+ 92	+ 94	+186
Total	+123	+126	+249
1976 population	324	312	636
Increases from 1976 to 1980			
Net social increase[a]	- 10	- 5	- 15
Net natural increase[b]	+ 39	+ 48	+ 87
Total	+ 29	+ 43	+ 72
1980 population	353	355	708

[a] Net social increase = in-migrants - out-migrants. [b] Net natural increase = births - deaths.

among total households increased from 31% in 1966 to 43% in 1974 to 63% in 1980.

The number of farmer households between 1976 and 1980 declined, mainly because many farmers, by selling or pawning their tenancy titles, became landless. By 1976, 13 farmers (more than 20%) had lost their tenancy rights and had become landless workers; only 4 landless workers had acquired land through inheritance or subrenting. The creation of new households through independence from parents and in-migration was higher among landless workers; the disappearance of old households through death and out-migration was higher among farmers. By 1980, the decrease by 8 in farmer households and the increase by 25 in landless-worker households resulted in a net increase of 17 households.

Occupational patterns. Changes in the occupational distribution corresponded to the decrease in number of farmers and the increase in number of landless workers. The changes also reflect growing urban influences on the village.

Rice farming continued to be the dominant enterprise, providing the most income-earning opportunities. Of the economically active male population in 1980, 72% were either self-employed in rice production on their own farms or in hired work for rice production; in 1974, 66% (Table 9). However, other facets of the self-employed-hired work profile changed drastically.

In 1974, more than 70% of those whose major occupation was rice farming were farmers themselves. In 1980, more than 60% were landless workers. That change reflects the decrease in number of farmers and the increase in number of landless workers. At the same time, the proportion of the male labor force within farmer families engaged in rice farming as a major economic activity declined, from 72% in 1974 to 59% in 1980. The proportion of those in landless-worker families hired in rice work as a major economic activity increased sharply from 54% in 1974 to 74% in 1980. In the female labor force, self-employment in rice farming as a major activity decreased and hired work increased substantially. As farmers and their families retreat from work on their own farms, rice farming in the village has become increasingly dependent on the hired labor of landless workers.

Duck raising had been an important major and minor hired-work activity. A decline in its importance was largely compensated for by an increase in hired work in rice as a major occupation and by fishing as a minor occupation.

Rice work as the major occupation is especially conspicuous for landless workers. In 1980, the major occupation of more than 70% of the landless male workers was rice farming, partly because of the substitution of hired labor for family labor in rice farming and partly because of the increased capacity of rice farming to absorb labor. In any

Table 9. Occupational pattern of economically active males (13-65 years old) in an intensively studied village, Laguna, Philippines, 1974 and 1980.

	Percent of sample							Total number
	Rice farm owner	Rice farm laborer	Duck raiser, fisherman	Other self-employed	Salaried	Schooling	House-hold	
				Major occupation				
Total, 1974	47	19	15	1	4	12	1	151
Total, 1980	25	47	4	0	8	13	3	204
Farmers, 1974	72	0	6	0	4	16	2	99
Farmers, 1980	59	9	1	1	9	19	1	87
Landless, 1974	0	54	33	4	6	4	0	52
Landless, 1980	0	74	6	0	8	8	4	117
				Minor occupation				
Total, 1974	4	17	16	1	0	–	–	–
Total, 1980	3	7	25	5	10	–	–	–
Farmers, 1974	6	14	17	2	0	–	–	–
Farmers, 1980	8	10	25	9	14	–	–	–
Landless, 1974	0	21	14	0	0	–	–	–
Landless, 1980	0	5	27	3	8	–	–	–

case, dependency on rice farming as the source of employment increased for landless worker families.

The influence of the urban labor market on village occupational patterns increased from 1974 to 1980. The number of males who engaged in skilled and unskilled carpentry work in the Pila poblacion and other nearby towns, and further away, in Manila, increased significantly. A major factor in the increase in urban employment seems to be recent improvements in the highway system and rapid development of nonfarm sectors in the greater Manila area.

Land tenure and size of operational holdings. The distribution of parcels and farms by land tenure changed little after 1976 because land reform was largely completed. In 1980, more than 70% of the total paddy field area operated by village farmers was under leasehold tenancy and more than 80% of the village farmer families were lessees, or part-lessees.

But average farm size declined from 2.3 ha in 1966 to 1.8 ha in 1980. Inequality in farm size among farmer families, as measured by Gini coefficient, remained 0.34 over the period. But if landless worker families are included, the inequality increases, from 0.53 in 1966 to 0.76 in 1980.

Average paddy area per farm, per household, and per capita became smaller because the total paddy field area cultivated by villagers decreased from 108 ha to 86 ha (Table 10). Except for 0.3 ha diverted to road construction in 1978, no paddy has been converted to other purposes in the village since 1976. The reduction in area mainly occurred because of the transfer of tenancy titles from villagers to outsiders. Selling tenancy rights to outsiders accounted for 58% of the gross decrease in villagers' operational holdings. Other important causes of the decrease were pawning and subrenting tenancy titles, cancelling subrenting. In pawning and cancelling of subrenting, control of the land is still with farmer families in the village.

Altogether, from 1976 to 1980 the village lost control of about 20% of the net operational holdings. That resulted partly from the establishment of well-protected leasehold titles for tenant farmers by land reform, which in turn gave tenants the right to dispose of leasehold land on their own account. On the other hand, increased productivity of rice farming, from \$571.43/ha in 1975 to \$1,600.00/ha in 1980, has caused a continuous rise in the price of tenancy titles.

Labor use. Phase I (1975) record keeping includes 12 cooperators, 4 large farmer families (cultivating 2 ha or more), 4 small farmer families (cultivating less than 2 ha), and 4 landless worker families. By 1980, some large farmer cooperators had become small farmers or even landless workers and some landless worker cooperators had become small

Table 10. Transfer of operational paddy field holdings in a rice village, Laguna, Philippines, 1976-80.

Type of transaction	Transactions within village		Transactions with outsider			
			Increase		Decrease	
	Increase (no.)	Decrease (ha)	No.	Ha	No.	Ha
Purchase or sale of tenancy right	2	1.5	1	0.5	15	18.0
Pawning in or out of tenancy right	1	0.5			3	1.2
Subrenting in or out	1	0.5			2	3.5
Cancellation of subrenting or pawning contract	9	3.3	1	0.5	4	1.4
Inheritance	7	6.5	1	2.0	2	6.5
Renting in from landowner			1	0.5		
Migrating in with land			3	5.4		
(Converted to road)					3	0.3
Total	20	12.3	7	8.9(a)	29	30.9(b)
Decrease in land area (ha) operated by village farmers: (b) – (a)				22.0		

farmers. After identifying such changes in all village households, 15 cooperators were selected for the phase II (1980) record keeping project. Included were 5 large farmer families, 5 small farmer families, and 5 landless worker families; 8 were old cooperators, the rest newly selected.

Cooperators kept detailed daily records of their economic activities, including the use of both family and hired labor. Records were checked twice a week (Tuesday and Friday) to correct inconsistencies. At the beginning and end of Phase II, assets and labor force in the household were surveyed. The record keeping period for Phase II was three seasons, 1 July 1980-31 January 1982. Results for the first year are presented here.

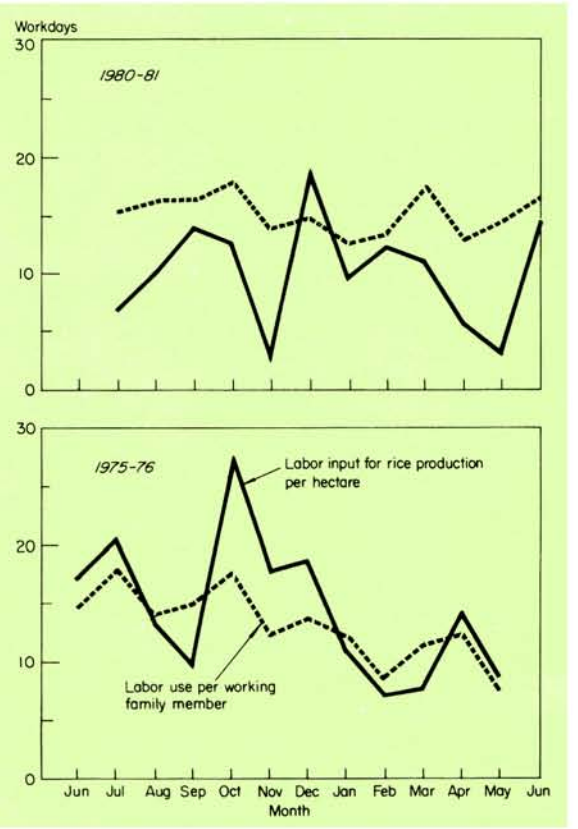
Rice farming in the village experienced significant problems during the record keeping period because construction of an irrigation system delayed the rice-cropping sequence almost 2 months, causing crop failures in the wet and dry seasons. Average yield of cooperator farmers was 2.5 t/ha in the 1980 wet season and 1.7 t/ha in the 1980-81 dry season.

These crop failures severely affected rice farming labor use and nonfarm work. Because a major part of the wages earned in rice farming is through crop sharing by harvesters, wage earnings from work in rice farming went down. Each working member of a cooperator household worked an average of 182 days/year in income-generating activities in 1980-81, about 15% more than in 1975-76.

Assuming that full use of the labor of a working family member is 20 labor days/month, labor use was 76% in 1980-81, compared with 65% in 1975-76.

In 1975-76, the seasonal pattern of labor use was determined primarily by its seasonality in rice production (Fig. 3). Peak periods of labor use in July, October, December, and April coincided with the months of planting and harvesting in the wet and dry seasons. In 1980-81, although monthly levels were lower, the labor input for rice production showed a similar seasonal pattern, but with a 2-month lag because of the irrigation construction. There was a reduction in the seasonal variation of labor use. Averaging all households, the coefficient of variation of labor use across months was 23% in 1975-76, 11% in 1980-81.

In 1975-76, each working family member spent about one-half the total workdays in self-



3. Monthly changes in labor inputs for rice production per hectare and labor use per working family member, average of all households, Laguna, Philippines.

employment, two-thirds of which was used for rice farming; and the other half for outside employment as hired labor, nearly 90% of which was in rice production (Table 11).

In 1980-81, number of workdays for both self-employment and hired labor increased, even though the time spent in rice production per working member declined substantially for both self-employment and hired labor. The decrease in number of workdays in rice production was more than compensated for by the increase in employment in nonrice farming and nonfarm enterprises, in the case of self-employment, and by nonfarm employment, in the case of hired labor. In total workdays, the shares of self-employment and hired labor were almost the same in 1975-76 and 1980-81.

On the average, shares of rice farming and farm hired labor in total labor use declined and those of other self-employment and nonfarm hired labor

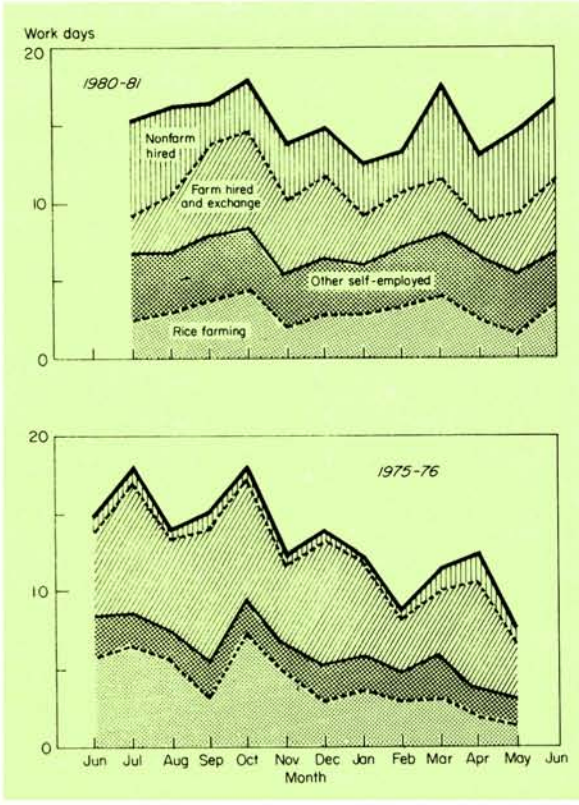
Table 11. Allocation of family labor among different tasks, workdays/working member per year, rice village, Laguna, Philippines, 1975-76 and 1980-81.

	All households		Large farmers		Small farmers		Landless workers	
	Days	%	Days	%	Days	%	Days	%
1975-76								
Self-employed	75.1	48	107.3	66	112.2	73	19.6	12
Rice farming	49.1	31	86.3	53	51.4	33	7.7	5
Nonrice farming	23.7	15	17.6	11	60.8	40	9.9	6
Nonfarm enterprises	1.6	1	3.4	2	0.0	0	0.0	0
Capital production	0.7	1	0.0	0	0.0	0	2.0	1
Hired	75.3	48	52.3	33	25.9	17	132.4	83
Farm employment	66.1	42	36.4	23	22.4	15	127.0	80
Nonfarm employment	9.2	6	15.9	10	3.5	2	5.4	3
Exchange	6.8	4	2.0	1	15.9	10	7.5	5
Total	157.2	100	161.6	100	154.0	100	159.5	100
1980-81								
Self-employed	83.4	46	107.9	65	107.5	48	32.1	19
Rice farming	36.9	20	48.4	29	62.2	28	0.0	0
Nonrice farming	32.0	18	26.4	16	43.1	19	28.8	17
Nonfarm enterprises	14.3	8	33.0	20	2.0	1	3.1	2
Capital production	0.2	0	0.1	0	0.2	0	0.2	0
Hired	92.6	51	49.0	30	108.2	49	131.5	80
Farm employment	42.4	23	5.5	4	47.9	22	82.8	50
Nonfarm employment	50.2	28	43.5	26	60.3	27	48.7	30
Exchange	5.9	3	9.0	5	5.6	3	1.4	1
Total	181.9	100	165.9	100	221.3	100	165.0	100

increased (Fig. 4). The increase in nonfarm hired labor, a negligible component of total number of workdays in 1975-76, was especially large.

The structure of employment and its change over time differed among the three types of households. Decreases in workdays in rice production, as both self-employment and hired labor, were most distinct among large farmer families. Although total number of workdays for self-employment and hired labor remained almost constant, self-employment workdays for activities other than rice farming and for nonfarm hired labor increased. In 1975-76, only one large farmer cooperator ran a passenger tricycle as a nonfarm enterprise. In 1980-81, two large farmers had tricycle operations and another operated a sari-sari store (small store for daily needs) in the village. Opportunities for large farmers in nonfarm hired labor were mainly in carpentry and office work outside the village. Landless worker families spent about 80% of their time, 132 days per working member per year, in hired labor in 1975-76 and 1980-81. However, the proportions of farm and nonfarm labor in total hired labor changed. Workdays in farm labor decreased and those in nonfarm labor increased. Time spent in nonfarm labor, negligible in 1975-76, accounted for 30% of family workers' time in 1980-81. The share of time in farm labor dropped from 80 to 50%.

A major opportunity for nonfarm labor, which has become available to landless worker families, is carpentry in nearby towns and in Greater Manila. Some carpentry jobs are temporary during the slack seasons for farm work. Some are more or less permanent. For example, one head of a landless worker household worked as a carpenter on a construction site in Manila throughout most of 1980-81. He stayed at the construction site during



4. Monthly changes in allocation of family labor among different tasks, working days per working member, average of all households, Laguna, Philippines.

weekdays, returning to the village on weekends.

An increase in total labor use by small farmer families was the most distinct change among the three types of households. It increased more than 40% between 1975-76 and 1980-81, mainly as hired labor. Self-employed workdays remained almost constant, but hired workdays increased more than four times. The share of hired workdays in total workdays jumped from less than 20% in 1975-76 to nearly 50% in 1980-81.

Days spent in rice farming increased and those in nonfarming work decreased between 1975-76 and 1980-81.

Even though workdays on their own farms increased, small-farmer family members also worked more for pay on other farms in 1980-81 than in 1975-76. Most remarkable was the huge increase in workdays in nonfarm hired labor: working members in small farmer households spent only 3.5 days in nonfarm hired labor in 1975-76, but 60 days in 1980-81, the most among the 3 types of households. As with landless-worker families, the major job opportunities for small farmers were carpentry and construction work in the Greater Manila area. In addition, some worked in other trades in Manila.

Small-farmer families allocate labor among different jobs to attain as full use of labor as possible. Family members engaged more in self-employment than in rice farming and in nonfarm hired labor during the slack rice-farming seasons. Monthly workdays on their own farms correlated negatively with workdays in nonrice farming ($r = -0.65$). Monthly workdays in farm labor also correlated negatively with those in nonfarm labor ($r = -0.55$). Small-farmer families attained almost full employment throughout 1980-81, except in January, February, and April.

Wage earnings. Total wage earnings for an average household in 1980-81 were almost three times more than those in 1975-76 (Table 12). Wage earnings from farm labor remained the same as in 1975-76, with 35% fewer work days. The increase in wage earnings was brought by the large increase in wages earned from nonfarm labor, corresponding to the increase in workdays in nonfarm labor.

The average wage per workday for farm labor increased 64% between 1975-76 and 1980-81, that for nonfarm labor increased nearly three times. The wage difference between farm and nonfarm labor, almost negligible in 1975-76, became substantial in 1980-81. The average yearly wage for nonfarm labor in 1980-81 was 85% higher than that for farm labor; in 1975-76, it was 9% higher.

Monthly changes in average wage for farm labor showed a clear seasonal pattern in which two peaks and two troughs appeared alternately (Fig. 5). The troughs correspond to the weeding periods, during which workers are hired mainly for weeding under the *gama* arrangement, without a wage. The peaks correspond to the harvesting periods, during which workers receive wages in kind on a crop-sharing basis, including the payments for their weeding services. In 1975-76, the average wages for farm labor during harvest were considerably higher than those for nonfarm labor. In 1980-81, the farm wage could barely catch up with the nonfarm wage during harvest and stayed far below the nonfarm wage the rest of the years.

In Table 13, the average wage per workday for

Table 12. Monthly wage earnings per working member, all sample households in a rice village, Laguna, Philippines, 1975-76 and 1980-81.

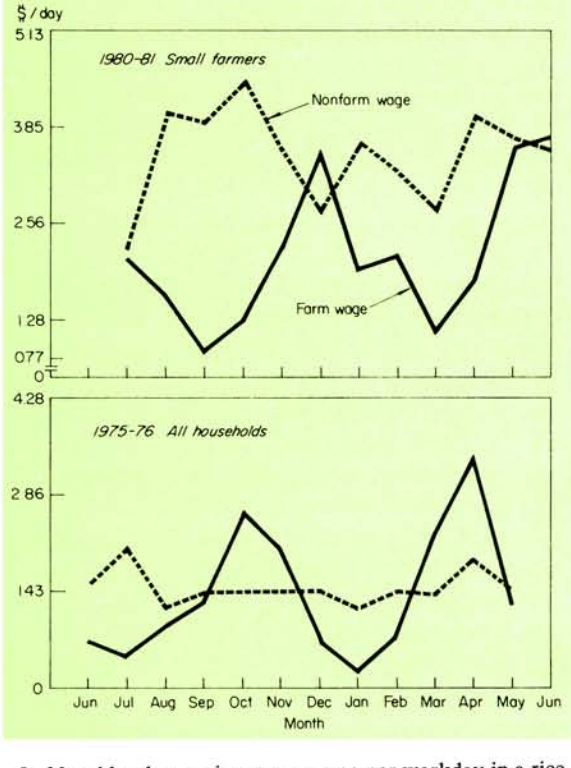
	Days employed		Wage earnings ($)		Av wage ($/day)	
	Farm	Nonfarm	Farm	Nonfarm	Farm	Nonfarm
1975-76	65.6	9.7	81.49	13.10	1.24	1.35
1980-81	42.4	50.2	85.70	188.20	2.03	3.75

hired labor and average income per workday in self-employment are compared. Average income per workday was computed by dividing imputed income of family factors in each private production account by the number of workdays of family members for current production. By nature, average income per day includes not only returns to family labor but also returns to capital assets owned by the family, such as land, livestock, and tricycle, and the profit from the enterprises.

In 1975-76, average income per day for self-employment was higher than average wage per day for hired labor for all households. In self-employment, nonrice farming, such as duck raising, fishing, pig raising, and fruit and vegetable production, gave the highest income per workday, followed by nonfarm enterprises (tricycle). Rice farming as self-employment had the lowest average income per workday, but it was still higher than the average wage per workday for both farm and nonfarm hired labor.

However, the average income per day from self-employment did not increase much between 1975-76 and 1980-81. The increase in average income per day for rice farming was less than 20%, presumably because of crop failures. In 1980-81, the income per day for rice farming was even lower than the average daily wage for hired labor. The tricyle operation returned 35% higher income per day in 1980-81 than in 1975-76. For duck raising, the average income per day declined by 20%. Fishing was the only exception — the income per day more than doubled, resulting in a larger increase in workdays in 1980-81 than in 1975-76.

The average wage per day for hired labor increased between 1975-76 and 1980-81. The wage



5. Monthly changes in average wage per workday in a rice village, Laguna, Philippines.

Table 13. Average wages per workday for hired employment and average income per workday for family members in self-employment, all households in a rice village, Laguna, Philippines, 1980-81 vs 1975-76.[a]

	Av daily wage ($)	
	1980-81[b]	1975-76[c]
Hired:		
Farm (rice) employment	2.16	1.41
Nonfarm employment	4.00	1.54
(Carpentry)	(3.23)	(1.68)
Self-employed:		
Rice farming	2.04	1.81
Nonrice farming	3.06	3.07
(Duck raising)	(2.01)	(2.86)
(Fishing)	(3.97)	(1.87)
Nonfarm enterprises	2.98	2.51
(Tricycle)	(3.22)	(2.51)
(Sari-sari store)	(1.33)	–

[a]No price adjustment made. [b]$1 = ₱7.50. [c]$1 = ₱7.00.

for nonfarm labor nearly tripled, resulting in a clear dominance in 1980-81 of nonfarm labor opportunities over other work opportunities. This dominance, in terms of wage-earning capacity, largely explains the significant increase of nonfarm labor in the portfolio of employment for the village labor force.

Rice farming in a coconut village. Rice farming is an important source of employment and income for villagers in many areas of Asia, even those who appear to depend on other sources. A second village, not far from the intensively studied rice village, was also studied. It lies in the coconut belt south of the well-irrigated rice area along the Laguna de Bay coast (about 5 km wide) in Laguna. Coconut groves cover all the land, except the provincial road passing through the village. Santa Lucia appears to be a pure coconut village.

Village households were stratified according to major occupation: coconut farmer, rice farmer, landless coconut worker, landless rice worker, firewood gatherer, fisherman, nonfarm enterprise, nonfarm employee, and others. All farm-related households were reinterviewed for more detailed data on labor allocation and income. A 50% sample of nonfarm households, was randomly drawn. A total of 173 households were covered in the second phase.

The villagers control, either as owners or as tenants, 180 ha of land, consisting of 84% coconut area located mainly inside the village and 16% rice area located entirely outside the village. Most of the 29 ha of rice land is scattered in the coconut land within a 5-km radius from the village, but 2 tenant farmers operate rice farms in the rice belt outside the coconut land. More than 60% of the rice area is irrigated double-cropped paddy fields.

Villagers own 27% of the land. They own more of the coconut land than rice land area and outsiders own most of the two-crop rice land.

Coconut holdings operated by farmers in the village are small. Six owners with more than 7 ha of coconut land own more than 40% of the total area. More than 50% of the owners have less than 1 ha each and together own only 12% of the total.

Absentee ownership is more pervasive in rice land. Villagers own 22% of the rice land cultivated by village rice farmers. They own only 0.8 ha, on the average; 70% of them own less than 1 ha.

The land tenure system in the village is a mixture of owner-operators and various types of tenants, reflecting the patterns in land ownership. In the operational coconut area, 25% is owner operated and 72% is under share tenancy contract.

Tenancy is higher for rice land than for coconut land, although the village has a relatively higher percentage of owner-operators than rice villages in the lowland rice belt where absentee landlordism is pervasive. More than half the farmers and half the operational area are leasehold. Share tenancy was the common form of tenure for rice land until the land reform of 1972 converted most of the tenants to leaseholders.

Some 20% of rice farmers still operate under share tenancy. Many of them have kinship relations with the landowners. Most of their fields are located in one-crop rainfed areas. The sharing arrangement is 50:50 (*hatian*) with cost sharing of seeds and fertilizers. Hired labor costs for transplanting are paid by the landowners and all other labor costs by the tenant.

Rice farms are small. All but two are less than 2 ha and 60% are less than 1 ha. Land holdings of most coconut farmers also are small, but not as small as the rice farms. More than 40% are less than 1 ha (Table 14). On the average, coconut tenants take care of larger areas than do owner-operators (3.9 ha vs. 1.5 ha), with a wider size distribution. Half of the tenants operate less than 2 ha, half more than 2 ha. Three tenants operate farms larger than 10 ha.

Comparing coconut and rice farming. Rice farming in the areas operated by Santa Lucia farmers has undergone major technological changes in recent years. Modern varieties have been introduced; improved cultural practices, such as straight-row planting and rotary weeding, have been adopted, and use of fertilizers and chemicals has been intensified. All these, including the complete adoption, by 1970-80, of modern rice varieties has played a key role in increasing rice output.

Coconut is the major crop in this village. Unlike coconut villages in remote areas, where the production process includes copra making, the final product in this village is the husked nut. However, there are two copra manufacturers with three copra driers within the village. The husked nuts are sold to dealers and transported by truck to a large

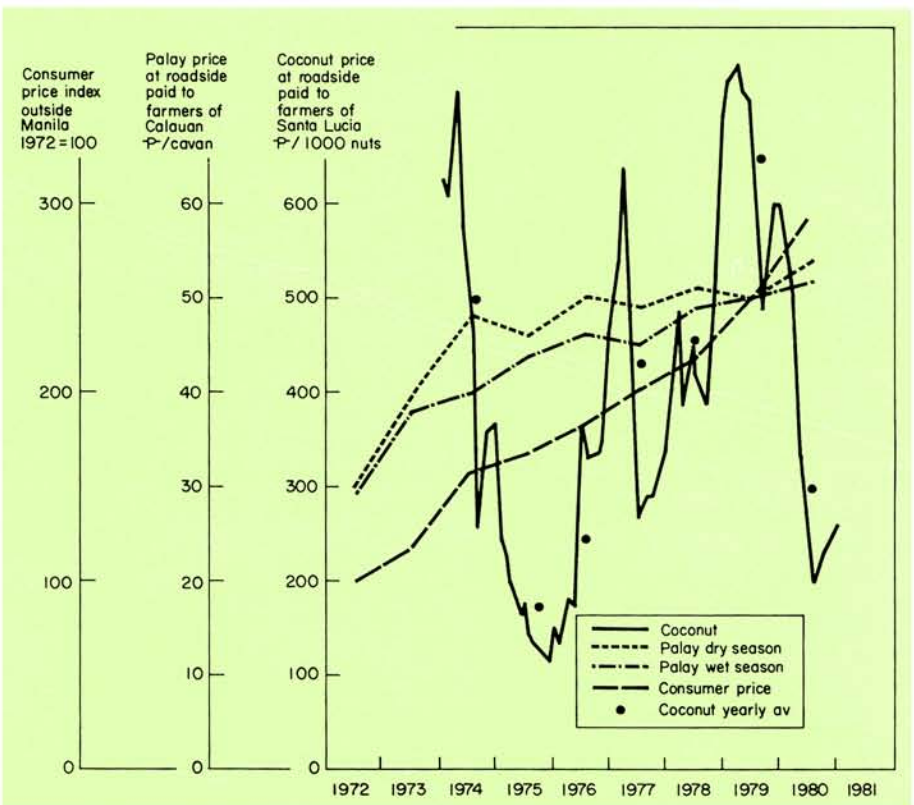
Table 14. Size of operational holdings of rice and coconut land in a coconut village, Laguna, Philippines, 1980-81.

Size class	Rice land				Coconut land			
	Farmers		Area		Farmers		Area	
	No.	%	Ha	%	No.	%	Ha	%
< 0.5	10	29.4	2.6	9	11	20.4	2.9	2
0.5-0.99	10	29.4	6.8	24	12	22.2	10.4	7
1.0-1.99	12	35.3	15.2	53	11	20.4	18.0	12
2.0-4.99	2	5.9	4.0	14	12	22.2	40.6	27
5.0-9.99	0	0.0	0	0	5	9.2	36.3	25
> 10.0	0	0.0	0	0	3	5.6	39.0	27
Total	34	100.0	28.6	100	54	100.0	147.2	100

San Pablo City copra-milling factory, which produces desiccated copra for export.

Coconut farming technology in the study area has not changed significantly. All coconut trees are of the old San Ramon variety. No trials with the new dwarf hybrid varieties have been undertaken. The trees are old; many of them more than 50 years old and some more than 100 years old. No significant change in planting density of coconut trees has been made in this area for the past few decades.

The price of rice has been relatively stable since 1975, following a sharp increase from 1972 to 1975 (Fig. 6). As a result, increases in revenue have been determined by increase in output. In output price,



6. Price fluctuations of coconut and rice, 1972-81.

coconut has fluctuated widely in the past decade, paralleling copra wholesale prices in Manila and the world market price of coconut oil.

The year-round average price of coconut in the village was much lower during the study year than in previous years. However, the average yearly price of coconut was higher in 1980 than during price troughs of 1975 and 1976. The increase in price between the two troughs was much higher than increase in rice prices. The long-term price trend has been favorable for coconut, as is shown by the 5-year moving average of copra wholesale prices.

The yields per hectare of crop land and per hour of labor are compared for coconut and rice in Table 15. Rice land generates about $0.60/labor hour, coconut land about $0.85/hour.

In this area, coconuts are harvested every 45-60 days. The yield per tree is about 50 nuts/year, close to the average for the Southern Tagalog region. With a planting density of 110-134 trees/ha, the yield is 5,600 nuts/ha ($181) for tenanted areas and 7,200 nuts/ha ($226) for owned areas.

Coconut land is much less productive than single-crop rice land and one-fourth that of double-crop rice land. But productivity of labor is higher for coconut than for rice, because coconut requires less labor input.

Farming practices in the rice paddy fields scattered in the coconut belt differ somewhat from those in the wetland rice belt. Use of hand tractors for land preparation is fairly common in the flat lowland area. The carabao is used in all land preparation in this area because it is almost impossible to use a hand tractor on fields with undulated topography, surrounded by thick coconut groves.

Current production work in coconut farming consists of five tasks, ranging from weeding (ground clearing) to hauling husked nuts to the roadside. Transplanting takes little labor.

Weeding, done mainly by family labor 3-4 times a year, requires 12% of the total labor input. Weeds, dry banana leaves, and coconut leaves and husks are burned in piles. This is the only source of fertilizer for coconut trees.

Ripe coconuts are harvested every 45 days, 8 times a year in this area. Long bamboo poles (*halabas*) assembled out of 5-7 parts, with a sickle-like knife at the top, are used. One hectare of coconut land requires about 4 days (15% of total labor inputs) a year to harvest.

One harvester is usually followed by one or two gatherers or pilers and one or two huskers. These 2 tasks together require about 14 days/ha, 40% of the total labor requirement.

Husked nuts are hauled to the roadside by horses or carabaos. Because of the distant location of coconut trees, hauling requires the most labor. Almost all the work after harvest is performed by hired laborers, who are paid in cash at a piece-rate per thousand nuts harvested, piled, husked, and hauled.

The dependency on hired labor is much higher for coconut than for rice (Table 16). Hired labor is 88% of the total labor input. However, the total labor requirement for coconut is only about 30 days/ha. For rice, it is about 80 days/ha for each crop. Double-cropped rice absorbs about six times as much labor as does coconut.

Factor and income shares. The structures of coconut and rice production factor and income shares are compared in Figure 7 and Table 17.

Coconut production uses no current inputs of fertilizer nor chemicals. Other than the trees themselves, capital requirements are small, consisting mainly of the services of horses to haul nuts. On

Table 15. Land and labor productivity of coconut and rice land in a coconut village, Laguna, Philippines, 1980.

	Rice land		Coconut land	
	Single crop	Double crop	Owned	Tenanted
Area (ha)	10.7	18.3	39.8	107.4
Annual yield	2.37[a]	5.86[a]	7205[b]	5619[b]
Value of output/yr ($)	343	875	226	181
Value/h labor ($)	0.58	0.64	0.83	0.86

[a] t/ha. [b] nuts/ha.

Table 16. Labor used in rice and coconut production in a coconut village, Laguna, Philippines, 1980.

Task	Labor use (days/ha)					
	Rice production			Coconut production		
	Family	Hired	Total	Family	Hired	Total
Land preparation	8.9	5.1	14.0	–	–	–
Transplanting	1.2	6.2	7.4	0.2	0.0	0.2
Weeding	4.9	22.0	26.9	2.5	1.0	3.5
Crop care	7.8	2.4	10.2	–	–	–
Harvesting, threshing	4.0	19.4	23.4	0.0	4.2[a]	4.2[a]
Piling	–	–	–	0.6	6.4	7.0
Husking	–	–	–	0.0	5.1	5.1
Hauling	–	–	–	0.1	8.2	8.3
Total	26.8	55.1	81.9	3.4	24.9	28.3

[a] Harvesting only.

Table 17. Factor payments and factor shares, computed by direct accounting, rice and coconut land, in a coconut village, Laguna, Philippines, 1980.

	Rice land		Coconut land	
	Factor payment ($/ha)	Factor share (%)	Factor payment ($/ha)	Factor share (%)
Total output	400.54	100.0	193.17	100.0
Current inputs	58.92	14.7	0.00	0.0
Owned capital	26.08	6.5	0.00	0.0
Hired capital	9.77	2.4	6.98	3.6
Family labor	56.14	14.0	5.42	2.8
Hired labor	123.28	30.8	43.88	22.7
Land	78.37	19.6	82.17	42.5
Operator's surplus	47.98	12.0	54.72	28.3

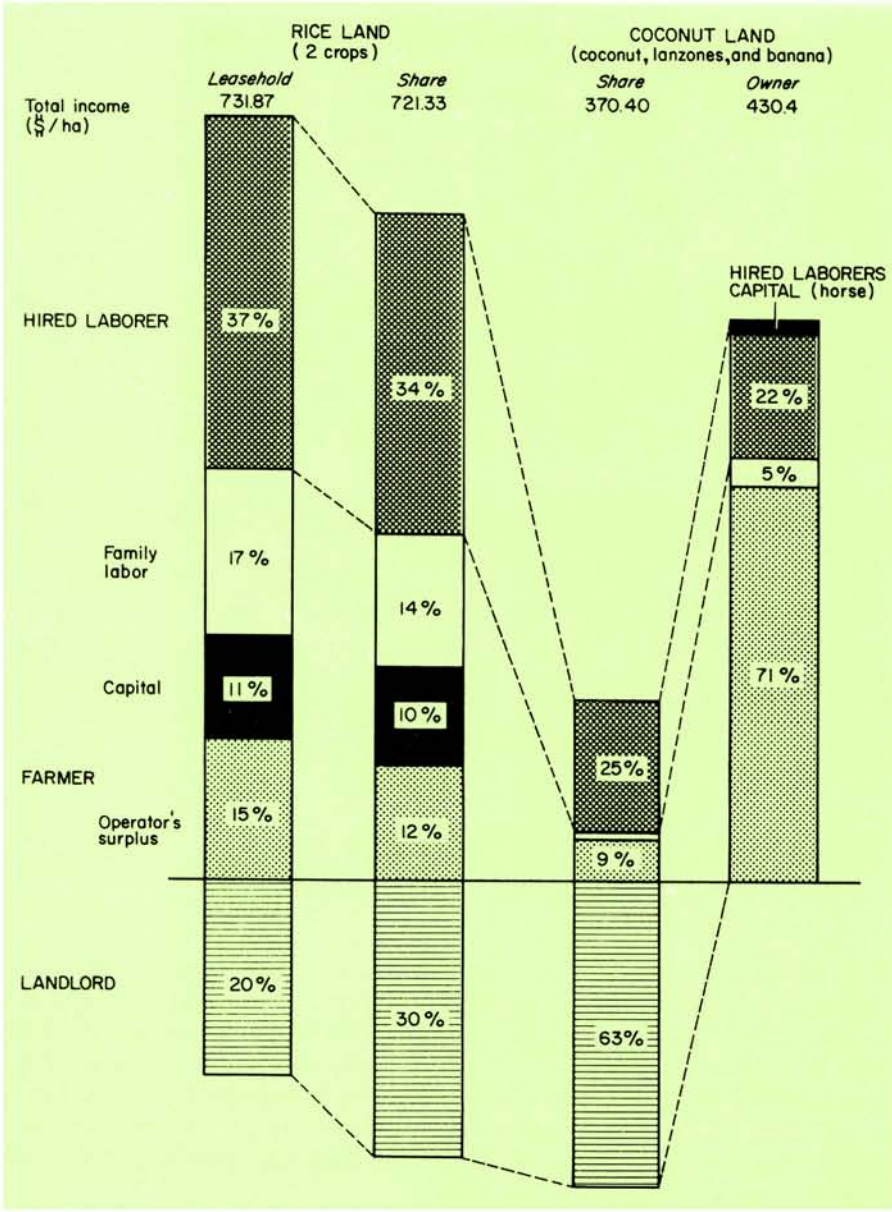
tenanted land, more than 60% of the output is received by the landowner as the return on their land and trees, with a very small part of the output left as operator surplus. A similar amount is left as operator surplus from owned area. That suggests that the operator surplus for the owner-operators consists mainly of the returns from their land and trees. Nearly 70% of the total output is shared to land and 30% shared to labor.

In rice farming, a major share of the output goes to labor, reflecting its more labor-intensive nature. The share for current inputs is also substantial because the new rice technology requires heavy application of fertilizers and chemicals. New rice technology increased the factor payment to labor directly through increased labor for such tasks as weeding and, indirectly, through increased total output.

A comparison of the production structures of coconut and rice can be clearly shown in terms of income shares (Fig. 7). For comparison, the income (value added) from rice production and its allocation among factor inputs and among earners is estimated for two crops of rice a year. Similarly, the production of major fruit trees planted between the coconut trees is taken into consideration for coconut land.

The results show that the income generated from 1 ha of rice land is considerably higher than that from 1 ha of coconut land. More importantly, the patterns of distribution of income among factors and among earners are different.

First, the amount of income flowing out of the village as land rent to absentee landowners is smaller for rice production than for coconut production, leaving more rice income to be shared within the village. Only a small portion of the total income from coconut land under share tenancy is



7. Income shares among earners per hectare per year of rice and coconut land, Laguna, Philippines, 1980.

left in the village. In the case of coconut land owned and operated by the village farmers, 100% of the income is left in the village, but the total is still smaller than the income from rented rice land that is left in the village after the land rent is paid out.

Second, in rice production, labor income takes nearly 70% of the income left in the village. More than 70% of the income from coconut land operated by owners is land income. Also, the income received by hired laborers employed in rice production accounts for nearly 50% of the rice income left in the village. Hired laborer income per hectare is significantly larger in rice production than that in coconut production, both relatively and absolutely.

This suggests that village rice farming provides important employment opportunities for the landless and near-landless population of the village whose livelihood mainly depends on wages from

Table 18. Yield and fertilizer use reported by farmers using mechanized and nonmechanized land preparation methods on 4 sites in the Philippines, Thailand, and Indonesia, 1979-80.

Area	Irrigation source	Season	Yield (t/ha)		Fertilizer (kg/ha)	
			Mechanized	Nonmechanized	Mechanized	Nonmechanized
Nueva Ecija, Philippines	Canal	Wet '79	4.4	4.0	232	281
		Dry '80	4.6	4.5	261	259
	Rainfed	Wet '79	3.0	1.7	147	124
Suphanburi, Thailand	Canal	Wet '79	3.0	2.1	49	24
	Rainfed	Wet '79	0.2	0.2	3	4
West Java, Indonesia	Canal	Dry '79	3.2	2.7	297	274
		Wet '80	5.0	4.8	343	348
South Sulawesi, Indonesia	Canal	Wet '79	1.6	1.1	84	45
		Wet '80	2.9	2.5	108	107
		Dry '80-81	4.7	5.7	130	77
	Rainfed	Wet '79	0.8	0.5	136	45
		Wet '80	2.4	2.5	156	89
		Dry '80-81	4.8	4.2	152	103

hired labor. Its existence helps to equalize income distribution between farmers and landless laborers. Because rice farming has experienced a major technological change in the past decade while coconut farming has had a stagnant technology, it could be inferred that the role played by rice farming in the coconut village has increased in importance over time.

MECHANIZATION CONSEQUENCES

Agricultural Economics Department

Farms using mechanized and nonmechanized methods for land preparation in four areas in the Philippines, Thailand, and Indonesia were compared. Data collection was completed at three sites during 1981 and a second year of data collection was initiated at the Thailand site to supplement information collected during adverse weather in 1979-80. A total of 1,320 farmer- and landless-laborer households were periodically interviewed. Some basic characteristics of the samples were reported last year. Further initial results are now available.

Mechanization of land preparation is expected to increase crop production by permitting farmers to increase their cropping intensity and yields. Farms with mechanized land preparation are expected to use less labor. The data from the four study sites are examined to test those hypotheses.

Impact of mechanization on yields. Table 18 shows the differences in yield and fertilizer use between farms using mechanized land preparation methods and those using nonmechanized methods. Mechanized farms consistently had higher yields, particularly in the wet season. However, they also applied higher levels of fertilizer, which may explain the extra yield.

In Thailand, adverse climatic conditions of crop year 1979-80 severely limited the analytical potential of the data. For the rainfed areas, no conclusions can be reached because yields were severely affected by drought. For the irrigated area, yields are much higher on mechanized farms, but so is fertilizer use.

In West Java, differences in yield and fertilizer use between mechanized and nonmechanized farms were small, although it appears that yields on mechanized farms are slightly higher, even allowing for the impact of fertilizer use. In South Sulawesi, large differences in yield between mechanized and nonmechanized farms are reported. However, in most cases mechanized farms used considerably more fertilizer than did nonmechanized farms, particularly in the wet season of 1979.

Impact on cropping intensity. Data on effects of cropping intensity show very little difference in cropping intensity between farms that used machines for land preparation and those that used animals and human labor (Table 19). Irrigated mechanized farms in Nueva Ecija, Philippines, had

Table 19. Cropping intensity reported by farmers using mechanized and nonmechanized land preparation methods, 4 sites in the Philippines, Thailand, and Indonesia, 1979-80.

Area	Irrigation source	Cropping intensity		Difference (%)
		Mechanized	Nonmechanized	
Nueva Ecija, Philippines	Canal	192	182	5
	Deepwell	129	119	8
	Rainfed	101	103	-2
West Java, Indonesia	All	217	211	3
South Sulawesi, Indonesia	Canal	188	192	-2
	Rainfed	183	167	10

Table 20. Total and hired labor used by farmers with mechanized and nonmechanized land preparation methods, 4 sites in the Philippines, Thailand, and Indonesia, 1979-80.

Area	Irrigation	Season	Total labor (days/ha)		Hired labor[a] (days/ha)	
			Mechanized	Nonmechanized	Mechanized	Nonmechanized
Nueva Ecija, Philippines	All	Wet '79	472	592	360	375
		Dry '80	483	706	381	442
West Java, Indonesia	All	Dry '79	513	532	n.a.	n.a.
		Wet '80	1,061	1,320	1,005	1,138
South Sulawesi, Indonesia	Canal	Wet '79	828	830	602	398
		Wet '80	581	690	390	369
		Dry '80-81	606	638	414	426
	Rainfed	Wet '79	1,047	1,027	681	574
		Wet '80	589	607	364	310
		Dry '80-81	633	630	369	396

[a] n. a. = not available.

a slightly higher cropping intensity than nonmechanized farms. In the two Indonesian sites, mechanical land preparation had slight impact on cropping intensity for 1979-80. Data were not adequate to evaluate the Thailand site.

Impact on labor use. In contrast to modest differences in cropping intensity and yields, labor use per hectare for each crop was substantially lower on mechanized than on nonmechanized farms (Table 20). Nueva Ecija mechanized farms used 20-30% less labor than did nonmechanized farms. The greater part of this difference, in both absolute and proportionate terms, was attributable to less use of family labor.

In West Java, labor use for the wet season is much lower on mechanized farms than on nonmechanized farms. Large differences are observed in the use of family and hired labor. Detailed data show that less use of hired labor on mechanized farms is explained by the reduction in manual land preparation by hired male laborers. No difference is recorded for hired female labor.

In South Sulawesi, total labor use on mechanized and that on nonmechanized farms were similar. But differences between family and hired labor are striking. Much less family labor is associated with mechanical land preparation but is compensated for by greater use of hired labor, so that in most seasons there is little difference in hired labor use.

Decomposition analysis. A subsample of 108 of the farm households was selected for a decomposi-

Table 21. Characteristics of sample farms by type of mechanization, Nueva Ecija, Philippines, 1979 wet season.

Operation	Carabao farms	2-wheel tractor farms
Sample size (av)	46.00	62.00
Area (ha)	1.95	2.39
Output (kg)	5089.50	9591.93
Yield (kg/ha)	2610.00	4013.36
Price of paddy[a] ($/kg)	0.14	0.16
Total pre-harvest labor (h/ha)	247.02	223.28
Total post-production labor (h/ha)	244.41	207.34
Total land preparation hours (man-machine or man-animal h/ha)	96.79	29.52
Level of fertilizer (kg N/ha)	40.13	57.98
Value of crop protection[a] ($/ha)	13.15	25.36
Loan for seasonal farm expense[a] ($/ha)	139.24	165.35
Long term loan for agricultural investment[a] ($/ha)	265.97	338.03
Cropping intensity[a]	1.36	1.92

[a] $1 = P 7.35. [b] Cropping intensity = $\frac{\text{gross cropped area in a given crop year}}{\text{area operated per crop}} \times 100$

Computed for wet- and dry-season data.

Table 22. Decomposition analysis of output differences between mechanized and nonmechanized farms, Nueva Ecija, 1979-80.

Effect	Absolute change	Percentage share
Sources of output differences		
Pure yield effect	4,356.54	31.40
Area effect	1,556.92	11.22
Cropping intensity effect	3,608.66	26.01
Price effect	688.63	4.97
Interaction effects	3,661.93	26.40
Total	13,872.68	100.00

tion analysis. The characteristics of these households, all of whose farms were either pump or gravity irrigated, are shown in Table 21. Output of farms using mechanized land preparation was nearly twice that of farms using animal land preparation. Decomposition of output into yield, area, cropping intensity, price, and interaction effects (Table 22) showed that the yield (31.4%) and cropping intensity (26.0%) were most important. Although interaction effects appear to be large, they represent an aggregate of several effects, not one of which is important on its own.

The yield effect was investigated further using a decomposition model based on the Cobb-Douglas production function. Differences in paddy yield per hectare were allocated between effects due to technical change and effects due to different input levels. The results in Table 23 suggest that most of the differences between yields of mechanized and nonmechanized farms can be attributed to differences in production technology rather than to differences in level of inputs used.

Differences in cropping intensity between mechanized and nonmechanized farms also were investigated using a covariance analysis, to account for such factors as irrigation, tenure status, farm size, and credit use, which might correlate with mechanization. The results shown in Table 24 indicate that, even after accounting for the effects of these confounding factors, mechanization increases cropping intensity significantly.

Table 23. Decomposition analysis of differences in yield per hectare between mechanized and nonmechanized farms, subsample of farms at 4 sites in the Philippines, Thailand, and Indonesia, 1979-80.

Component	Share (%)
Total yield difference	42.44
Sources of yield difference	
A. Technical change	46.95
B. Difference in input levels	
Fertilizer	0.96
Crop protection	2.80
Labor	-5.25
Total due to difference in input levels	-1.49
Total due to all sources	45.46

Table 24. Covariance analysis of the effects of mechanization on cropping intensity, 4 sites in the Philippines, Thailand, and Indonesia, 1979-80.

Independent variable	Estimated coefficient
Intercept	126.05**
Land (FS)	-4.80*
Mechanization dummy (M)	27.01**
Irrigation dummy (T)	35.53**
Tenure dummy (T)	8.07 (0.19)[a]
Short-term loan for dry-season dummy (L)	15.11*
R^2	0.644
N	102

[a] Figure in parentheses is probability of $|T| > 't'$ statistic.

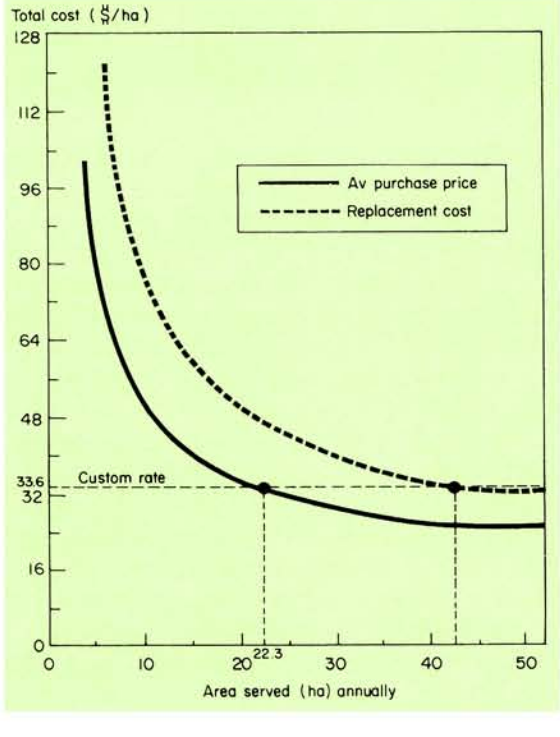
Table 25. Private benefit-cost analysis of 2- and 4-wheel tractors, Nueva Ecija, Philippines, 1972 and 1980.[a]

Item	Two-wheel tractors		Four-wheel tractors	
	1972	1980	1972	1980
Capital investment ($)	1,080.00	1,760.00	11,200.00	26,000.00
Fixed cost/yr ($)	215.00	350.00	1,465.00	3,400.00
Variable costs/h ($)	0.37	1.71	1.47	5.03
Annual utilization (h)	429.00	258.00	1,396.00	808.00
Total cost ($)	372.00	790.00	3,521.00	7,471.00
Total revenue ($)	247.00	497.00	4,347.00	6,644.00
B:C	0.66	0.63	1.24	0.89

Table 26. Break-even area served and custom rate for operation of tractor ownership in West Java, Indonesia, 1979-80.

Item	Gasoline tractor		Diesel tractor	
	Av purchase price[a]	Replacement cost[b]	Av purchase price	Replacement cost
Based on actual custom rate				
Break-even area served (ha/year)	22.28	42.66	25.12	55.41
Actual area served (ha/year)	20.70		23.94	
Differences[c] (ha/year)	-1.58	-21.96	-1.18	-31.47
Based on actual area served				
Break-even custom rate ($/ha)	34.67	49.00	37.91	66.19
Actual custom rate ($/ha)	33.60		36.81	
Differences[c] ($/ha)	-1.112	-15.40	-0.1104	-29.38

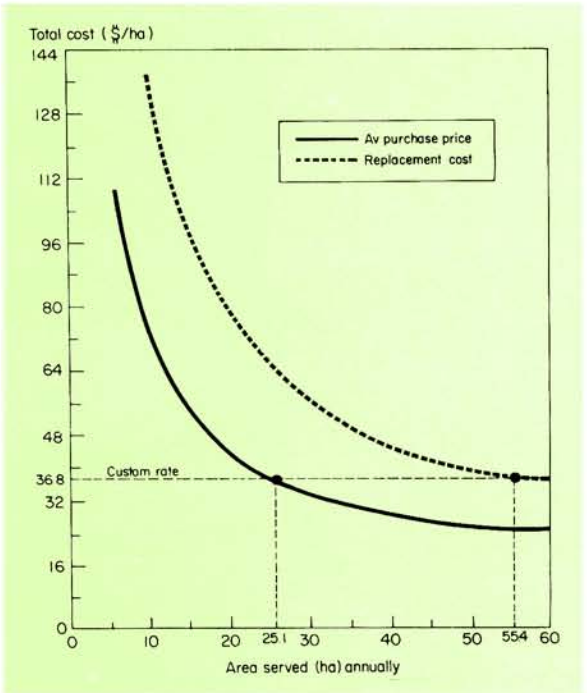
[a]Buying price I is average buying price of sample tractor. The buying prices are $1253.76 and $2176.29 for gasoline tractor and diesel tractor, respectively. [b]Buying price II is buying price of new tractor ready for use. These are $2400 for gasoline tractor and $4800 for diesel tractor. [c]Between actual custom rate and break-even custom rate.



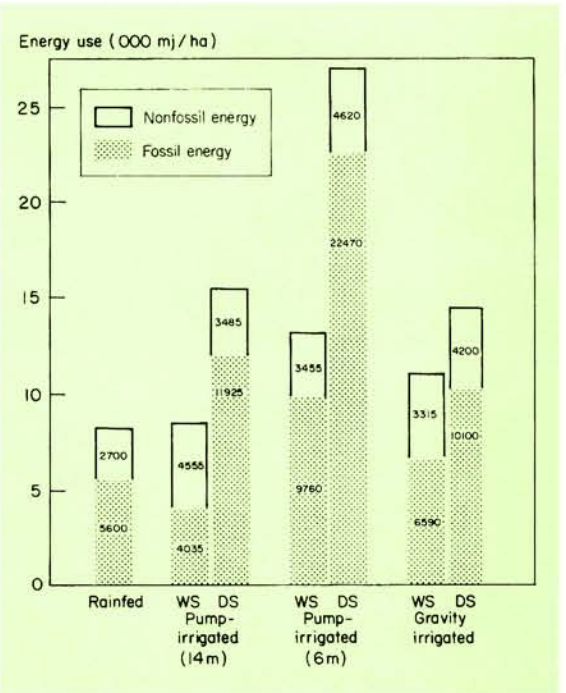
Profitability of tractor ownership. *Central Luzon.* To determine the changes that took place between 1972 and 1980 in the profitability of tractor ownership, 75 four-wheel tractor owners and 50 two-wheel tractor owners from 13 municipalities were studied. Surprisingly, neither type of ownership appeared profitable in 1980. However, private profitability of two-wheel tractors remained constant throughout the study period while the profitability of four-wheel tractor ownership declined markedly (Table 25). The major factor responsible for the decline seems to be the reduction in use of four-wheel tractors brought about by the wide adoption of power tillers, eliminating part of the custom land preparation market.

West Java. The break-even area for tractor ownership served at prevailing custom rates and the break-even custom rate for the prevailing area were computed and compared with actual values. The results indicate the need for an increase in

8. Costs curve area served, gasoline tractor, West Java, Indonesia, 1981.



9. Costs curve area served, diesel tractor, West Java, Indonesia, 1981.



10. Energy use by source on case study farms for 1970 wet and 1980 dry seasons, Nueva Ecija, Philippines.

Table 27. Rice yield and fossil energy productivity of selected farms, Nueva Ecija, 1979-80.

Farm type	Yield (t/ha)		Fossil energy productivity	
	Wet season	Dry season	Wet season	Dry season
Gravity irrigated	5.2	4.7	8.8	5.6
Pump irrigated (6 m)	4.3	4.2	4.6	2.3
Pump irrigated (14 m)	2.1	1.1	5.4	1.7
Rainfed	2.2	–	4.7	–

either the custom rate or the area served in order to break even (Table 26). While the increase is only marginal at the average price of tractors, it is extremely high at the replacement cost. Cost curves for each tractor type are shown in Figures 8 and 9.

Energy used in rice production. Daily records from the Philippine site were used for a case study of energy used by farms with different sources of water. The distribution of energy between fossil and nonfossil sources, by season and for each irrigation source, is shown in Figure 10. The highest energy use was by shallow pump-irrigated farms and the lowest by rainfed farms. A breakdown of inputs demonstrates that fertilizer and pump sets account for the largest proportion of fossil energy inputs. Table 27 shows that gravity irrigation is most efficient, in yield per hectare and in productivity of fossil energy used.

Cropping Systems Program

Physical and biological environment

Multiple Cropping, Plant Pathology, and Entomology Departments

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CLASSIFYING THE PHILIPPINE CLIMATE BY CLUSTER ANALYSIS

Multiple Cropping Department

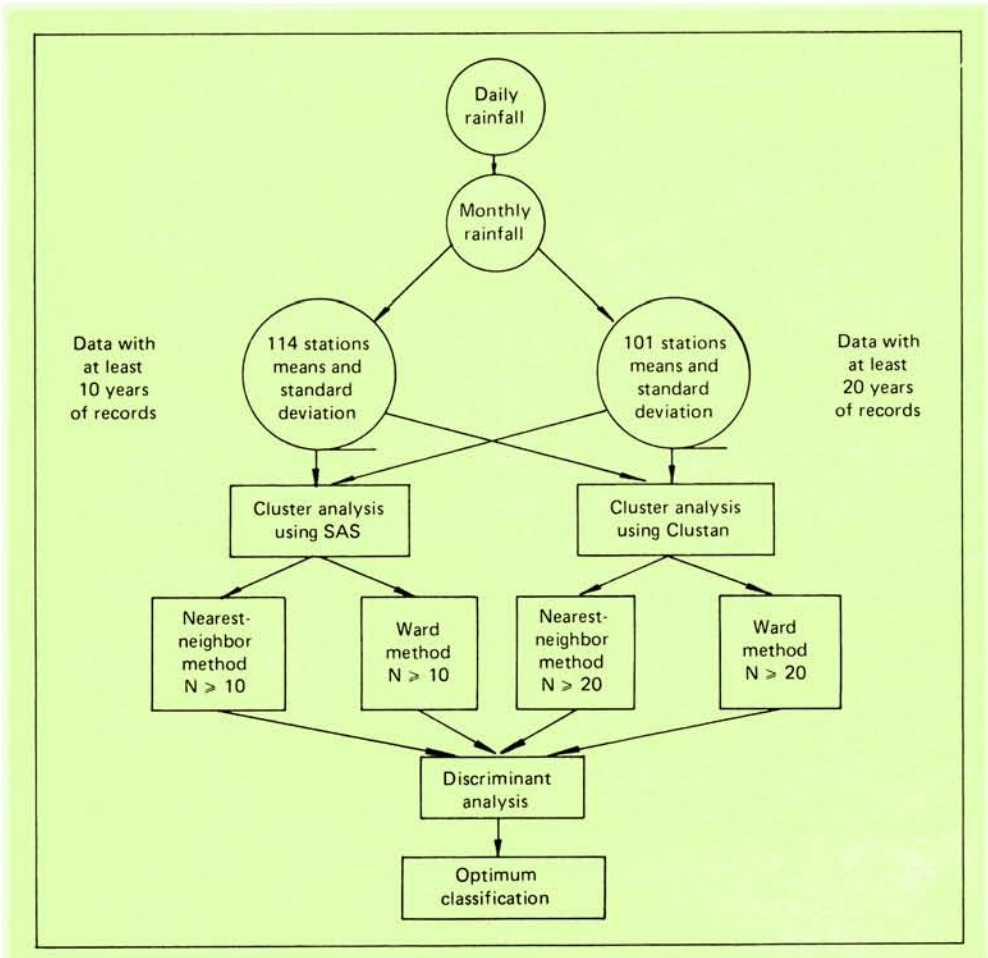
The climatic factor that most influences agriculture in the humid tropics is rainfall. Two types of cluster analysis (Nearest-neighbor and Ward Agglomerative Techniques) were made of rainfall records of more than 20 years from 101 Philippine weather stations. The process involves 1) establishment of a data basis, 2) standardization of a data matrix, 3) calculation of a similarity matrix, and 4) grouping of entities, usually in the form of dendograms, on the basis of the similarity matrix (Fig. 1).

The dendograms constructed by the Ward method yielded the more meaningful classification. Geographical distribution and rainfall patterns for the seven optimum classification groups are shown in Figures 2 and 3.

The fairly compact climatic groups, with few inliers and outliers, are:

Group 1 — most of the Ilocos region, Coron Island, Quezon City, Antique, and southern Negros — has a long dry period (less than 100 mm rain) from December to April. Rainfall exceeding 100 mm starts in April or May. Rainfall peaks at 600 mm in July and August.

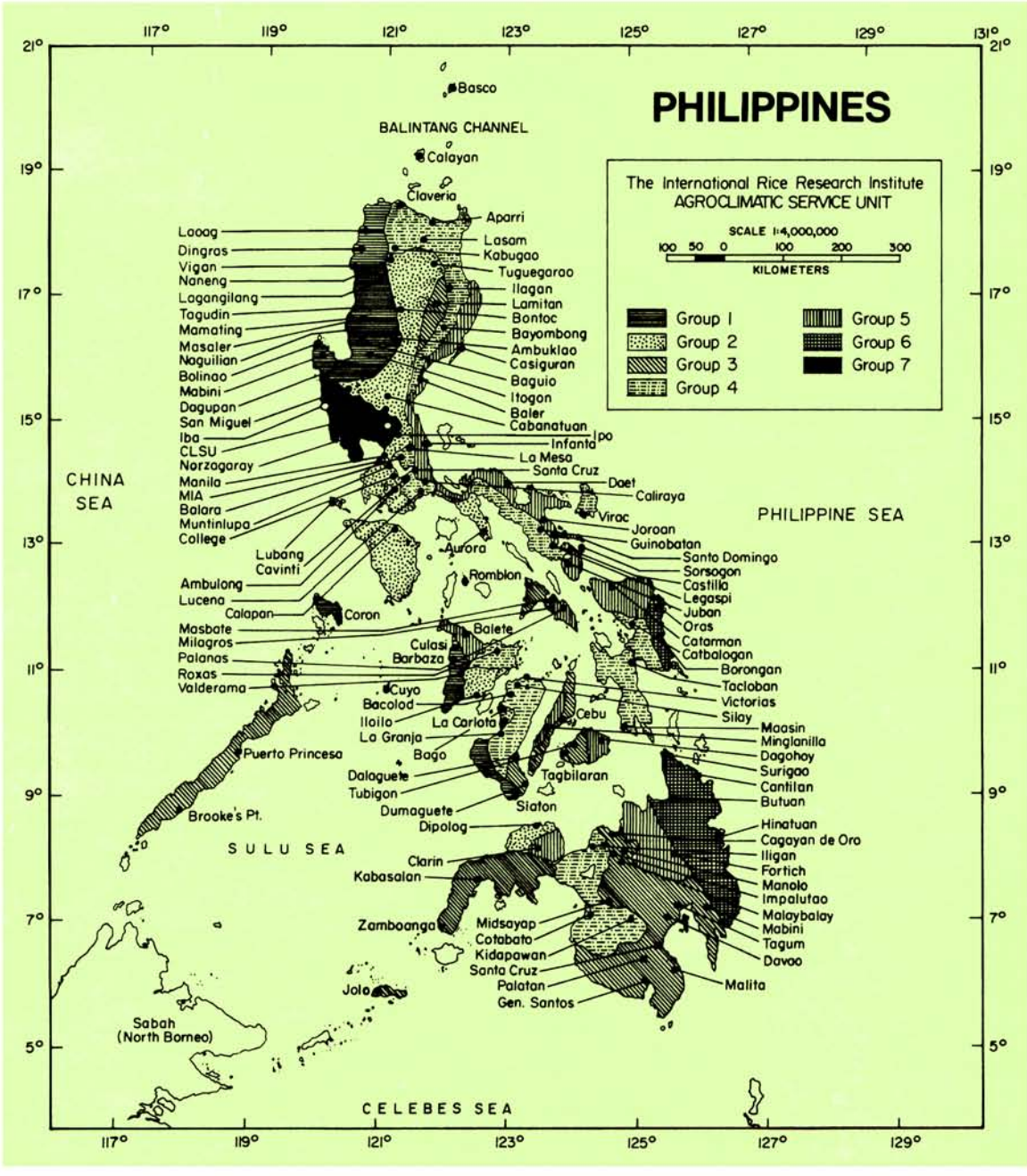
Group 2 — areas bounded by Bontoc, Naneng, and Tuguegarao; Cabanatuan; southern Tagalog provinces; Mindoro; Romblon; Iloilo and the adjacent portion of Negros; and the northern tip of Zamboanga del Norte — has a dry period from January to April, and no pronounced wet period. Rainfall exceeds 300 mm during July and August.



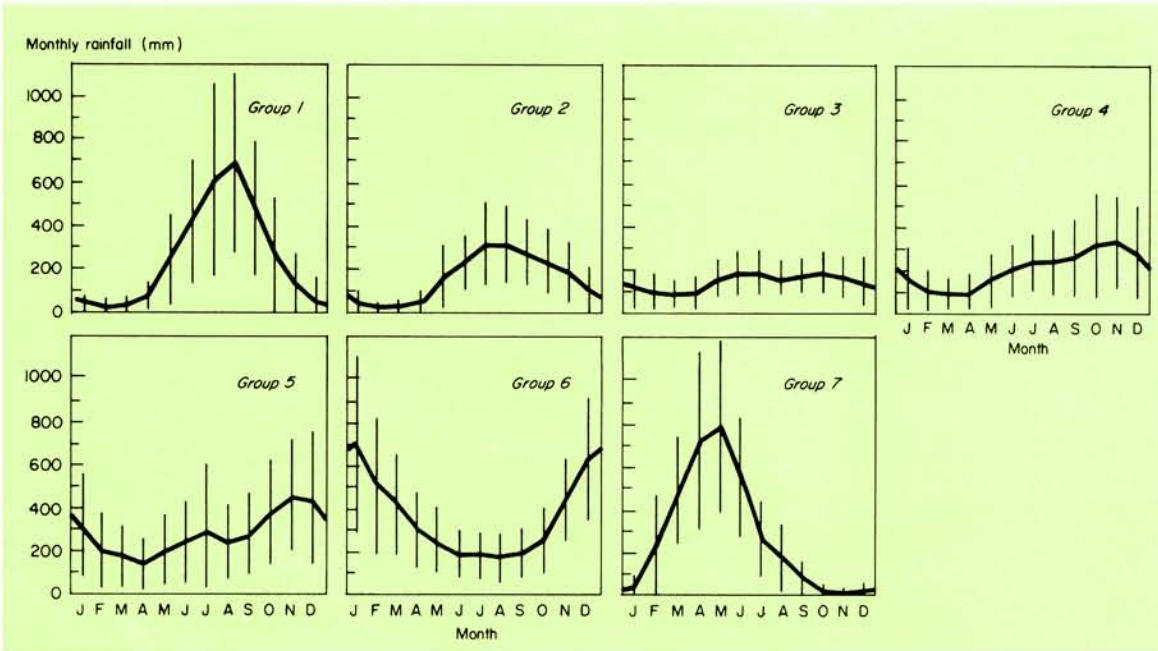
1. System flow of chronological steps in analyzing rainfall records.

Group 3 — Lamitan of Cagayan Valley, the whole of Palawan, western Masbate, southeastern Negros, eastern Cebu, the western half of Bohol, and central and western Mindanao, including Jolo — has no pronounced dry and wet periods. Rain fluctuates from 100 to 200 mm throughout the year.

Group 4 — northeastern and southeastern



2. Geographical location classification of rainfall patterns in the Philippines.



3. Averages and standard deviations of monthly rainfall of optimum rainfall classification groups in the Philippines.

Luzon, including Virac; eastern Samar; the whole of Leyte, the greater part of Negros; Capiz, and Lanao — has no pronounced dry period. October and November have rainfall exceeding 300 mm.

Group 5 — eastern Luzon, northeastern Samar, eastern Masbate, Aklan, western Cebu, the eastern half of Bohol, Occidental Misamis, and Agusan — has no dry period. November and December have rainfall exceeding 400 mm.

Group 6 — eastern Samar and eastern Mindanao — has no dry period. December and January have rainfall exceeding 600 mm.

Group 7 — Central Luzon — has a long dry period, from September to January. Pronounced wet months (at least 500 mm rainfall) are from March to June. April-May rainfall may exceed 600 mm.

LANDFORM CLASSIFICATION

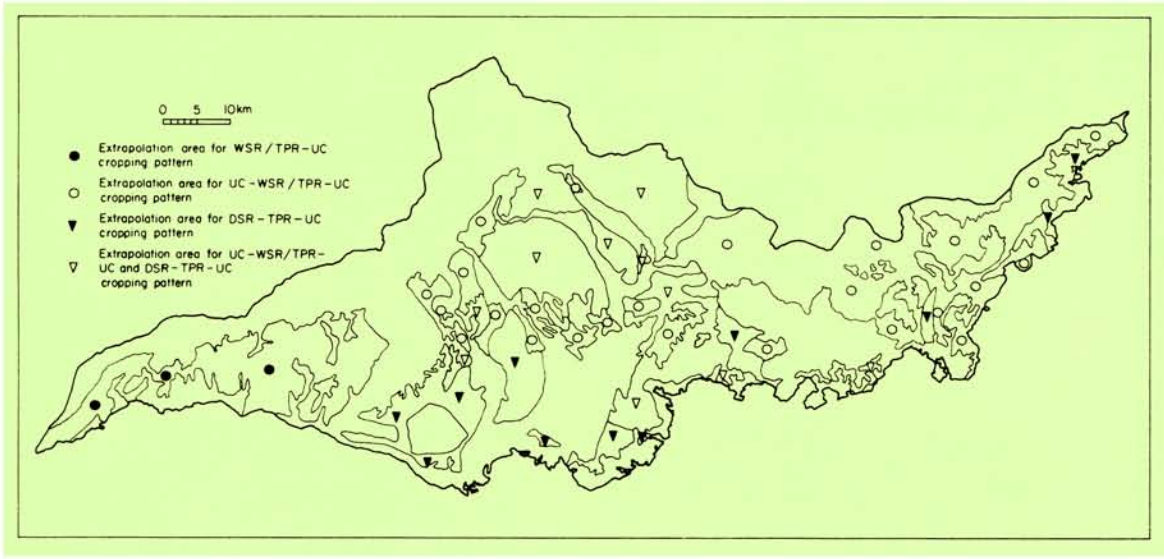
Multiple Cropping Department

A four-category land classification system adopted in Cagayan Valley (Annual report for 1980) was used to characterize rice land in Iloilo Province. Aerial photo interpretation techniques were used to map landforms for all of Panay Island. Four land systems, 10 land subsystems, 35 landform units, and 80 land surface units were recognized. Landform units are identified by characteristic terrain features. The same or a similar sequence of crop species can be cultivated each year in a landform unit. In Iloilo Province, 22 landform units were mapped. Most rainfed rice in Iloilo is grown on alluvial terrace and bench terrace landform units (Table 1).

Areas with rainfall, soil type, and landform units

Table 1. Rice planted on different landform units in Iloilo Province, Philippines, 1981.

Landform unit	Rainfed rice (ha)
Alluvial terrace	76,939
River scar	487
Recent river terrace	864
Interhill miniplain	445
Hillslope	32
Alluvial fan	18
Drainageways	4,308
Bench terrace of plain land system	17,391
Marine terrace	217
Bench terrace of hill land system	2,315
Valley floor	642
Peak	67
Bench terrace of mountain land system	837
Total	104,562



4. Extrapolation area map, Iloilo Province, Philippines.

Table 2. Extrapolation areas for promising cropping patterns in Iloilo Province, Philippines.

Cropping pattern[a]	Extrapolation area (ha)	Percent of total area
WSR/TPR-mungbean	37,906	16
Mungbean-WSR/TPR-mungbean	92,679	39
DSR-TPR-mungbean	40,690	17
Mungbean-WSR/TPR-mungbean and DSR-TPR-mungbean	66,552	28
Total	237,827	

[a]WSR = wet-seeded rice, TPR = transplanted rice.

similar to those of about 30 research sites established by IRRI and Kabsaka were delineated (Fig. 4). The areas where promising cropping patterns can be adapted were calculated for the 44 Iloilo municipalities. The extrapolation for Iloilo Province is presented in Table 2.

EVAPOTRANSPIRATION MODEL TESTING

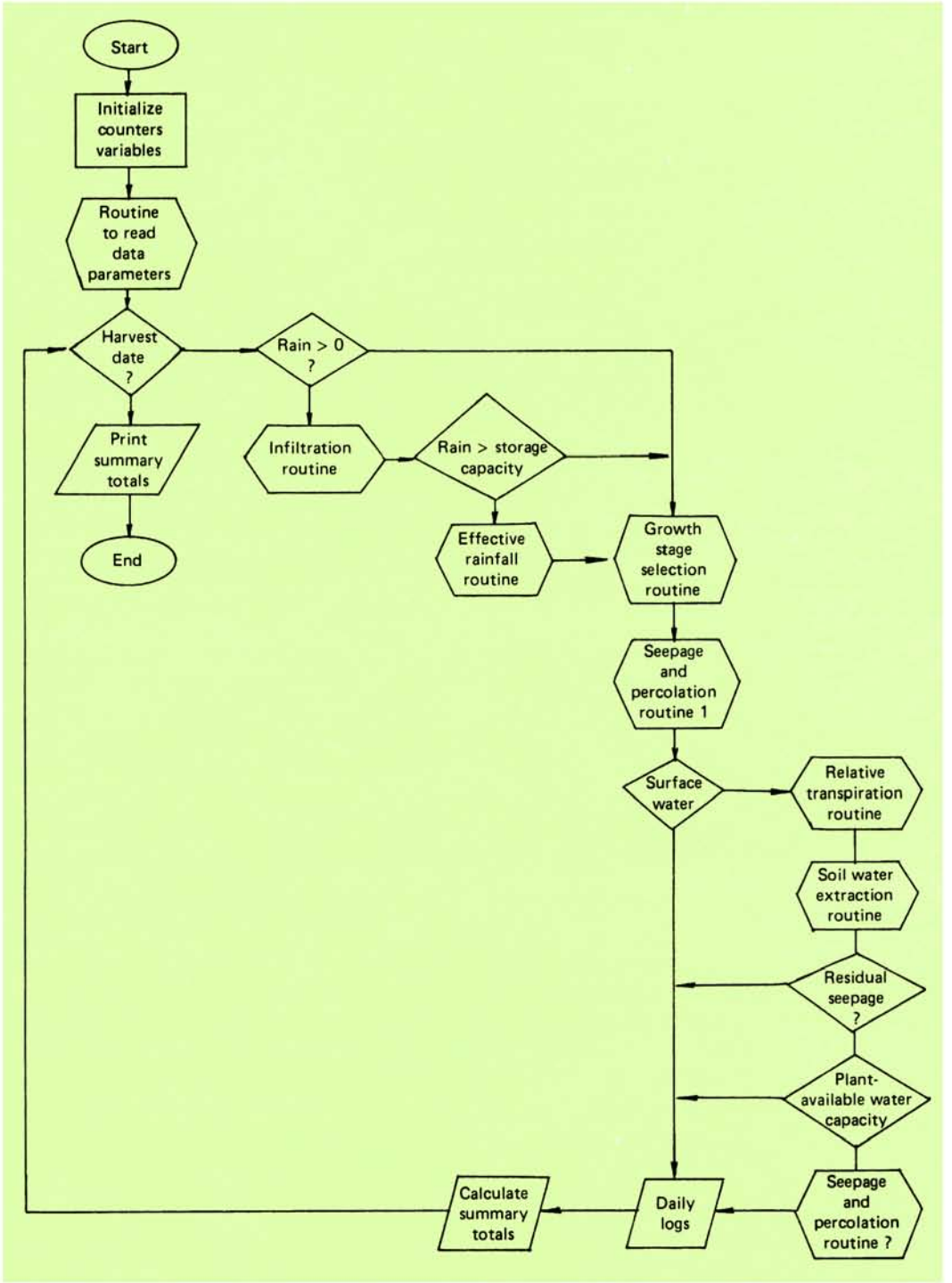
Multiple Cropping Department

A method for tying together weather and land is needed if site description information is to be used in the design of cropping systems. Such a method also would enable comparison of cropping pattern potential and test data. To the extent that a rainfed rice-based cropping pattern is dependent on local rainfall, a model from which crop evapotranspiration can be derived could be used to project expected productivity of cropping patterns over time.

An evapotranspiration model developed for maize was used as the starting point. A simplified flow chart is shown in Figure 5. Estimated crop and soil parameters and state variables are described in Table 3. Rainfall and pan evaporation are the two driving variables. The model time step is 1 day.

To estimate seepage and percolation losses, soil texture, estimated pore space, and seasonal period were taken into consideration. The growing year was divided into 7 periods based on seasonal rainfall accumulation (Table 4). To adjust for changes in crop development, the growth period was divided into six stages, counting backward from date of harvest. All variability in growth due to differences in seedling age and early moisture stress was accommodated in the nonfixed intervals.

Data on soil profile, grain yield, rainfall, pan evaporation, and daily water depths were collected 1976-79 at the Iloilo Cropping Systems Research Project. Fields were classified into land surface units on the basis of land system, slope shape, and landform position. The land surface unit used to test the model occurred on broad interfluves or flat extensive areas. Except for overflow from torrential rains, the water movement was assumed to be vertical.



5. A simplified flow chart of the evapotranspiration model from which alternative crop water adequacy indexes were derived. IRRI, 1981.

Table 3. Driving and state variables and parameters required by the evapotranspiration model.

Description	Unit
Daily rainfall	cm/day
Daily pan evaporation	cm/day
Maximum extractable water in each of 5 soil layers, from the surface down, in increments of 5, 10, 15, 30, and 40 cm	cm water/layer
Current extractable water in each of 5 soil layers	cm water/layer
Maximum permissible water depth above the soil surface, as a function of crop growth stage	cm water
Current water depth above soil surface	cm water
Seepage and percolation rate, as a function of soil textural class and period in wet season	cm water/day
Combined crop-pan factors for successive periods before harvest (10, 10, 24, 30, 10, and remainder days). The last factor was applied to all crop days preceding 84 days before harvest.	dimensionless
Factors used to partition maximum evapotranspiration and evapotranspiration reduced for soil water stress conditions among 5 soil layers in each of 6 growth stages	dimensionless
Maximum evapotranspiration	cm/day
Relative transpiration ratio	dimensionless
Evapotranspiration reduced for soil water stress conditions	cm/day
Potential surface evaporation, adjusted for extractable water limitations	cm/day
Plant-available water capacity in each of 5 soil layers	cm water/layer
Water held between saturation and field capacity in each of 5 layers	cm water/layer
Water not readily available to crops in each of 5 layers	cm water/layer

The primary method used to evaluate alternative parameters and driving variables was correlation analysis, with significant correlations predicted on the assumption that yield would increase as model-derived evapotranspiration increased. The test was on the change that alternative parameter estimates produced in model-derived evapotranspiration and the effect of those changes on the correlation between evapotranspiration and yield.

Three supplementary methods were used model-derived stress days correlated with actual stress days, model daily water depth compared with observed daily water depth, and percentage changes in model-derived evapotranspiration caused by modified parameter estimates.

Four alternative crop water adequacy indexes were compared — model-derived evapotranspiration accumulated over a 34-day period from heading to maturity, model-derived evapotranspiration accumulated over a 64-day period, model-derived stress days accumulated over the 34 days, and model-derived stress days accumulated over the 64 days.

Three levels of model-derived evapotranspiration over 64-day levels were used to separate 4 water-adequacy classes for wet-sown and transplanted IR36 crops in Iloilo (Table 5).

WEATHER AT THE SOLANA CAGAYAN, CROPPING PATTERN TEST SITE

Multiple Cropping Department

Rainfall. The rainfall pattern for each month, except July and December, closely followed the 25-year monthly average (Fig. 6). Higher rainfall in

Table 4. Periods in the growing season determined by rainfall accumulation and corresponding classes.

Period of the growing season	Accumulated rainfall (mm)	Class
Very early	100[a]	1
Early	200[b]	2
Midearly	400[b]	3
Midrainy	400[ab]	4
Midlate	400[b]	3
Late	200[b]	2
Very late	100[b]	1

[a]Starting from 1 January, daily rainfall accumulated over subsequent days to amount indicated. [b]Starting from 31 December, daily rainfall accumulated over preceding days to amount indicated.

Table 5. Criteria for model-derived evapotranspiration over 64 days to assess water adequacy.

Water adequacy[a]	Evapotranspiration (cm)	
	Dark soil	Light soil
Adequate	> 32	> 40
Subadequate	20 to 32	28 to 40
Marginal	5 to 20	13 to 28
Very deficient	< 5	< 13

[a]Water adequacy refers to evapotranspiration, as determined through computations with the evapotranspiration model.

May, June, and August benefited dry-season rice and the first transplanted rice crops, unlike in the 1980-81 crop year. Rainfall ceased abruptly in late November. The post-transplanted rice (TPR) mungbean crop, which depended on soil residual moisture, suffered from drought.

Tropical depressions. Eight typhoons (Table 6) caused 3-4 rainy days, each with 37-134 mm precipitation. Typhoon Kuring caused considerable damage to the mungbean crop but was beneficial to the dry-seeded rice crop. Typhoon Anding in late November caused flooding in the second and third strata, which hampered transplanting of the second TPR crop in the TPR - TPR - mungbean pattern.

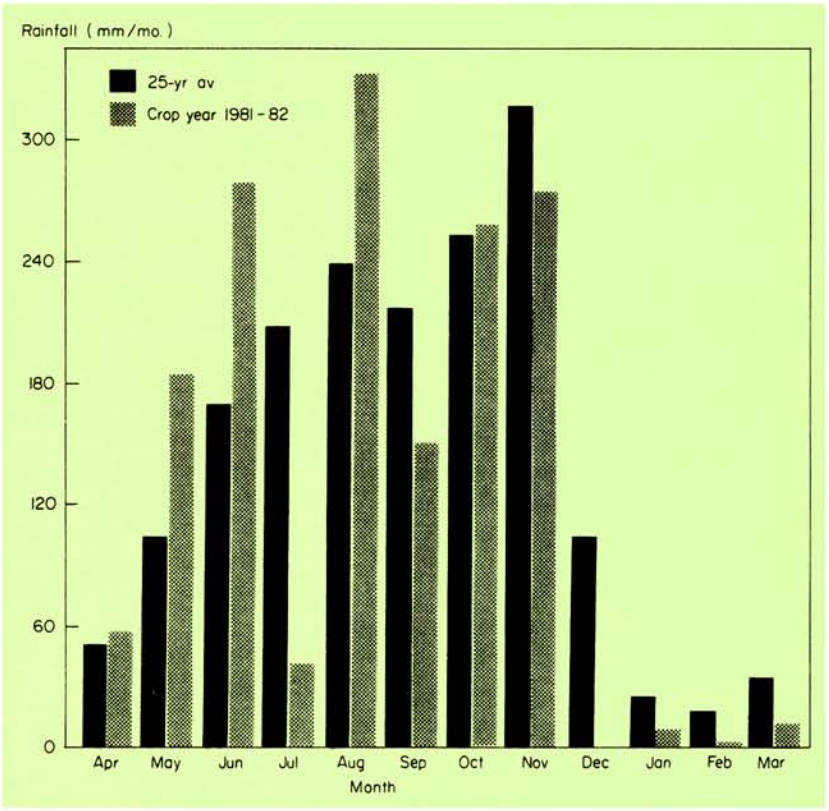
Solar radiation. The high solar radiations in April and May corresponded to higher temperatures (Fig. 7) and evapotranspiration.

DISEASE SURVEYS

Plant Pathology Department

Rice. In the 1980-81 cropping season at Solana, Cagayan, brown spot [*Cochliobolus miyabeanus* (I & K) Drechsler ex Dastur] was observed at panicle initiation in the late-maturing rice crop. Infection was light (about 1% of the leaf area affected) and confined to lower leaves. Seedlings had remained in the seedbed as long as 50 days. That resulted in nutrient deficiency and brown spot susceptibility.

In the 1981 season, bacterial leaf streak (*Xan-*



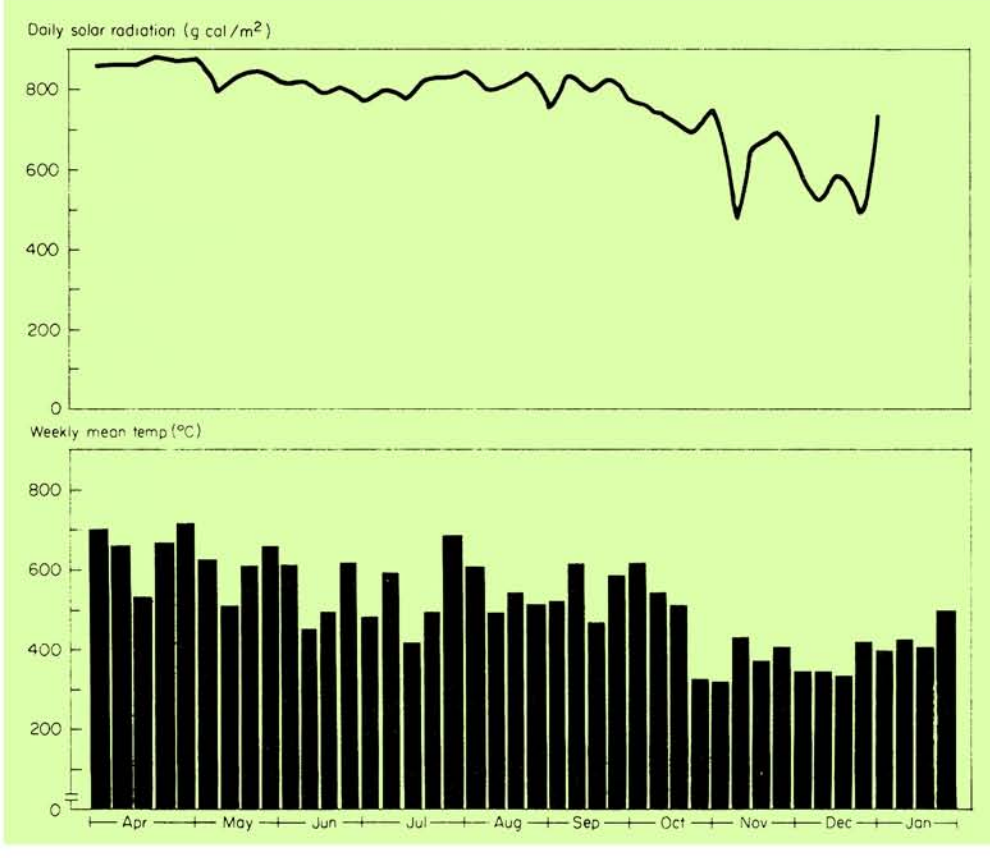
6. Monthly rainfall in the 1981-82 cropping season and the 25-year average in Solana, Cagayan, Philippines.

Table 6. Tropical depressions in 1981 – their duration and total rainfall, Solana, Cagayan, Philippines.

Tropical depression	Tropical depression dates	Total rainfall (mm)	Rainy days (no.)	Highest daily rainfall	Date
Bining	8-11 Jun	116.8	4	50.9	11 Jun
Kuring	15-17 Jun	74.0	3	41.6	17 Jun
Miling	3-6 Aug	82.0	4	53.7	6 Aug
Osang	13-15 Aug	95.9	3	75.6	14 Aug
Rubing	19-21 Sep	133.9	3	85.3	20 Sep
Unsing	3-5 Oct	48.2	3	20.3	3 Oct
Walding	20-22 Oct	37.2	3	19.3	21 Oct
Anding	23-25 Nov	60.3	3	47.2	25 Nov

thomonas campestris pv. *oryzicola* Dye) occurred at stem elongation to booting stages in the research-managed field. In plots with only basal nitrogen application, dry-seeded plants were chlorotic and bacterial leaf streak was severe (<25% leaf area affected).

Four of 13 research-managed, cropping pattern, and farmers' fields had sheath blight [*Corticium sasakii* (Shirai) Matsumoto] from panicle initiation to ripening, with a mean incidence of 58.3% and a severity rating of 3.4 (lesions present on about half of the leaf sheath area).



7. Average weekly solar radiation and temperature at Solana, Cagayan, Philippines, 1981-82.

All entries in the medium-maturing variety trial were healthy, except Wagwag-Tawataw, which had light (<5%) bacterial leaf streak infection.

One farmer's field with transplanted IR46 suffered from about 25% incidence of tungro virus disease. Light infection of brown spot also occurred, particularly in chlorotic plants.

Mungbean. On mungbean planted after rice, damping-off incidence was 0 - <1% in 3 of 4 fields in strata 1 and 2. Fungal growth on infected seedlings suggested that the pathogen involved was *Sclerotium rolfsii* Sacc. Powdery mildew (*Erysiphe polygoni* D. C.) with a severity rating of 1-3 (1-5% leaf area affected) was observed as early as the cotyledon leaf stage. No record of disease occurred on the mature mungbean crop because of drought.

Mungbean grown before rice suffered from *Cercospora* leaf spot (*Cercospora* spp.). Spots also were observed on pods. The local variety had severity ratings of 7-9 (>25% leaf area affected) on the lower leaves and 3-5 (1-25% leaf area affected) on the upper leaves. CES ID-21 grown in research-managed fields had severity ratings of 5-7 on the lower leaves and 0-3 on the upper, confirming the variety's resistance to *Cercospora* leaf spot.

YIELD LOSSES FROM INSECTS

Entomology Department

Losses were measured as the differences between yields from plots with complete insecticide protection and yields from untreated plots. In the rainfed wetland environment of Solana, Cagayan Province, insect pests of rice and mungbean were not important in 1981.

In the early monsoon mungbean sown in April, yield differences between protected (1.22 t/ha) and unprotected (1.08 t/ha) plots were not significant. In Pangasinan, mungbean planted after rice typically has more than 70% yield losses. All of the key pests in Pangasinan were present in Solana, but populations were extremely low.

IR52 direct seeded in dry soil as a first rice crop did not show yield-loss differences between protected (3.26 t/ha) and unprotected (3.47 t/ha) plots.

The 1980 loss of stand because of ants (Annual report for 1980) did not recur in 1981. Extensive flooding in October-November 1980 possibly suppressed the ant population.

In IR52 transplanted in August as a single crop, the difference in yield between protected plots (3.6 t/ha) and unprotected plots (3.1 t/ha), was not significant. No insect surpassed economic thresholds in any field. Traditional rice variety Wagwag also showed no yield loss between protected (3.18 t/ha) and unprotected (3.44 t/ha) plots, even though the crop matured over 7 months, ample time for a pest buildup.

The absence of significant insect pest buildups on mungbean and rice is attributed to the 4-month dry fallow preceding the monsoon growing season. This extensive host-free period greatly suppressed insect populations. In addition, the alternating drought and flood typical of the area are not conducive to sustained insect pest multiplication during the growing season.

Cropping systems program

Social and economic environment

Agricultural Economics Department

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AGROECONOMIC PROFILE OF SOLANA, CAGAYAN, PHILIPPINES, RESEARCH SITE

A baseline survey (1979-80) of 100 farm household respondents in 3 villages (Bangag, Bauan, and Iraga) of Solana, Cagayan, Philippines, collected the agroeconomic data needed to design the experimental cropping patterns tested in 1980-81 (Table 1). Subsequent special surveys and farm record keeping by 48 farmer-cooperators collected additional information for evaluating new cropping patterns and component technologies (Table 2). These data and data from secondary sources comprise a basic profile of the agricultural activities, and the characteristics of the farmers, their families, and local institutions.

Agronomic practices. The Solana, Cagayan, research site is a little more than 500 km north of Manila and 8 km northwest of Tuguegarao, on the flood plains and terraces of the Cagayan River. Farmers in the area recognize two agricultural land types: lowland rice fields (*talon*), and upland areas (bangkag) (Fig. 1).

They divide the shallow lowland area into two strata according to the relative elevation of their fields and differences in water regimes. Farmers plant comparatively earlier maturing local rice varieties in the higher portion (*parang*) than in the lower portion (*kalayakan*).

The upland area also is stratified by relative elevation. Its topography ranges from gently to steeply sloping. The lowest terraces, bordering the Cagayan River, are *labbeng* and the elevated terraces, *koman*.

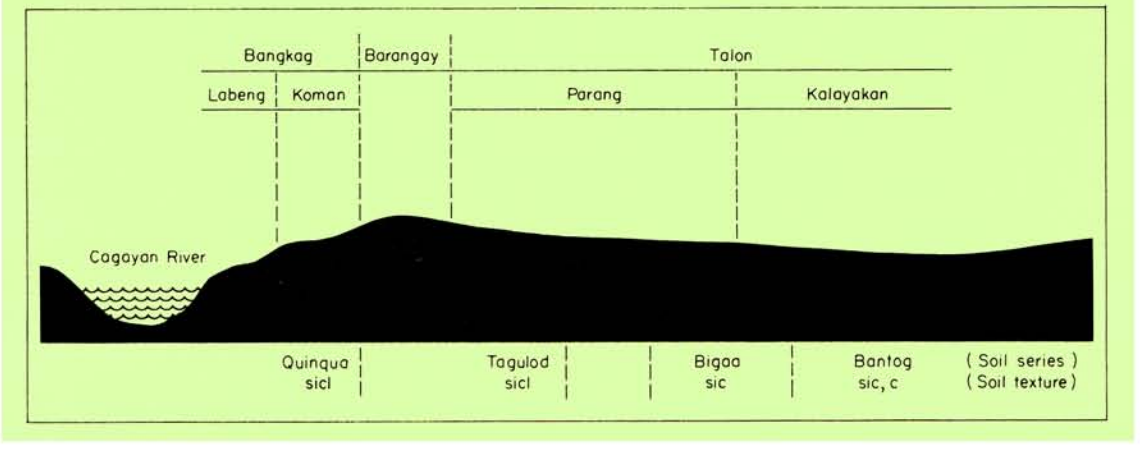
The dry season is short (January-April); the wet season takes place during the rest of the year. Typhoons and flooding in September, October, and November limit continuous crop production. Rainfall is less than 100 mm/month from January to April and more than 200 mm/month from July to November. The rainy season normally begins in late May and rainfall often continues until the

Table 1. Baseline farmer respondents in Solana, Cagayan, 1979.

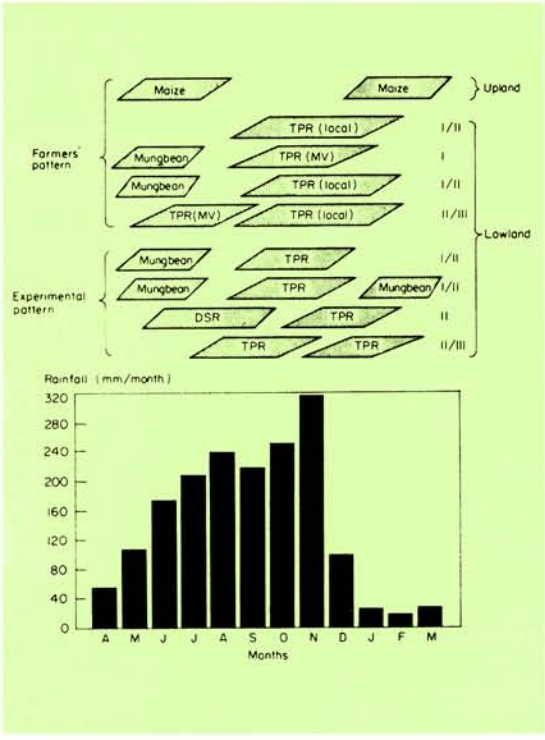
Survey barangay	Farmer respondents (no.)	Farm households (no.)	Respondents (% of households)
Bangag	34	325	10.5
Bauan	36	514	7.0
Iraga	30	356	8.4
Total	100	1195	8.4

Table 2. Farmer cooperators in Solana, Cagayan, selected from 1979-80 baseline survey, 1980.

Farm size (ha)	Farmer cooperators (no.)			
	Bangag	Bauan	Iraga	Total
0.50 - 1.25	3	3	3	9
1.75 - 2.50	5	5	5	15
3.00 - 3.75	5	5	5	15
4.25 - 5.00	3	3	3	9
Total	16	16	16	48



1. Schema of landscape and soil classifications of the IRRI cropping systems outreach site. Solana, Cagayan Valley, Philippines, 1981.



2. Farmers' traditional and IRRI experimental cropping patterns, graphed against 25-year monthly rainfall averages for Solana, Cagayan, Philippines, 1981.

beginning of the dry season in December.

Farmers use alternative cropping patterns to accommodate landscape and rainfall variations. Figure 2 compares farmer cropping patterns with 1981-82 experimental patterns. The distribution of lowland and upland areas into major cropping patterns in 1979-80 is summarized in Table 3. A calendar of crop cultivation activities is in Table 4.

Lowland cropping patterns. In the higher portion of the lowland area, a mungbean-transplanted rice (TPR) pattern occupies 80% of the total land area, followed by fallow-TPR (12%). In the lower portion, mungbean-TPR accounted for 77% of the land area, fallow-TPR for 16%, and TPR-TPR for 7%.

Lowland rice cultivation. Almost all the rainfed area is planted to local photoperiod-sensitive Wagwag varieties, popular because of good eating quality and tolerance for drought and flood. Farmers also claim that Wagwag varieties compete well with weeds and require no chemical fertilizers or pesticides to produce yields.

But local varieties require 5-6 months to maturity and only 1 rice crop can be cultivated in a year. Some Solana farmers have begun to incorporate modern varieties (MV) into their cropping pat-

Table 3. Distribution of lowland and upland fields by farmer cropping patterns, Solana, Cagayan, 1979-80.

Cropping pattern[a]	Area (%)	
Lowland	*Parang*	*Kalayakan*
Mungbean - TPR (local) Mungbean - TPR (MV)	80	77
Fallow - TPR	12	16
TPR (MV) - TPR (local)	–	7
Mungbean - fallow	4	–
Mungbean - TPR (MV) - TPR (local)	–	–
Maize or cowpea - TPR	4	–
Total	100	100
Upland	*All land*	
Maize - maize	68	
Maize - maize/mungbean	6	
Maize/mungbean - maize or maize/mungbean	8	
Maize - mungbean or tobacco	6	
Maize/peanut - maize/peanut or maize	5	
Tobacco - maize	4	
Mungbean - mungbean	2	
Mungbean/maize - fallow	1	
Total	100	

[a]TPR = transplanted rice, MV = modern variety. A dash (–) indicates sequential planting. A slant (/) denotes interplanting.

Table 4. Calendar of farmers' major crop production activities[a], Solana, Cagayan, 1979-80.

Month	Agricultural activity	
	Lowland	Upland
April	Mungbean: Land preparation and planting TPR (MV): Seedbed and land preparation	Maize: Land preparation and planting
May	Mungbean: Planting/management practices TPR (MV): Planting TPR(L): Seedbed and land preparation	Maize: Planting Mungbean: Planting
June	Mungbean: Harvest, threshing/drying TPR (MV): Planting TPR(L): Seedbed and land preparation	Maize: Cultural activities Mungbean: Cultural activities
July	Mungbean: Harvest, threshing TPR (MV): Harvest TPR(L): Land preparation and planting	Maize: Harvesting Mungbean: Harvesting
August	TPR(L): Land preparation and planting TPR (MV): Harvesting, threshing/drying	Maize: Harvest, transport Mungbean: Harvest, transport
September	TPR (MV): Harvesting TPR (L): Planting	
October	TPR(L): Planting	
November		
December	TPR (L/MV): Harvest begins at the end of month	Maize: Land preparation Mungbean: Land preparation
January	TPR(L/MV): Harvest threshing/drying	Maize: Land preparation
February	TPR(L): Harvesting, threshing, drying	
March	TPR (L/MV): Drying, cleaning, storing	Maize: Harvesting, cleaning Mungbean: Harvesting, cleaning

[a]A typical Solana farmer has about 1.5 ha each in lowland and upland areas. TPR = transplanted rice, MV = modern variety, L = local variety.

terns, either as a second crop following mung or as the first of two TPR crops.

Seedbed preparation for MV as a first crop in a two-rice crop pattern begins in late April. For traditional rices as a single crop or after mung, seedbed preparation does not begin until June or July. In the lower areas, seedbeds usually are puddled because water can be accumulated; in slightly higher areas, farmers resort to dry seedbed establishment. Seeding rates range from 40 to 60 kg/ha.

Land preparation for the first rice crop begins in May, shortly after land preparation has begun on plots where mung will be planted. Fields are

plowed and puddled for a second rice crop in July-August. Land preparation for rice as a single crop also takes place about the same time.

It is done almost exclusively with carabao. One or two plowings followed by one or two harrowings is the conventional tillage practice.

Water status dictates where transplanting begins. If standing water is high on the lower land, transplanting starts in higher fields. As soon as sufficient water is available on the lower fields, rice as a first crop is transplanted, sometimes as early as June, using 20-day-old seedlings. Transplanting of local varieties on the lowest fields is usually done in September with older seedlings, which farmers believe can withstand flooding better than MV. Single-crop or second-crop rice is transplanted in higher fields in July.

Crop care after establishment is minimal (Table 5). Hand weeding is done more to collect forage for carabao than to clear the fields of weeds. In 1979-80, a few farmers reported using chemical fertilizers (17%), pesticides (23%), and herbicides (14%); but recently the use of these inputs has stopped. Even the few farmers who planted MV did not apply any fertilizer or pesticide in 1981-82. Rising costs may be causing lower use of inputs.

Modern varieties as a first crop on lower fields is harvested in August and September, in time for a second local rice crop to be transplanted. Local varieties are harvested from mid-January to early March, depending on field location. In general, local varieties established on the lowest fields are harvested later than those on upper fields. Farmers harvest and thresh their crops manually.

Table 5. Farmers' cultural practices for the most dominant crop, Solana, Cagayan, 1979.

Cultural practice	Farmers reporting (%)		
	Rice	Mungbean	Maize
Tillage level			
Low tillage[a]	–	66	–
Minimum tillage[b]	63	28	75
High tillage[c]	37	6	25
Method of establishment			
Broadcast	–	20	–
Furrow	–	80	100
Transplanting (random)	100	–	–
Fertilizer application[d]	17	–	–
Insecticide application	23	26	–
Herbicide application	14	–	–
Seeding rate (kg/ha)	40-60	10-15	15

[a]Low tillage – opening of furrows only. [b]Minimum tillage – 1 plowing + 1-2 harrowing(s). [c]High tillage – 2 plowings, 1-2 harrowing(s). [d]Applied nitrogen averaged 6.54 kg/ha.

Lowland mungbean cultivation. Mungbean is the most important cash crop in the lowland areas. It commands a higher market price than rice, maize, and other crops commonly sold for cash throughout the year.

Under rainfed conditions, mungbean is planted in lowland areas as a single crop once a year in April-June; in upland areas, it is intercropped with maize or is a monocrop cultivated two to three times a year, depending on weather conditions.

Land preparation for mungbean begins after the first rains in late March or April. While land preparation for mungbean ranges from no tillage (opening of furrows only) to high tillage (2 plowings plus 1-2 harrowings), most farmers follow no-tillage practices, — they open the furrows and harrow after planting.

The time of crop establishment is critical to successful mungbean cultivation. A very early crop may suffer from drought and a late planting may be severely affected by flooding. Where land preparation is done with minimum to high tillage, mungbean is sown in furrows or broadcast; when no tillage is done, seeds are sown in furrows only. Seeding rates are 10-15 kg/ha. The popular variety now is Araña, which has a relatively shorter maturity than most MV.

Minimal care is provided after crop establishment (Table 5). The few farmers who use insecticides apply a very small dosage only when insect damage is clearly evident during the flowering stage.

If the mungbean crop fails early because of flooding or drought, farmers replant if they can afford the seed cost. If the mungbean crop is successful or the damage is minimal, farmers can have one to four harvests, the first in early June and the postharvest in mid-July. Mungbean pods are picked manually and dried in the sun before threshing and storage.

Upland cropping patterns. Maize-maize occupied 78% of the area. The remaining area was planted to such minor patterns as maize + mungbean - maize + mungbean, and maize - maize + mungbean (Table 3). The land shares of each pattern varies. Mungbean cultivation is similar to

practices in the lowlands. Intercropped mungbean is planted between maize rows.

Upland maize cultivation. Maize is the second most important crop, providing half of the energy requirements of farm households. It often is cultivated two times a year.

Maize is planted as a monocrop or intercropped with other upland crops. The first maize crop is established April-May and harvested July-August. The second maize crop is established after flooding in December and harvested in March.

Land preparation for maize ranges from minimum tillage (1 plowing followed by 1 harrowing) to high tillage (2 plowings followed by 1-2 harrowings). Seeds are sown in furrows at 15 kg/ha. The local variety is Los Baños, which has relatively short maturity and is shorter statured than most MV.

Hilling-up is commonly done 1 month after emergence, then minimal care is provided (Table 5). The few farmers who use pesticides apply small dosages only when damage is clearly evident.

To the extent feasible, maize is field dried. To prevent its exposure to rain and insect damage, it should be harvested wet and sun-dried on patios, roads, or other open spaces. All maize is harvested manually and stored unhusked. Husking and shelling are not done until the product is about to be sold or used as food.

Farm households. Available socioeconomic data show that Solana and the broader Cagayan River valley are largely agricultural, with most farm households engaged in agriculture (Table 6). A higher proportion of Solana's population is engaged in agriculture, and has a lower per capita income and a more polarized distribution of income and farm size than the Republic of the Philippines as a whole.

From 69 to 88% of the households in Bangag, Bauan, and Iraga villages were engaged in farming

Table 6. Selected socioeconomic characteristics of Solana municipality, Cagayan Province, and the Republic of the Philippines. Sources: *1981 Philippine Statistical Yearbook,* **NEDA, Manila, 1981;** *1971 Census of Agriculture,* **National Census and Statistical Office, NEDA, Manila, 1972;** *Cagayan Valley (Region II) Five Year Development Plan, 1978-82,* **NEDA, Tuguegarao, 1977.**

Socioeconomic characteristic	Solana[a]	Cagayan	Philippines
Land area (km²)	n.a.	9,002.7	300,000.0
Population			
Actual (1975)	19,525.0	644,000.0	47,914,000.0
Projected (1980)	21,587.0	712,000.0	42,071,000.0
Density (1980) (persons/km²)	n.a.	79.1	159.7
Education			
% literate (1976)	81.0	80.8	83.4
% completed elementary (1970)	n.a.	36.8	40.0
Employment (1976)			
Total labor force (persons)	21,349.0	697,000.0	16,244,000.0
% in agriculture	55.0	66.1	50.0
% unemployed	8.0	4.2	4.5
Income distribution (1971)[b]			
% earning below $312/yr	n.a.	60.0	40.0
% earning above $1,562.50/yr	n.a.	10.0	20.0
Median family income ($)	n.a.	253.90	385.16
No. of farms by size (1971)			
Total	3,470.0	53,496.0	2,354,843.0
Less than 5.0 ha	3,064.0	48,788.0	1,991,239.0
Less than 5.0 ha (%)	88.3	91.2	84.6
Other indicators (1976)			
Paved roads – km/10,000 persons	21.3	n.a.	28.2
Hospital beds (no./1,000 persons)	n.a.	12.3	10.9

[a] n.a. = not available. [b] US$1 = ₱6.40.

Table 7. Farm and nonfarm households in Solana, Cagayan. Source: National Census and Statistics Office, Solana, Cagayan, 1980.

Barangay	Landless households		Farm households		Total	
	No.	%	No.	%	No.	%
Bangag	143	31	325	69	468	100
Bauan	69	12	514	88	583	100
Iraga	115	24	356	76	471	100
Total	327	21	1,195	79	1,522	100

Table 8. Sources of information on farming technology used by farmer respondents, Solana, Cagayan, 1979.

Information source	Never (%)	Sometimes (%)	Often (%)
Government technician	67	26	7
School on the air	25	43	32
Other farmers	37	38	25
Farm input dealers	76	22	2
Barangay leaders	80	15	5

(Table 7). A composite profile of a typical Solana farm household has been based on data collected from 100 farm families in 1979 and from farm records and special survey data collected from 48 farmer cooperators since 1980.

Farm household characteristics. The typical Solana farmer is about 43 years old, with 24 years of farming experience and 3 years of formal education. He may not be literate himself but probably at least one among the six members of his family — usually an older child — can read and write. A family of the farmer, his wife, and three to six children may belong to one of several ethnic groups — Ilocano and Ibanag backgrounds are most common, with some Itawis.

Institutional participation. Solana farmers appear to be only token participants in government-sponsored programs. Only about 15% were involved in Samahang Nayon, 3% in Masagana-99, and none in Masaganang Maisan. Those programs were organized as sources of improved agricultural technology. Instead, Solana farmers most often relied on fellow farmers or the regular radio farm broadcasts for farm information (Table 8).

Farm size and land use. A typical farmer cultivates a landholding of about 3.0 ha divided into 4 parcels and spread over 2 basic land types. About 1.66 ha (55%) of the land he cultivates is in lowland rice-growing areas and about 1.34 ha (45%) is in upland maize-growing terraces (Table 9). The upland area may be located in lower or upper terraces, or on both. The inclusion of both lowland and upland in a typical Solana farm probably helps avert risk and spreads family labor over the crop year.

The Solana farmer cultivates his land holdings as intensively as his current technology permits. On a sizeable proportion of his land, he grows two crops a year — mungbean and rice in lowland areas and two maize crops or maize and mungbean on upland terraces. The result is a multiple cropping index ranging from 180 to 196 for all farm sizes (Table 10). This high cropping intensity reflects efforts to spread risk and labor resources over as

Table 9. Landholdings of farmer respondents, Solana, Cagayan, 1979.

Farm size group (ha)	Farmers (no.)	Parcels (no.)	Area (ha)		
			Lowland	Upland	Total
1.00 or less	12	1.5	0.64	0.17	0.81
1.01 - 2.00	20	2.6	0.92	0.74	1.66
2.01 - 3.00	25	3.0	1.56	1.02	2.58
3.01 - 4.00	20	4.0	2.09	1.53	3.62
4.01 - 5.00	15	4.9	2.17	2.44	4.61
5.01 or more	8	5.9	3.55	3.29	6.84
Av	(100)	3.7	1.66	1.34	3.00

Table 10. Multiple cropping index by farm size, Solana, Cagayan, 1979.

Farm size (ha)	Multiple cropping index		
	Lowland	Upland	Av
1.00 or less	184	194	196
1.01 - 2.00	173	189	180
2.01 - 3.00	180	182	181
3.01 - 4.00	179	195	185
4.01 - 5.00	182	154	167
5.01 or more	196	194	195
Av	185	189	185

Table 11. Tenure status of farmer respondents in Solana, Cagayan, 1979.

Tenure status	Farmers (%)	Av farm size (ha)
Owner-operator	21	2.22
Share tenant	46	2.86
Part-owner	33	3.70
All groups	100	3.00

Table 12. Tenant-landlord sharing arrangements for tenanted lands of cooperator farmers in Solana, Cagayan, 1980-81.

Sharing arrangement[a]	Lowland (%)	Upland (%)	Total (%)
50-50	4	9	7
60-40	–	8	4
66-33	68	65	66
70-30	12	8	10
75-25	16	10	13

[a] Allocation of output, by %, between share tenant and land owner.

many low-yielding crops as can be cultivated on the different land types.

Land ownership and tenancy. Solana farmers are both owners and share tenants. Share tenancy appears to be relatively widespread — about 46% of the farmers, who cultivate about 66% of the area, are tenants (Table 11). Mortgaging of land is infrequent. Land-tenancy patterns suggest that the typical Solana farmer both owns and rents land in the lowland and terraced areas. Crop-sharing arrangements on tenanted land range from 50-50 to 75-25, depending on the crop, location, and sharing of input costs (Table 12).

Household and farm assets. The typical farm household possesses the simple household and farm assets necessary for daily existence and farming operations. The farmer and his family live in a single-floor dwelling of temporary wood wall construction with bamboo slat floors and a straw-thatched roof (Table 13). Furniture and appliances are simply constructed. The most common items are beds, tables, chairs, cabinets or clothes boxes, and a radio or record player (Table 14).

Farming implements are those needed for crop cultivation (Table 15). Their value approaches $68. Implements for an average-size farm include one upland plow and harrow and one lowland plow and harrow, a cart or sled, scythe, rake, shovel, mattock, winnower, sacks, and baskets. Wealthier families may have sprayers and mechanical threshers as well, although these are rarely seen. Livestock are an important farm asset and the typical farmer can be expected to have 2 carabao, 2 swine, and about 10 chickens regardless of how much land he cultivates (Table 16).

Agricultural employment. Like most farming communities, the Solana study villages have two distinct labor sources: farm household labor and hired labor. The degree of dependence on these labor sources is determined by such factors as fa-

Table 13. Characteristics of dwellings, by farm size, of Solana, Cagayan, farmer cooperators, 1979.

Type of dwelling	Dwellings (no.)				Total
	0.50-1.25 ha	1.75-2.50 ha	3.00-3.75 ha	4.25-5.00 ha	
By number of levels					
Single floor	8	11	13	9	41
Two floors	1	4	2	0	7
By type of construction[a]					
Temporary	6	10	10	9	35
Semipermanent	3	5	5	0	13

[a] Temporary houses are combinations of bamboo, cogon or nipa, and wood; semipermanent houses are combinations of GI sheets, bamboo, and cement.

Table 14. Average number and value of furniture and appliances, by farm size, owned by Solana, Cagayan, farmer cooperators, 1979.

Item	Cooperators farming[a]							
	0.50-1.25 ha[b]		1.75-2.50 ha[c]		3.00-3.75 ha[d]		4.25-5.00 ha[e]	
	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Radio or record player	3	24	5	39	4	33	5	48
Both radio and record player	1	41	2	102	2	104	3	128
Sewing machine	1	41	–	–	–	–	–	–
Beds	3	20	6	41	5	27	1	7
Tables/chairs	13	112	51	286	55	309	41	169
Cabinets	1	45	5	44	88	73	3	71
Clothes box	10	82	8	65	22	180	3	24
Total	32	361	77	577	96	726	56	447
Av	–	45	–	48	–	48	–	56

[a]US$1 = ₱7.35. [b]8 farmer cooperators surveyed. [c]12 surveyed. [d]15 surveyed. [e]8 surveyed.

Table 15. Average number and value[a] of farm implements, by farm size, owned by Solana, Cagayan, farmer cooperators, 1979.

Item	Cooperators farming							
	0.50-1.25 ha[b]		1.75-2.50 ha[c]		3.00-3.75 ha[d]		4.25-5.00 ha[e]	
	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Plow:								
Lowland	9	119	13	195	17	163	10	116
Upland	6	81	12	124	22	162	12	139
Harrow	27	131	16	124	24	214	18	122
Cart	3	187	7	408	11	680	8	753
Sled	–	–	2	3	2	2	2	3
Harness	7	15	14	14	22	33	12	14
Wooden thresher	–	–	8	15	8	18	5	14
Bolo	8	5	33	45	48	95	31	56
Scythe	10	1	28	6	28	10	16	5
Rake, shovel, or mattock	–	–	17	13	31	18	18	14
Sacks	22	4	109	32	126	24	69	40
Baskets	38	40	53	50	112	104	–	–
Threshing or drying net	6	44	4	20	8	50	6	38
Sprayer	–	–	–	–	2	31	39	45
Winnower	9	4	11	5	18	9	10	4

[a]US$1 = ₱7.35. [b]8 farmer cooperators surveyed. [c]12 surveyed. [d]15 surveyed. [e]8 surveyed.

Table 16. Average number and value[a] per head of livestock, by farm size, owned by 44 Solana, Cagayan, farmer cooperators, 1980.

Animal	Cooperators farming							
	0.50-1.25 ha		1.75-2.50 ha		3.00-3.75 ha		4.25-5.00 ha	
	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Carabao	2	177	2	214	2	240	2	216
Swine	2	24	2	31	2	34	2	50
Poultry	7	1	11	1	8	1	10	1

[a]US$1 = ₱7.50.

Table 17. Family labor used for dominant farming operation in Solana, Cagayan, farm cooperator families, 1980-81. Source: Farm record keeping data, April 1980-March 1981.

	Labor hours					
	Farm operators		Family members		Total	
	No.	%[a]	No.	%[a]	No.	%[b]
Land preparation	11,397	64	6,538	36	17,935	58
Planting	1,035	16	5,529	84	6,564	21
Weeding	1,967	55	1,608	45	3,575	12
Other crop care	99	66	50	34	149	1
Harvesting	925	33	1,841	67	2,766	
Total	15,423	49	15,566	51	30,989	100

[a]% total manhours for each operation. [b]% total manhours for all operations.

mily size, farm size, cropping patterns, and cultivation activities.

Family labor. Most essential farming activities such as land preparation and crop care after planting are undertaken with family labor. About three of six household members are potential farm workers capable of performing several major field operations.

Heads of farm households play key roles in farm operations. However, in some cases, other household members provide an equal amount of labor, particularly if the landholding is quite large or if farm operations such as harvesting and planting must be done quickly (Table 17). Farmers prepare their land on a staggered basis, usually several weeks before scheduled planting, thus maximizing the use of available family labor.

Hired labor. The time constraint imposed by planting and harvesting operations forces many farmers to turn to hired labor, regardless of the size of the farm holding (Table 18). In the study area, hired labor ranged from 19 to 79% of total labor inputs, depending on type of farm operation.

The most important source of hired labor was other farm households within the villages or in contiguous villages (Table 19). Even if the household is operating a farm, some of its members may work as hired laborers outside their own farm or the operator himself may hire out his labor at certain times. About 80% of the hired labor force

Table 18. Labor used for farm operation, by farm size for all crops, Solana, Cagayan, farmer cooperators, 1980-81.

	Labor hours					
	Family		Hired		Total	
	No.	%[a]	No.	%[a]	No.	%[b]
Farm operation						
Land preparation	17,935	78	5,061	22	22,996	40
Planting	6,564	38	10,853	62	17,417	30
Weeding	3,575	81	816	19	4,391	7
Other crop care	149	51	141	49	290	1
Harvesting	2,766	21	10,365	79	13,131	22
Total	30,989	53	27,236	47	58,225	100
Farm size[c] (ha)						
0.50-1.25	2,877	54	2,456	46	5,333	9
1.75-2.50	9,531	54	8,221	46	17,752	31
3.00-3.75	11,798	57	8,854	43	20,652	36
4.25-5.00	6,783	47	7,705	53	14,408	24
Total	30,989	53	27,236	47	58,225	100

[a]% of total manhours for each operation or farm size. [b]% of total manhours for all operations or farm sizes. [c]The gap between farm size groups of 48 economic cooperators was intended to provide greater resolution among groups.

Table 19. Hired labor used for dominant operation by Solana, Cagayan, farmer cooperators, 1980-81.[a]

Farm operation	Labor hours					
	Landless households		Farming households		Total	
	No.	%	No.	%[b]	No.	%[c]
Land preparation	388	8	4,673	92	5,061	18
Planting	1,864	17	8,989	83	10,853	40
Weeding	218	27	598	73	816	3
Other crop care	4	3	137	97	141	1
Harvesting	2,984	29	7,381	71	10,365	38
Total	5,458	20	21,778	80	27,236	100

[a]Source: Farm record keeping data, April 1980-March 1981. [b]% of total workhours for each operation. [c]% of total workhours for all operations.

came from farm households; the rest, from landless households. This roughly corresponds to the makeup of landless and farm households in the villages (Table 7).

The relative participation of hired labor from farm and landless households varied by activity (Table 19). Relatively little hired landless household labor was used for land preparation, but much was used for a large share of planting (17%), weeding (27%), and harvesting (29%).

The several labor-hire arrangements identified in Solana reflect farmers' accommodation of crop production requirements into limited cash resources. The share of labor hours paid for with cash wages ranged from 76% for weeding to 0% for harvesting (Table 20). On the average, only 36% of the hired labor hours in crop cultivation were paid for in cash in 1980-81.

Relative wealth, as measured by farm size appeared to have some effect on paying for hired labor with cash. Only about 27% of the labor hours hired by the smallest farmers were paid for in cash; while 45% of the labor hours hired by the largest farm group was paid for in cash. However, this pattern did not hold for middle farm sizes. Larger farmers may be more wealthy and in a better position to pay cash wages for hired labor or they may have more cash farm expenses and find other non-cash wage arrangements also attractive.

Exchange payment for hired labor is found in

Table 20. Forms of hired labor payment, by selected cultivation activities and farm sizes, among Solana, Cagayan, farmer cooperators, 1980-81.

	Labor hours									
	Cash		Exchange		Deferred		Crop share		Total	
	No.	%[a]	No.	%[a]	No.	%[a]	No.	%	No.	%[b]
Operation										
Land preparation	2,979	59	1,811	36	271	5	–	0	5,061	18
Planting	6,226	57	2,316	22	2,311	21	–	0	10,853	40
Weeding	621	76	195	24	–	0	–	0	816	3
Other crop care	34	24	20	14	87	62	–	0	141	1
Harvesting	–	0	–	0	–	0	10,365	100	10,365	38
Total	9,860	36	4,342	16	2,669	10	10,365	38	27,236	100
Farm size (ha)										
0.50-1.25	666	27	644	26	267	11	879	36	2,546	9
1.75-2.50	3,534	43	1,207	15	670	8	2,810	34	8,221	30
3.00-3.75	2,156	24	1,590	18	994	12	4,114	45	8,854	33
4.25-5.00	3,504	45	901	12	738	10	2,562	33	7,705	28
Total	9,860	36	4,342	16	2,669	10	10,365	38	27,236	100

[a]% of total work hours for each operation or farm size. [b]% of total work hours for all operations or farm sizes.

Table 21. Farm labor wage rates in Solana, Cagayan, 1980.[a]

Operation	Prevailing cash wage[b] (all crops) ($/h)	Deferred wage Effective wage rate[c] ($/h)		
		Rice	Maize	Mungbean
Land preparation	0.12	–	0.18	0.16
Planting/transplanting	0.07	0.19	0.15	0.14

[a]Source: Farmer record keeping data, April 1980-March 1981, and farmer interviews. US$1 = ₱7.50. [b]Including meals. [c]Includes laborers who received zero wage due to crop failure.

many Philippine farming communities. In Solana, its importance in crop production varies among cultivation activities.

Traditionally, hired-labor participation is open to everyone in the village. Farmers help other farmers in farm or nonfarm activities and are paid in food, drink, or tobacco.

The current procedure calls for balanced reciprocity. Depending upon the agreement or financial capability of the farmer, food and drink may not be provided hired labor. Almost always reciprocity is in the same type of farming operation; plowing labor is exchanged for plowing labor.

Table 22. Average farm household cash income and expenses of Solana, Cagayan, farmer cooperators, 1980-81.

Item	Income or expense	
	$	%
Farm income	163	52
Crop sales	85	27
Livestock sales	72	23
Other	6	2
Household income	150	48
Labor wages	35	11
Salaries, pensions	58	19
Other	57	18
Total income	313	100
Farm expenses	42	11
Crop production inputs	12	3
Hired labor	17	5
Livestock inputs	9	2
Other	4	1
Household expenses	345	89
Food	158	41
School	34	9
Transportation	24	6
Other	129	33
Total expenses	387	100
Balance (1980-81)	-74	–

The most interesting hired-labor arrangement was payment after harvest. Under it, the farmer-employer agrees to pay, at harvest, a fixed amount of the produce per day of labor supplied, in addition to any meals provided at the time work is performed. The laborer agrees to a future payment in kind, which at future prices may be considerably above the cash wage prevailing at the time labor is contracted. But in turn, the laborer agrees to share the risk of precipitous price drops at harvest or of crop failures. If prices drop, the laborer receives a future real wage less than the current cash wage; if the crop fails, the laborer receives nothing. If the crop yields poorly but does not totally fail, the laborer may receive at harvest only a portion of the deferred-crop payment.

Labor hours under deferred-wage payment arrangements averaged only 10% of the total hired labor observed, but they were as high as 21% of hired labor hours for planting and 62% for other crop care (Table 20).

In 1980, the prevailing cash wage for planting was about $0.07/hour, the average deferred wage was about $0.19/hour for rice, $0.15/hour for maize, and $0.14/hour for mungbean (Table 21). These deferred in-kind payments increased planting wage rates 89-155% over what would have been paid at the $0.07/hour rate at planting time.

Similarly, the prevailing cash wage (food included) for land preparation was $0.12/hour. For payments deferred until harvest, the average effective wage was about $0.18/hour for maize and $0.16/hour for mungbean.

Harvesting and threshing operations are always done on a crop-sharing arrangement.

Income and expenditures. The low yield from traditional agriculture is reflected in the low levels of cash income and expenditures in farm households (Table 22). Farm records for the 1980-81

Table 23. Market prices of major crops in Solana, Cagayan, 1980-81 and 1981-82.

Crop	Market price[a] ($/kg)					
	1980-81[b]			1981-82[c]		
	Av	Max	Min	Av	Max	Min
Rice	0.16	0.18 (Feb-Mar)	0.15 (Apr-Aug)	0.18	0.19 (Feb-Mar)	0.15 (Apr)
Maize	0.17	0.18 (Feb-Mar)	0.15 (Sep)	0.17	0.19 (Dec)	0.15 (Apr-Aug)
Mungbean	0.93	1.44 (Dec-Jan)	0.67 (Apr-May)	0.67	0.89 (Apr-Jun)	0.59 (Aug-Feb)
Cowpea	0.92	1.44 (Dec-Jan)	0.67 (Apr-May)	0.71	0.89 (Apr-Jun, Jan)	0.59 (Aug-Nov)
Soybean	0.53	1.44 (Dec-Jan)	0.46 (Apr-Jul)	0.53	0.59 (Apr-Jul)	0.48 (Dec-Jan)

[a]Months of maximum and minimum prices are shown in parentheses. [b]US$1 = ₱7.50. [c]US$1 = ₱7.80.

crop year show an average household cash income of $313 and average expenses of $387. That expenses exceeded income reflects extremely adverse weather that affected crop production and sales. While some items for home consumption and inputs for crop production are needed by every Solana household, they are acquired by cash and noncash arrangements developed over the years.

Crop sales. Cash earnings of farm households are generated largely from crop sales, livestock sales, and off-farm work. Cash from crop sales provided about 27% of the total farm household earnings in 1980-81. Crop sales were mainly rice, maize, mungbean, and tobacco.

Rice and maize serve a dual purpose in the Solana farm household economy — as sources of cash earnings and as staple foods. Although mungbean is widely cultivated and commands a good market price, it meets only a small share of the cash requirements of a farm household because of its low yield.

The crops traditionally grown by Solana farmers have well-established markets. Despite the distance from farms to market centers, all-weather roads facilitate marketing of farm products and procurement of farm inputs. Most local traders buy directly from the farmers. Within the research area, at least five rice mills bought rice, maize, and mungbean in 1979. But the seasonality of harvests causes notable variation in crop prices. Table 23 summarizes the average, maximum, and minimum prices for major crops during the 1980-81 crop year.

Secondary cash sources. Livestock sales (19%) and wage employment (37%) were important sources of cash income in 1980-81. Swine and poultry are raised for market as well as for home consumption. The farm operator and adult members of his family occasionally work for wages in farm and nonfarm activities.

The importance of livestock and labor to household income and expenditure is greater than their contribution to cash earnings suggests. Carabao plowing services and family labor are often contracted on an exchange, deferred-payment, or crop-share basis.

Expenditure patterns and practices. With the low cash income from sales of crop and livestock products and from off-farm employment, Solana farmers have little discretionary cash resources. In 1980-81, major outlays were for consumer goods such as food stuff (41%), children's schooling (9%), and farm expenses (11%). Transportation, clothing, kerosene, fuel wood, liquor, tobacco, and fiestas were other important items of expense.

Farmers have found ways to get around cash constraints without resorting to borrowing from money lenders. Share tenancy is commonly preferred to cash rent in acquiring land to cultivate. By tenanting a carabao (taking care of the animal for its owner), a farmer can obtain an offspring without cash payment. During peak cultivation periods, a farm household can obtain additional labor in exchange for farm household labor at a future time or for a crop share at harvest. Table 24 shows the frequency with which these noncash arrangements pay for land, labor, and carabao.

CREDIT AND ADOPTION OF NEW CROPPING SYSTEMS

New cropping technologies usually require larger cash inputs than are needed in traditional farming and lack of credit often is identified as a constraint

Table 24. Noncash land, livestock, and labor acquisition by Solana, Cagayan, farmer cooperators, 1980.[a]

Farm size (ha)	Cooperators (no.)	Cooperators using noncash means to acquire					
		Land[b]		Livestock[c]		Hired labor[d]	
		No.	%	No.	%	No.	%
0.50-1.25	5	2	40	1	20	2	40
1.75-2.50	16	12	75	9	50	9	50
3.00-3.75	15	11	70	5	33	8	50
4.25-5.00	12	10	80	4	33	11	90
Total	48	35	73	19	40	30	62

[a]Source: Data collected from 48 IRRI agricultural economics farmer cooperators. [b]Farmers who are pure tenants and owner-tenants. [c]Farmers who acquired one or more carabao by tenancy or barter. [d]Farmers who used deferred or exchange labor arrangements to contract labor to work on their farms.

to the adoption of new technologies. Governments and development agencies have devoted massive amounts of resources to the development of large-scale rural credit schemes to facilitate new technology adoption.

However, often such schemes are cumbersome to administer and costly to maintain and may be plagued with nonrepayment problems. Moreover, the desirability or necessity of maintaining such credit schemes is questioned: if the new technology is more profitable and stable, why do governments need to continue to supply subsidized low-interest credit?

The role of credit in technology adoption was studied in Iloilo Province, Philippines. Cropping systems research there had demonstrated the feasibility of more productive double cropping to replace the traditional single rice crop. The pilot program Kabsaka, which incorporates a credit component, has been operating for some years in some villages in an effort to extend the new system.

The survey showed:

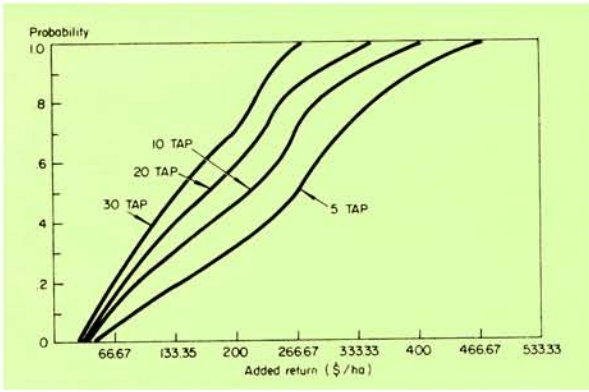
- Irrespective of whether or not a formal credit scheme operated, the new cropping system was widely adopted in all study villages.
- Of 77 farmers who participated in Kabsaka in 1977, 36 were not participating in 1980. However, nearly all were continuing to practice the major elements of the Kabsaka technology package.
- Often, the real cost of institutional credit was high (time spent travelling, filling out forms, and obtaining clearances) and timing of credit less than satisfactory.
- Farmers' capacity to self-finance their inputs increased because of higher incomes.
- Informal credit sources expanded particularly in areas with no formal credit scheme. Fertilizer was available on credit, to be paid back in kind after harvest, in every village that had no formal credit scheme. This credit was available in the village itself, at the time it was needed and at an interest cost comparable to the real cost of institutional credit.

These findings suggest that, while low-interest institutional credit schemes may help stimulate early adoption, they may not be necessary for sustained adoption of appropriate production technology. Village-level institutions may have the capacity to respond to new economic opportunities.

ECONOMICS OF SHORT CROP TURNAROUND

Early crop establishment and a shorter turnaround period between crops can help increase cropping intensity in rainfed environments. Direct seeding techniques achieve early crop establishment, and increased use of animal power or machinery can help achieve short turnaround between crops. However, many factors affect the net economic benefits from such strategies. Erratic early rains can make early crop establishment more risky; higher energy requirements may increase costs substantially, reducing the economic benefits of subsequent crop yields.

When a double rice crop system was introduced in the Oton-Tigbauan area in Iloilo, Philippines, the average turnaround period between first and second rice crops was 23 days. That lowered second-crop yields and sometimes caused the second-crop failure. The rainfed crop growth simu-



3. Cumulative density functions of added returns from different turnaround periods (TAP): wet-seeded rice – wet-seeded rice – mungbean pattern on plateau land. Iloilo, Philippines, 1981.

lation model developed earlier for this location was used to analyze the economics of reducing turnaround time by increasing the use of animal or machine power.

Information on farmers' management practices and cropping decision rules incorporated into the model also allowed for analysis of the impact of short-run changes in cropping strategies in response to rainfall patterns.

The performances of three intensive cropping patterns on plateau, plain, and sideslope landscape positions were analyzed. Cropping patterns were wet seeded rice (WSR) - TPR - mungbean, dry-seeded rice (DSR) - TPR - mungbean, and WSR - WSR - mungbean.

Turnaround times were 5, 10, 20, and 30 days with animal power and 7 days using a power tiller. The model simulated crop performance under each of 31 years, using historical rainfall data. Cumulative frequency distributions of net benefits were developed (Fig. 3).

The results showed that shorter turnaround periods were more profitable and less risky in all landscape positions for each pattern. Use of a power tiller, which was assumed to reduce turnaround time to 7 days, was attractive in all cases except when sufficient animal power could be obtained at prevailing hiring rates to reduce turnaround to 5 days. However, this result depended on the relatively low custom hire rates of the years, analyzed. Rates have risen substantially since then.

In this environment, cropping patterns in which the first crop was dry seeded gave slightly higher profits on the average, but wet seeding was less risky. Farmers in Iloilo have preferred wet seeding.

This approach and model will be used to study similar problems at other cropping systems research sites. Quantifying the benefits of shortened turnaround time can contribute to the examination of social benefits-costs of increased mechanization.

Cropping systems program

Pest control

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DISEASE CONTROL

Plant Pathology Department

Chemical control of damping-off in legumes. *Sclerotium rolfsii*, *Rhizoctonia solani*, and *Pythium debaryanum* caused damping-off in legume seedlings at research sites in Cagayan and at IRRI. Fungicides for seed treatment to control pathogens occurring singly have been identified. Since the pathogens also exist in combination, multiple-disease fungicides were tested.

In trial 1, commercially available soil fungicides PCNB, carboxin + captan, and PCNB + thiadiazole were effective against preemergence damping-off caused by *Sclerotium* and *Rhizoctonia*, singly and in combination (Table 1). Thiophanate methyl and mancozeb + benomyl, effective on *Rhizoctonia* alone, was inactive in the presence of *Sclerotium*, suggesting that *Sclerotium* is more aggressive than *Rhizoctonia*.

In trial 2, none of the fungicides tested protected mungbean seedlings against preemergence damping-off caused by *Sclerotium* and *Pythium* in combination (Table 1). Metalaxyl, excellent on *Pythium* alone, was inactive in the presence of *Sclerotium*. PCNB + thiadiazole, carboxin + captan, and PCNB, effective on *Sclerotium* alone, also were inactive in the presence of *Pythium*.

Attack on emerging seedlings at the ground level caused postemergence damping-off at the research sites. Fungicides applied as foliar spray were tested in the IRRI greenhouse. PCNB + thiadiazole, thiophanate methyl, iprodione, PCNB, and mancozeb + benomyl were promising against *Rhizoctonia* postemergence damping-off (Table 2). PCNB and carboxin + captan were effective against *Sclerotium* postemergence damping-off (Table 3).

Foliage diseases of mungbean. Cercospora leaf spot and powdery mildew are common diseases of mungbean. The economic feasibility of controlling powdery mildew by foliar spraying with thiophanate methyl has been reported. In 1981, other commercially available fungicides were evaluated.

Mancozeb + benomyl and chlorothalonil at recommended rates significantly controlled multiple Cercospora leaf spot, powdery mildew, and rust infections (Table 4). While disease control affected yield, chlorothalonil gave the most prom-

Table 1. Effect of fungicides as seed treatment on preemergence damping-off of mungbean caused by *Sclerotium rolfsii* (Sr), *Rhizoctonia solani* (Rs), and *Pythium debaryanum* (Pd), occurring singly and in combination. IRRI, 1981.

Fungicide	Rate (g a.i./kg seed)	Preemergence damping-off[a] (%)						
		Sr	Pd	Rs	S + P	S + R	P + R	S + P + R
				Trial 1				
Metalaxyl	0.7	55 bc	2 b	76 a	71 ab	68 a	87 a	68 ab
Orthocide RE-26745	3.0	76 ab	2 b	44 b	57 bcd	68 a	83 a	45 bc
PCNB + thiadiazole	0.9	23 d	24 a	11 c	41 cde	19 b	39 b	49 abc
Mancozeb	1.9	55 bc	23 a	79 a	87 a	60 a	95 a	73 ab
Carboxin + captan	1.4	3 e	17 ab	1 c	19 e	7 b	18 b	29 c
Thiophanate methyl	0.7	74 ab	31 a	8 c	67 abc	71 a	36 b	59 abc
PCNB	1.4	5 e	45 a	3 c	36 de	12 b	21 b	57 abc
Mancozeb + benomyl	4.4	41 cd	35 a	1 c	71 ab	65 a	41 b	56 abc
Untreated	–	87 a	24 a	85 a	77 ab	69 a	93 a	79 a
				Trial 2				
Metalaxyl	0.7	100 a	0 c	9 abc	97 a	93 ab	34 c	97 a
Propamocarb HCl	0.4	99 a	63 b	9 ab	98 a	95 a	80 b	100 a
PCNB + thiadiazole	0.9	29 d	100 a	2 bc	95 a	28 c	97 a	81 bc
Mancozeb	1.9	81 c	99 a	12 a	100 a	81 ab	98 a	99 a
Carboxin + captan	1.4	11 d	95 a	1 bc	95 a	4 d	81 b	69 c
Thiophanate methyl	0.7	97 ab	99 a	1 c	100 a	93 ab	98 a	100 a
PCNB	1.4	24 d	100 a	1 c	90 a	3 d	97 a	89 ab
Mancozeb + benomyl	4.4	87 bc	99 a	6 abc	93 a	78 b	91 ab	94 ab
Untreated	–	95 ab	100 a	15 a	97 a	93 ab	97 a	98 a

[a] % infection = $\frac{\text{no. of seeds sown} - \text{no. of seedlings emerged}}{\text{no. of seeds sown}}$ x 100. Data gathered at 6 and 11 days after sowing. Each figure represents mean of 3 replications. Analysis based on values transformed to arcsin. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 2. Greenhouse evaluation of fungicides for control of *Rhizoctonia* postemergence damping-off of cowpea and mungbean. IRRI, 1981.

Fungicide[a]	Rate (g a.i./kg seed)	Postemergence damping-off[b] (%)			
		Trial 1		Trial 2	
		Cowpea	Mungbean	Cowpea	Mungbean
Iprodione	0.25	17.1 de	6.8 c	42.9 cde	38.0 cd
Orthocide RE-26745	0.25	98.7 a	97.3 a	–	–
Triphenyltin acetate	0.30	–	–	60.2 cd	57.5 bc
Mancozeb	2.16	64.1 b	64.4 b	76.7 bc	41.5 cd
Metalaxyl	0.19	94.1 a	97.6 a	–	–
Serinal	0.50	–	–	72.5 bc	50.9 bc
PCNB	3.76	49.1 bc	62.7 b	15.6 ef	17.6 de
Carboxin + captan	0.94	40.3 bcd	36.7 b	44.4 cde	73.2 b
Thiophanate methyl	0.67	16.4 e	37.7 b	25.6 def	31.0 cd
Mancozeb + benomyl	2.93	33.7 cde	39.4 b	31.7 cde	21.8 de
PCNB + thiadiazole	3.06	3.5 f	9.5 c	2.2 f	2.3 e
Propamocarb HCl	0.003	65.5 b	69.0 b	94.4 ab	82.2 ab
Chlorothalonil	3.38	62.7 b	63.3 b	41.7 cde	34.6 cd
Untreated	–	98.8 a	95.1 a	100.0 a	96.7 a

[a] Applied as foliar spray 5 days after sowing. [b] % infection = $\frac{\text{total no. of seedlings} - \text{no. of damped-off seedlings}}{\text{total no. of seedlings}} \times 100$. Data taken at 5 and 11 days after sprays. Each figure represents mean of 3 replications. Analysis based on values transformed to arcsin. Separation of means in a column by Duncan's multiple range test at the 5% level.

ising benefit-cost ratio (Table 5).

Reduction of fungicide rates by 70% significantly controlled powdery mildew (Table 6) and increased the benefit-cost ratio although there were no significant yield increases. When the recommended rates were reduced by 50%, the 3 fungicides were effective against Cercospora leaf spot (Table 7). When all rates were lowered to the level recommended for thiophanate methyl, only mancozeb + benomyl was promising. Then, thiophanate methyl was comparable to mancozeb + benomyl.

To determine the timing and minimum spraying schedule of fungicide to control Cercospora leaf spot, spraying once, twice, three times, and four times was tested. With an initial infection of <1% in the field, spraying twice reduced infection at 43 days after emergence (DE) more than spraying once (Table 8). From disease readings at 54 DE, spraying twice was as effective as spraying 3 and 4 times.

In Solana, Cagayan, experiments on chemical control of damping-off and powdery mildew in mungbean after rice in four separate fields were terminated because of drought.

In mungbean before rice, the establishment of mungbean was delayed for 1 week to obtain a sufficient inoculum source from early plantings.

Table 3. Greenhouse evaluation of fungicides for control of the incidence of Sclerotium postemergence damping-off of cowpea and mungbean. IRRI, 1981.

Fungicide	Rate (g a.i./liter H_2O)	Postemergence damping-off (%)	
		Cowpea	Mungbean
Iprodione	0.38	71.9 bcd	78.2 ab
Orthocide RE-26745	0.25	47.4 de	32.4 cd
Mancozeb	2.16	88.9 abc	81.9 ab
Metalaxyl	0.19	97.7 a	90.1 a
PCNB	3.76	26.6 e	6.3 d
Carboxin + captan	1.88	1.1 f	51.7 bc
Thiophanate methyl	0.67	98.8 a	89.7 a
Mancozeb + benomyl	2.93	100.0 a	91.3 a
PCNB + thiadiazole	3.06	70.0 cd	22.2 cd
Propamocarb HCl	0.005	96.4 ab	82.9 ab
Chlorothalonil	3.38	96.3 abc	87.2 ab
Untreated		100.0 a	98.8 a

That experiment also was terminated because 5 days of continuous rains caused a poor crop stand.

Dry-seeded rice was grown to test chemical control of grain discoloration. Preventive treatments were applied from heading to flowering stage but could not be evaluated because there was no grain discoloration that season.

Soil-borne diseases in dryland fields. A shift from *Rhizoctonia* and *Fusarium* had been found in the pathogens isolated from infected cowpea plants

Table 4. Evaluation of commercially available fungicides for control of foliage diseases of mungbean planted after rice. IRRI, 1981.

Disease	Fungicide[a]	Rate (g a.i./liter H_2O)	Disease rating[b]/leaf	
			45 DE	59 DE
Cercospora leaf spot	Thiophanate methyl	0.31	2.4 a	5.0 a
	Mancozeb + benomyl	2.50	1.1 b	2.9 b
	Chlorothalonil	2.64	1.3 b	1.6 b
	Check		2.3 a	5.3 a
Powdery mildew	Thiophanate methyl	0.31	0.3 b	0.7 b
	Mancozeb + benomyl	2.50	0.1 b	0.1 b
	Chlorothalonil	2.64	0.2 b	0.1 b
	Check		2.9 a	3.7 a
Rust	Thiophanate + methyl	0.31	2.5 ab	5.5 a
	Mancozeb + benomyl	2.50	1.4 b	2.6 b
	Chlorothalonil	2.64	1.2 b	2.2 b
	Check		3.3 a	6.8 a

[a]Applied as foliar spray at 31 DE (days after emergence). [b]Based on 1-9 scale: for Cercospora leaf spot, 1 = <1% leaf area affected, 3 = 1-5%, 5 = 5-25%, 7 = 25-50%, 9 = >50%; for powdery mildew: 1 = 1-5% leaf area affected, 3 = 5-25%, 5 = 25-50%, 7 = 50-75%, 9 = >75%; for leaf rust: 1 = light, 3 = moderately light, 5 = moderately heavy, 7 = heavy, 9 = severe. All leaves ranging from 3-5/plant considered, 6 plants/plot. Each figure represents mean of 4 replications. Separation of means in a column or per disease by Duncan's multiple range test at the 5% level.

Table 5. Cost and return of chemical control of foliage diseases of mungbean planted after rice. IRRI, 1981.

Fungicide[a]	Rate (g/liter H_2O)	Yield (t/ha)	Gross return[b] ($/ha)	Variable cost[c] ($/ha)	Net return to fungicide use ($/ha)	Benefit: cost
Thiophanate methyl	0.31	1.5 b	925	38	887	1.63
Mancozeb + benomyl	2.50	2.0 a	1219	194	1025	1.84
Chlorothalonil	2.64	1.8 ab	1106	100	1007	2.43
Check	–	1.4 b	863	0	863	–

[a]1.125 kg thiophanate methyl used up/ha, 9.375/ha for mancozeb + benomyl, and 9.914 for chlorothalonil; with 33.33 h of spraying/ha. [b]Mungbean at $0.62/kg. [c]Includes cost of fungicides (thiophanate methyl at $26/kg, mancozeb + benomyl at $20/kg, and chlorothalonil at $9/kg) and cost of applying the fungicides ($0.25/ha of spraying).

Table 6. Effect of lower application rates of 3 commercially available fungicides on severity of powdery mildew and on yield of mungbean after rice. IRRI, 1981.

Fungicide[a]	Rate (g FP/liter H_2O)	Powdery mildew rating[b]/leaf		Grain yield (t/ha)
		50 DE	60 DE	
Thiophanate methyl	0.31	1.39 b	2.99 ab	1.90 a
Mancozeb + benomyl	1.79	0.85 b	2.36 b	1.69 a
Chlorothalonil	1.90	0.96 b	2.36 b	1.66 a
Untreated	–	3.99 a	3.82 a	1.64 a

[a]Applied as foliar spray at 32 DE (days after emergence). [b]On a leaf basis using 4-5 leaves/plant; each leaf rated as follows: 1 = 1-5% leaf area affected, 3 = 5-25%, 5 = 25-50%, 7 = 50-75%, and 9 = >75% infection. Each figure represents mean of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 7. Evaluation of 3 commercially available fungicides applied as foliar spray for control of Cercospora leaf spot of mungbean. IRRI, 1981

Fungicide[a]	Rate (g a.i./liter H_2O)	Disease rating[bc]/leaf	Grain yield[c] (t/ha)
Thiophanate methyl	0.44 (recommended)	1.54 bc	1.11 abc
	0.22	1.70 b	0.99 bc
Mancozeb + benomyl	1.95 (recommended)	0.89 e	1.37 a
	0.98	1.13 cde	1.22 ab
	0.44	1.08 de	1.10 abc
Chlorothalonil	1.32 (recommended)	1.18 cde	1.05 abc
	0.66	1.27 cde	1.14 abc
	0.44	1.39 bcd	1.01 bc
Untreated	–	2.52 a	0.86 c

[a]Applied at 26 DE (days after emergence). [b]On a leaf basis using 4 leaves/plant; each leaf rated as follows: 1 = <1% leaf area affected, 3 = 1-5%, 5 = 5-25%, 7 = 25-50%, and 9 = >50% infection; data taken at 40 DE. [c]Each figure represents mean of 4 replications; separation of means in a column by Duncan's multiple range test at the 5% level.

Table 8. Effect of frequency of fungicide spraying on severity of Cercospora leaf spot and yield of mungbean. Lot UQ4-IRRI, 1981.

Spraying date (DE)	Disease rating[ab]/leaf				Grain yield[b] (t/ha)
	24 DE	34 DE	43 DE	54 DE	
15+25+35+45	1.3	1.0 ab	0.9 b	1.0 f	1.15 a
25+35+45	1.4	1.4 ab	1.2 b	1.4 ef	1.03 abc
35+45	1.4	1.3 ab	1.6 b	1.7 e	1.06 ab
45	1.4	1.6 a	3.1 a	3.2 cd	0.62 e
15	1.2	1.2 ab	2.9 a	3.7 bc	0.80 cde
15+25	1.2	1.3 ab	1.4 b	4.0 ab	0.94 abcd
15+25+35	1.3	0.9 b	1.5 b	2.9 d	0.83 bcde
No spraying	1.3	1.4 ab	2.6 a	4.4 a	0.77 de

[a]Each leaf rated as follows: 1 = <1% leaf area affected, 3 = 1-5%, 5 = 5-25%, 7 = 25-50%, and 9 = >50% infection. [b]Each figure represents mean of 4 replications; separation of means in a column by Duncan's multiple range test at the 5% level.

during first cropping. Incidence of *Rhizoctonia* infection on cowpea was not reduced when rice was the first crop. The third cropping showed a prevalence of *Fusarium* infection in continuously cropped cowpea. Disease incidence was low in cowpea with rice and maize (Table 9). Incidence of soil-borne diseases was lower in the fourth and fifth croppings, but *Fusarium* and *Rhizoctonia* were still the prevailing pathogens. Rice reduced diseases on cowpea in the sixth cropping.

It appears that continuous cropping of cowpea allows *Fusarium* to increase its inoculum in the soil, causing a high infection. Table 10 shows that, based on sclerotia count, populations of *Rhizoctonia* and *Sclerotium* were minimal and did not change substantially with cropping pattern and with number of croppings. Low disease incidence attributed to these two pathogens could be accounted for by low populations in the soil. Efficient methods to determine populations of *Fusarium* and *Pythium* in the soil are still being developed.

Compost favors the growth of saprophytes antagonistic to soil pathogens, thereby reducing soil-borne diseases. But addition of compost to a field planted continuously with cowpea did not affect the incidence of soil-borne diseases (Table 11).

Continuous cropping of cowpea also caused severe stunting, reduction in plant populations (apparently due to damping-off and stem or root

Table 9. Soil-borne diseases and their incidence[a] in 3 cropping patterns[b] in dryland fields (DH7). IRRI, 1980-81.

Cropping pattern	Infection	Pathogen[c]	Infection	Pathogen	Infection	Pathogen
			3rd cropping			
	17 Jun 1980		*7 Jul 1980*		*18 July 1980*	
Cowpea-cowpea-*cowpea*	Damping-off 1.6%	38.5% *Fusarium*[d] 30.6% *Rhizoctonia* 4.0% *Sclerotium*	Stem and root rot 25.1%	87.5% *Fusarium*[e] 12.5% *Rhizoctonia*	Stem and root rot 27.0%	100% *Fusarium*[e]
Dryland rice-green maize-*cowpea*	Damping-off 1.3%	26.6% *Sclerotium* 25.7% *Rhizoctonia* 3.8% *Fusarium*	Stem and root rot 2.1%	79.2% *Fusarium*[e] 12.5% *Rhizoctonia* 4.2% *Sclerotium* 4.2% *Pythium*	Stem and root rot 0.5%	100% *Fusarium*[e]
Dryland rice-cowpea-*cowpea*	Damping-off 1.8%	40.8% *Rhizoctonia* 18.3% *Fusarium* 11.7% *Sclerotium*	Stem and root rot 6.3%	77.8% *Fusarium*[e] 22.2% *Rhizoctonia*	Stem and root rot 10.2%	95.8% *Fusarium*[e] 4.2% *Rhizoctonia*
			4th cropping			
	15 Dec 1980		*24 Dec 1980*		*14 Jan 1981*	
Cowpea-cowpea-cowpea	Damping-off 5.1%	100% *Fusarium*[e]	Stem and root rot 14.1%	92.6% *Fusarium*[e] 7.4% *Rhizoctonia*	Stem and root rot 5.5%	48.8% *Fusarium* 41.9% *Rhizoctonia* 1.4% *Sclerotium*
Dryland rice-green maize-cowpea	None	–	None	–	None	–
Dryland rice-cowpea-cowpea	None	–	None	–	None	–
			5th cropping[f]			
	8 Jun 1981		*19 Jun 1981*		*30 Jun 1981*	
Cowpea-cowpea-cowpea	Damping-off 0.8%	42.7% *Fusarium* 33.3% *Pythium* 18.8% *Rhizoctonia* 15.6% *Sclerotium*	Stem and root rot 12.2%	94.5% *Fusarium* 4.8% *Rhizoctonia* 2.4% *Pythium*	None	–
Dryland rice-green maize-cowpea	None	–	None	–	None	–
Dryland rice-cowpea-cowpea	None	–	None	–	None	–
			6th cropping			
	21 Oct 1981		*11 Nov 1981*		*17 Dec 1981*	
Cowpea-*cowpea*-cowpea	None	–	Stem and root rot 32.1%	100% *Fusarium*[e]	Stem and root rot 7.4%	86.1% *Fusarium* 2.6% *Pythium* 0.6% *Rhizoctonia*
Dryland rice-*green maize*-cowpea	None	–	None	–	None	–
Dryland rice-*cowpea*-cowpea	None	–	Stem and root rot 3.6%	100% *Fusarium*[e]	Stem and root rot 11.1%	90.1% *Fusarium* 1.4% *Rhizoctonia* 0.3% *Pythium*

[a] Infection figures followed by % indicate incidence, based on the ratio of infected plants to the total population x 100. [b] Each figure represents mean of 4 replications. [c] One tissue section may yield several fungi in isolation plates and hence, may have a total of >100%. [d] 38.5% of infected seedlings yielded Fusarium in isolation plates. [e] No isolation done since Fusarium was readily detected from infected plants. [f] Same crop as in 4th cropping since 4th crop suffered from drought.

Table 10. Effect of cropping pattern on sclerotia count[a] of *Sclerotium rolfsii* (Sr) and *Rhizoctonia solani* (Rs). DH7-IRRI, 1980-81.

Cropping pattern	Sclerotia count/200 g soil[b]							
	3rd cropping		4th cropping		5th cropping		6th cropping	
	Sr	Rs	Sr	Rs	Sr	Rs	Sr	Rs
Cowpea-cowpea-cowpea	1.5	3.0	2.5	3.5	3.0	3.5	3.0	2.5
Dryland rice-green maize-cowpea	2.3	3.8	6.5	5.0	0.8	3.0	1.5	6.0
Dryland rice-cowpea-cowpea	1.0	6.0	0	2.5	1.1	2.5	4.3	2.8

[a]Determined by sieving-flotation method; soil samples taken at sowing; each figure represents mean of 4 replications. [b]Based on oven-dry weight.

Table 11. Effect of compost on incidence of soil-borne diseases on continuously cropped cowpea.[a] Lot DH7-IRRI, 1980-81.

Cropping	Infection[b] (%)	
	With compost	Without compost
4th	25.0	24.7
5th	10.8	12.3
6th	40.0	37.8

[a]Compost derived from rice straws incorporated into the soil every planting time at 5 t/ha. [b]Based on the total incidence of damping-off and stem or root rot throughout crop growth; each figure represents mean of 4 replications.

Table 12. Effect of continuous cropping on growth and yield of cowpea.[a] Lot DH7-IRRI, 1980-81.

Cropping pattern	Plant ht[b] (cm)	Stand count[c] (no./25 m^2)	Grain yield (t/ha)
Cowpea-cowpea-cowpea	29.9	485.0	0.53
Dryland rice-cowpea-cowpea	44.8	720.3	0.85

[a]Taken from 6th cropping; each figure represents mean of 4 replications. [b]At 21 days after emergence. [c]At harvest.

rot), and yield reduction (Table 12). Stunting was observed first in the third crop. Yield was erratic because cowpea alternated with dryland rice lodged, yielding less than stunted plants that did not lodge.

INSECT CONTROL

Entomology Department

Chemical control recommendations. Chemical insect control practices were tested for 5 years (1976-80) in researcher-managed cropping pattern trials in farmers' fields in Pangasinan Province, Philipppines. Insect control recommendations were developed for six crops — first-crop vegetable maize, dry-seeded rice, wet-seeded rice, and transplanted rice as single rice crops after maize or as second rice crops with mungbean as a third crop.

Results emphasize the current methodology used to determine chemical insect control recommendations for preproduction evaluation. Farmers' insect control practices set limitations on the level and method of insect control technology recommended.

Farmers' insecticide use. Farmers do not apply insecticide to maize, because maize plants are used as draft animal forage throughout the crop. They are aware of detrimental effects of insecticide residues on their animals. Neither do they spray a crop taller than themselves because of the danger of inhaling uncontrollable insecticide drift.

Farmers have access to knapsack sprayers and have increased insecticide applications on mungbean from an average of less than one per field in 1975 to more than two in 1978. Farmers who observed the vigorous plant growth in the cropping pattern fields and researcher-managed plots adopted insecticides spontaneously. Insecticide use on rice has remained at an average of less than one application per field.

Yield losses and growth stages. Insecticide treatments were monitored by sampling insect popula-

tions. Insecticide treatments designed to eliminate yield loss were improved for each crop during the 5-year testing period. New insecticides, higher dosages, or more frequent applications were introduced when insecticide regimes were not able to keep insect numbers below economic levels. A method of quantifying yield loss by growth stage became an invaluable aid in evaluating timing of insecticides among the practices under evaluation.

Matching key pest to yield loss. Knowledge of the insect species responsible for yield loss aided in the choice of insecticides to be evaluated.

Benefit-cost evaluation. Net returns and marginal profit were calculated for share tenants, the prevalent tenancy in Pangasinan. Share tenant farmers purchase all crop inputs and pay one-third of their harvest for land use. Harvesters commonly are paid one-sixth of the harvest. A 3%/month interest rate on borrowed cash represents a Manbilayka government program loan.

Calculation of net return was based only on factors associated with insecticide usage. After 44% of the yield was subtracted as harvester and landlord shares (1/6 + 1/3 of 5/6 = 8/18 = 44%), the remainder was multiplied by the crop price to obtain a gross return. Gross return less insecticide cost (chemical, interest, labor) produced the net return. Labor was based on 4 work hours/ha to apply granules and 16 work hours/ha to apply sprays.

The benefit-cost ratio was computed as yield difference between the potential practice and the untreated control multiplied by crop price divided by insecticide cost (chemical, labor). Based only on material and labor costs, the benefit-cost ratio for Pangasinan is 1.9.

When a consistent economic difference was not evident between insecticide treatments based on net returns, marginal profits, and benefit-cost ratios, a probability function based on the cumulative frequency distribution of net returns for each replication over all years was calculated. A treatment that showed consistently higher probability of greater net returns over the whole range of observations was chosen. If the resulting curves crossed, the practices were not consistently different and the least costly practice was chosen.

The lowest cost practice would be to use insecticides on the basis of economic threshold values of insect pest populations. Because of the dynamic nature of insect pest populations, nontreatment cannot be recommended. Vegetable maize is the exception because farmers are resistant to currently available chemical insect control technology. In this crop, cultural control recommendations substitute for insecticide control.

Insecticide recommendations, vegetable maize. Oriental maize borer *Ostrinia furnacalis* was the only potential key pest of early-monsoon vegetable maize observed. Because insecticide usage was not acceptable, four harmonious cultural control measures were recommended: 1) early planting, 2) synchronous planting, 3) applying minimal nitrogen fertilizer (60 kg/ha) at hilling up, and 4) using early-maturing varieties. Farmers have learned by experience that late plantings, asynchrony of planting dates, and late-maturing varieties not only are higher risks because of water logging, but also result in high incidences of maize borer and downy mildew. The 60 kg N/ha rate applied at hilling up resulted from an earlier trial (Annual report for 1979). Higher rates of nitrogen or its basal application resulted in higher maize borer populations.

Insecticide recommendations, first rice crop. Insect occurrence and yield loss in direct-seeded rice sown in May-June (early monsoon) in dry or puddled soil was minimal and highly sporadic on rice varieties resistant to brown planthopper *Nilaparvata lugens* and green leafhopper *Nephotettix virescens* (Table 13, 14).

The only recorded yield loss occurred in 1977 in dry-seeded rice. Growth stage-yield loss treatments showed that the loss occurred during the vegetative stage. Insect pest levels being very low, however, the yield difference was attributed to direct plant growth stimulation (Annual report for 1979).

Caseworm *Nymphula depunctalis* and whorl maggot *Hydrellia sasakii* do not occur in dry-seeded rice because fields remain unflooded during the vegetative stage with the normal delayed onset of high rainfall. Soil pests that occur in dryland rice cannot become established in wetland fields.

Insect pests exceeded economic thresholds only in 1976 wet-seeded rice (whorl maggot, yellow stem borer *Scirpophaga incertulas*, leaffolder *Cnaphalocrocis medinalis*) and 1977 dry-seeded rice crops (leaffolder). Since no yield loss resulted, the threshold values were raised (Table 15).

Table 13. Insect occurrence on first-crop dry-seeded bunded IR36 rice and yield response to insecticide treatments to measure yield loss (complete-untreated) and compare 2 potential practices (prophylactic and economic threshold).[a] Manaoag, Pangasinan, 1977-80.

Year	Month planted	Fields (no.)	Yield (t/ha) with insecticide treatment			Untreated	Insect pests in untreated plots							
							Stem borer[e] (%)				Leaffolder[f]-damaged leaves 60 DE		Rice bugs[g]	
							Deadhearts 40 DE		Whiteheads					
			Complete[b]	Prophylactic[c]	Economic[d] threshold		%	Range	%	Range	%	Range	no./m²	Range
1977	June	8	6.4 a	5.9 ab	5.7 b	5.5 b	0.4	0.1 -0.7	0.1	1.0 -0.2	13	6-23	1.1	0 -1.7
1978	May	6	3.4 a	3.7 a	3.6 a	3.6 a	1.4	0.1 -3.1	0.4	0.02-1.6	3	0-7	0.2	0 -0.1
1979	May	6	4.4 a	4.4 a	4.1 a	4.1 a	3.2	1.3 -7.3	0.6	0 -2.9	2	1-3	0.4	0.3-0.5
1980	May	5	3.9 a	3.9 a	3.9 a	3.9 a	1.9	0.03-5.4	0.1	0.05-0.3	1	0-2	0.3	0.2-0.6

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. [b]1977 -- 1.5 kg a.i. carbofuran G/ha in seed furrow, 0.75 kg a.i. monocrotophos EC/ha 40 days after crop emergence (DE) and milk stage; 1978 -- 0.5 kg a.i. carbofuran G/ha in seed furrow, 0.75 kg a.i. endosulfan EC/ha 45, 55 DE, 0.75 kg a.i. carbaryl WP/ha at milk and soft dough stage; 1979 -- 1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35, 45, 55, 65 DE; 0.05 kg a.i. decamethrin EC/ha at milk, soft-dough, and hard-dough stage; 1980 -- 4 g a.i. bendiocarb WP/kg seed (seed treatment); 1 kg a.i. monocrotophos EC/ha 25, 35, 45 DE, 1 kg a.i. Brodan EC (20% chlorpyrifos + 11.5% BPMC)/ha 55, 65, 75 DE; 1 kg a.i. : BHC EC/ha at milk, soft-dough, and hard-dough stage. [c]0.5 kg a.i. carbofuran G/ha in seed furrow. [d]Economic thresholds surpassed only in 1977 and 0.75 kg a.i. endosulfan/ha applied 55 DE for leaffolder and milk stage for rice bug. [e]*Scirpophaga incertulas:* 5-m² sample. [f]*Cnaphalocrocis medinalis:* 100 - leaf sample. [g]*Leptocorisa oratorius:* 5-m² sample.

Table 14. Insect occurrence on first-crop wet-seeded rice and yield response to insecticide treatments designed to measure yield loss (complete - untreated) and to compare 2 potential practices (prophylactic + economic thresholds and economic thresholds).[a] Manaoag, Pangasinan, 1976, 1979-80.

Year	Variety	Month planted	Fields (no.)	Yield (t/ha) with insecticide treatment				Insect pests in untreated plots									
								Case-worm[e]-cut leaves 35 DS		Whorl maggot[f] 35 DS		Stem borers[g] (%)				Leaffolder[h] - damaged leaves 35 DS		Rice bug[i]	
												Deadhearts 35-45 DS		Whiteheads					
				Complete[b]	Prophylactic + economic threshold[c]	Economic[d] threshold	Untreated	%	Range	Grade	Range	%	Range	%	Range	%	Range	no./m²	Range
1976	IR28	June	4	3.7 a	3.8 a	3.9 a	3.9 a	-	-	5.0	3-7	5.5	0 -10.0	2.1	1.4-2.5	11	1-25	0.7	0.4-1.1
1979	IR36	June	4	4.5 a	4.5 a	4.4 a	4.4 a	0	0	1.0	1	1.3	0.3- 3.2	0.2	0.1-0.2	2	1- 3	0.4	0.1-0.8
1980	IR36	June	4	3.8 a	3.7 a	3.7 a	3.7 a	0	0	1.0	1	0.2	0.2- 0.3	0.5	0.1-1.5	3	0-13	0.3	0-1

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. DS = days after sowing. [b]1976 - 2 kg a.i. carbofuran G/ha broadcast 1 DS, 0.75 kg a.i. monocrotophos EC/ha 35, 45 DS and milk stage. 1979 - 1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35, 45, 55, 65 DS, 0.05 kg a.i. decamethrin EC/ha at milk, soft, and hard dough stage. 1980 - 1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35 DS, 1 kg a.i. chlorpyrifos (20%) + BPMC (11.5%) 45, 55, 65 DS, 1 kg a.i. γBHC/ha at milk, soft, and hard dough. [c]1977 - 1 kg a.i. carbofuran G/ha soil incorporated before sowing (SI), 0.75 kg a.i. monocrotophos EC/ha 60 DS (leaffolder) all fields. 1979 - 1 kg a.i. carbofuran G/ha SI. 1980 - 1 kg a.i. carbofuran G/ha (SI), 0.75 kg a.i. monocrotophos EC/ha 65 DS (leaffolder) 1 field. [d]1977 - 0.75 kg a.i. monocrotophos EC/ha 15 DS (whorl maggot) and 60 DS (leaffolder) all fields. 1979 - no insecticide applied since economic threshold was surpassed. 1980 - 0.75 kg a.i. monocrotophos EC/ha 66 DS (leaffolder) 1 field. [e]*Nymphula depunctalis* - visual per-plot estimate. [f]*Hydrellia sasakii,* 1-9 scale based on per-plot estimate of % damaged leaves; 1 = 0, 3 <25%, 5 = 26-49%, 7 = >50%, 9 = >50% with torn leaves. [g]*Scirpophaga incertulas,* 5-m² sample. [h]*Cnaphalocrocis medinalis:* 100-leaf sample [i]*Leptocorisa oratorius:* 5-m² sample, milk stage.

Table 15. Economic threshold values for the major rice insect pests and recommended insecticide. Manaoag, Pangasinan, 1976 and 1982.

Pest	Year	Economic threshold value	Insecticide[a]	Insecticide cost/ application[b] ($/ha)
		Seedbed		
Caseworm,	1976	10% defoliation	Monocrotophos	23
armyworm	1982	25% defoliation	Carbaryl	16
		Vegetative stage		
Whorl maggot	1976	Grade 5	Monocrotophos	23
	1982	Grade 3	Monocrotophos	23
Caseworm	1976	15% defoliation	Monocrotophos	23
	1982	10% cut leaves	Malathion	5
Stem borer	1976	10%	Monocrotophos	23
deadhearts	1982	15%	Chlorpyrifos	16
		Reproductive stage		
Stem borer	1976	3%	Monocrotophos	23
deadhearts	1982	5%	Chlorpyrifos	16
Leaffolder	1976	10% damaged leaves	Monocrotophos	23
	1982	15% damaged leaves	BPMC	10
		Ripening stage		
Rice bug	1976	4/m^2	Monocrotophos	23
	1982	8/m^2	Diazinon	12

[a]Dosage: 0.75 kg a.i./ha. [b]Based on 1976 insecticide price for 1976 and 1982.

The virtual absence of insect pests from first-crop rainfed rice in Pangasinan resulted from the insect-suppressing effect of a 4- to 5-month rice-free dry fallow (January-May). Because prophylactic application of basally applied carbofuran failed to show a significant yield response, even as a result of growth stimulation, the recommended insecticide practice for dry-seeded and wet-seeded rice became the least costly (economic threshold), using the values in Table 15. Insecticide usage is not expected to exceed one application per field.

Insecticide recommendations, single transplanted rice crop. Yield losses to insect pests in the July-planted single rice crop averaged 1 t/ha (Table 16). Annual yield losses were significant (Table 17). Of the yield loss, 0.7 t/ha was concentrated in the vegetative stage. In 1976-78 higher-than-average yield losses during the vegetative stage occurred under relatively high incidences of whorl maggot, caseworm, and yellow stem borer. Except in 1979, yield losses at the vegetative stage exceeded losses at all other growth stages combined.

Although populations of each pest were not always high, yield losses were greatest when relatively high populations of two or more pests occurred together.

No yield losses were recorded in the seedbed. Yield losses in the reproductive and ripening stages occurred in less than half of the years, and in those years yellow stem borer populations were higher than normal. *Leptocorisa oratorius* did not exceed its economic threshold in any field. In 1979, when a yield loss was recorded during the ripening stage, whitehead incidence was particularly high, indica-

Table 16. Yield loss by growth stage in transplanted single-crop rice. Manaoag, Pangasinan, 1976-80.

Year	Yield loss[a] (t/ha)			
	Total	Vegetative	Repro-ductive	Ripening
1976	0.9	0.9	0.0	0.0
1977	0.8	0.8	0.0	0.0
1978	1.6	0.9	0.7	0.0
1979	1.3	0.4	0.4	0.5
1980	0.4	0.4	0.0	0.0
Mean	1.0	0.7	0.2	0.1

[a]No yield loss recorded in seedbed. Yield losses in each growth stage were adjusted proportionally to conform with the total yield loss.

ting that therefore stem borer, not rice bug, was the pest responsible. In other years, higher rice bug infestations did not cause yield loss.

Given the yield losses during the vegetative stage, two potential insecticide practices may be recommended: 1) prophylactic application of 1 kg a.i. carbofuran G/ha, soil incorporated during the last harrowing before transplanting + economic thresholds for other growth stages (prophylactic practice), and 2) economic thresholds at all growth stages. Economic evaluation did not support either practice, even though prophylactic practices were included in field trials (Table 18). Because of high costs of insecticide, cost of prophylactic practice was substantially higher ($35-$90/ha) than the economic threshold ($11-$55/ha), offsetting the yield differences. Marginal profits and benefit-cost ratios favored the prophylactic practice in 1976 and 1977 and the economic threshold practice in 1979 and 1980.

However, net returns were higher with the prophylactic practice in 3 of the 4 years. When net returns for each practice were plotted as a cumulative frequency distribution over all observations, the prophylactic practice showed a consistently higher probability of obtaining higher net returns (Fig. 1) and therefore became the recommended practice.

Insecticide recommendations, second transplanted rice crop. Second transplanted rice crop yields were substantially lower than first or single rice crop yields. This crop is only recommended for areas in Pangasinan with more favorable water status (Table 19). The average loss to insects of 0.5 t/ha was significant each year; 80% of it (0.4 t/ha) occurred during the vegetative stage (Table 20). Average losses also were significant during other growth stages.

Yellow stem borer and rice bug numbers were higher in this crop than in preceding crops; caseworm and leaffolder populations were lower. Considering that this crop occurs at the end of the rice season, when insect pest populations have increased on the preceding crops, it was surprising that insect pest numbers were not higher.

Evaluation of the two potential insecticide practices — prophylactic application of carbofuran G during the vegetative stage + economic thresholds and economic thresholds alone showed significant

Table 17. Insect occurrence on transplanted single-crop rice and yield response to insecticide treatments designed to measure yield loss (complete - untreated) and to compare 2 potential practices (prophylactic + economic thresholds and economic thresholds).[a] Manaoag, Pangasinan, 1976-80.

Year	Variety	Month planted	Fields (no.)	Yield (t/ha) with insecticide treatment				Insect pests in untreated plots											
				Complete[b]	Prophylactic[c] + economic thresholds[d]	Economic[e] threshold	Untreated	Whorl maggot 35 DT		Caseworm-cut leaves 35 DT		Stem borer (%)				Leaffolder-damaged leaves 55 DT		Rice bug	
												Deadhearts		Whiteheads					
								Grade	Range	%	Range	%	Range	%	Range	%	Range	no./m^2	Range
1976	IR28	July	5	4.7 ab	5.4 a	4.2 bc	3.8 c	6.8	6-8	—	—	11.3	2.9-28.0	2.8	0.9-9.6	1	0-2.5	1.4	0 -3
1977	IR36	Aug	7	4.7 a	4.6 a	4.0 b	3.9 b	7.9	6-9	15	7-20	1.0	0.2- 1.9	1.3	0 -4.3	8	2-14	0.4	0 -0.8
1978	IR36	July	6	3.7 a	3.1 b	—	2.1 c	7.0	3-9	12	4-45	2.3	1.1- 4.6	1.9	0.7-4.9	1	0-2	0.2	0 - .1
1979	IR36	July	6	5.6 a	5.0 b	4.7 bc	4.3 c	6.7	5-9	1	0-6	1.7	1.5- 1.8	1.5	0.3-7.1	4	3-4	0.5	0.2-0.6
1980	IR36	July	4	4.2 a	4.2 a	4.0 b	3.8 c	3.5	1-7	0	0	0.2	0.1- 1.8	1.6	0.3-3.7	8	0-4.7	0.1	0.2-0.6

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. [b]1976 - 0.75 kg a.i. monocrotophos EC/ha 5, 10, 25, 40, 70 days after transplanting (DT); 1977 - 1.5 kg a.i. carbofuran G/ha soil incorporated during last harrowing before transplanting (SI), 1.5 kg a.i. γ BHC G broadcast 40 DT, 0.75 kg a.i. endosulfan EC/ha milk stage; 1978 - 1 kg a.i. carbofuran G/ha SI, 0.75 kg a.i. endosulfan EC/ha 35, 45 DT, 1 kg a.i. carbaryl WP/ha milk and soft dough; 1979 - 0.75 kg a.i. monocrotophos EC/ha 7, 14 days after seedling emergence (DE), 1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35, 45, 55 DT, 0.05 kg a.i. decamethrin EC/ha at milk, soft, and hard dough stage; 1980 - 0.75 kg a.i. monocrotophos EC/ha 7, 14 DE, 1 kg a.i. monocrotophos EC/ha 5, 15, 25 DT, 1 kg a.i. chlorpyrifos (20%) + BPMC (11.5%) 35, 45, 55 DT, 1 kg a.i. γ BHC EC/ha at milk, soft, and hard dough stage. [c]1 kg a.i. carbofuran SI. [d]1976 - 0.75 kg a.i. monocrotophos EC/ha 25, 35 DT (stem borers); 1977 - 0.75 kg a.i. endosulfan EC/ha 45 DT (leaffolder) yields. 1979 - 0.75 kg a.i. endosulfan EC/ha 35, 40 DT (deadhearts), all fields. 1980 - 0.75 kg a.i. BPMC EC/ha 55 DT (leaffolder), 1 field. [e]1976 - 0.75 kg a.i. monocrotophos EC/ha 25 DT (whorl maggot, deadhearts), all fields. 1977 - 1.5 kg a.i. diazinon G/ha broadcast 5 DT (whorl maggot), 0.7 kg a.i. endosulfan EC/ha 45 DT (leaffolder), all fields, 1979 - 0.75 kg a.i. carbaryl WP/ha 5, 15 DT (whorl maggot), all fields. 1980 - 0.75 kg a.i. monocrotophos EC/ha 35 DT (whorl maggot), 0.75 kg a.i. BPMC EC/ha 55 DT (leaffolder), both 1 field.

Table 18. Economic evaluation of 2 potential insecticide practices – economic threshold and prophylactic + economic threshold – for transplanted single-rice crop.[a] Manaoag, Pangasinan, 1976-80.

Practice	Yield[a] (t/ha)	Cost[b] ($/ha)	Insecticide usage[c] Marginal[d] profit ($/ha)	Net returns[e] ($/ha)	Benefit: cost[f]
		1976			
Untreated	3.8 b	0	–	315	–
Economic threshold	4.2 b	55	-21	294	1.2
Prophylactic	5.4 a	90	71	365	3.1
		1977			
Untreated	3.9 b	0	–	324	–
Economic threshold	4.0 b	31	-20	304	0.6
Prophylactic	4.6 a	62	21	325	2.0
		1978			
Untreated	2.1 b	0	–	201	–
Prophylactic	3.1 a	35	28	229	3.6
		1979			
Untreated	4.3 b	0	–	359	–
Economic threshold	4.7 ab	19	19	376	3.6
Prophylactic	5.0 a	69	-27	349	1.7
		1980			
Untreated	3.8 c	0	–	316	–
Economic threshold	4.0 b	11	7	323	3.3
Prophylactic	4.2 a	46	-18	351	1.5

[a]Separation of means within a year by Duncan's multiple range test at the 5% level. [b]Insecticide cost = chemical + 12% interest (3%/month X 4 months) + labor for application (4 h/ha for granule, 16 h for knapsack spraying). [c]Based on 1976 prices, $1 = ₱7.30, 1 laborhour = $0.14, 1 kg palay = $0.15, share tenant farmers. [d]Gross returns based on net returns + insecticide cost. Cost of untreated check not subtracted from treatments. [e]Yield – 44% (17% harvesters' share less 33% of the remainder for landlords' share) X palay price – insecticide cost. [f]Marginal benefit-cost ratio calculated after subtracting yield of untreated check from each treatment. Insecticide cost = chemical + labor only.

yield gain from the prophylactic practice over the untreated check only in 1978 (Table 21). Prophylactic practice resulted in superior net returns and an acceptable benefit-cost ratio (greater than 1.9) in only 2 of 5 years. Therefore, the recommended practice would be the least costly alternative (economic threshold, $0-$55/ha).

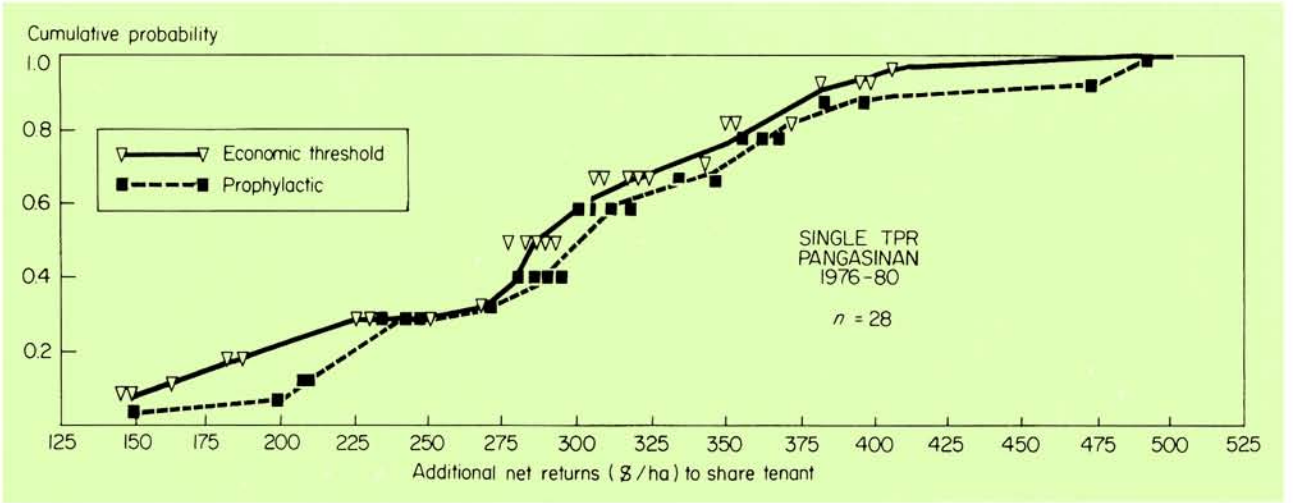
Although the economic threshold did not perform as well as the untreated check through 5 years, recent changes in economic-threshold values as well as in insecticides used improved its performance in 1978-80.

Insecticide recommendations, mungbean. In Pangasinan, insect pests are the single most yield-limiting factor in mungbean production. When the crop was not protected with insecticide, yield losses averaged 74% (0.89 t/ha) per crop; two-thirds occurring in the postflowering stage. The primary pest was *Heliothis armigera* (Table 22, 23). Preflowering insect pests — predominantly beanfly *Ophiomyia phaseoli*, thrips *Thrips palmi*, and flea beetle *Medythia suturalis* — accounted for one-third of the yield loss.

Those proportions were not consistent. In 1978, four times more yield loss occurred in the preflowering stage when beanfly numbers were particularly high. Thrips were noticed in the first trials in Pangasinan but its importance as a preflowering pest was overlooked until 1978, when yields were higher in mungbean sown into standing rice stubble than in high-tillage mungbean. One reason for the higher yield was that the rice stubble controlled thrips.

Six different practices were evaluated and modified annually in timing and chemicals.

The preflowering component of the recommended practice was determined in 1977, when it was realized that two applications were essential to



1. Frequency distribution of cumulative net returns as a probability function for share tenants. Two insecticide practices for single-crop transplanted rice (TPR) over a 5-year period. Manaoag, Pangasinan, 1976–80.

Table 19. Insect occurrence on transplanted second-crop rice and yield response to insecticide treatments designed to measure yield loss (complete - untreated) and to compare 2 potential practices (prophylactic + economic thresholds and economic thresholds). Manaoag, Pangasinan, 1976-80.

Year	Variety	Month planted	Fields (no.)	Yield[a] (t/ha)				No insecticide treatment									
				Complete[b]	Prophylactic[c] + economic[d] thresholds	Economic[e] thresholds	Untreated	Whorl maggot 35 DT		Caseworm-cut leaves 35 DT		Stem borers (%)				Leaffolder-damaged leaves 55 DT		Rice bug	
												Deadhearts 35-45 DT		Whiteheads					
								Grade	Range	%	Range	%	Range	%	Range	%	Range	no./m²	Range
1976	IR28	Oct	6	3.1 a	3.3 a	3.1 ab	2.6 b	6.2	5-7	0	0	3.0	0.5-6.7	5.1	0.5-11.2	0	0	4.8	2-11
1977	IR36	Oct	7	2.2 a	2.1 ab	2.0 ab	1.9 b	4.0	3-6	6	5-10	1.2	0.4-3.3	2.7	1.2-12.6	1	0-2	0.0	0
1978	IR36	Oct	3	2.2 a	2.2 a	1.4 b	1.4 b	1.0	1	0	0	2.8	2.2-3.7	0.9	0.3- 1.3	1	1	2.3	2-4
1979	IR36	Nov	5	3.5 a	3.4 ab	3.2 ab	2.9 b	1.8	0-5	0	0	4.1	0.3-7.1	0.2	0.2- 0.3	0	0	1.2	1-2
1980	IR36	Oct	4	2.8 a	2.7 ab	2.6 ab	2.5 b	4.0	1-7	0	0	1.2	0.2-3.6	1.2	0.2- 3.0	0	0	0.5	0-1.2

[a]Separation of means in a row by Duncan's multiple range test at the 5% level. [b]1976 - 2 kg a.i. carbofuran G/ha soil incorporated during last harrowing before transplanting (SI), 0.75 kg a.i. monocrotophos EC/ha 25, 40 days after transplanting (DT) and milk stage. 1977 - 1.5 kg a.i. carbofuran G/ha, SI, 1 kg a.i. γ BHC G/ha broadcast 40 DT. 1978 - 1 kg a.i. carbofuran G/ha SI, 0.75 kg a.i. endosulfan EC/ha 35, 45 DT, 1 kg a.i. carbaryl WP/ha at milk and soft dough stage. 1979 - 0.75 kg a.i. monocrotophos EC/ha 7, 14 days after seedling emergence (DE), 1 kg a.i. monocrotophos EC/ha 5, 15, 25, 35, 45, 55 DT, 1 kg a.i. γ BHC EC/ha milk, at soft and hard dough stage. 1980 - 0.75 kg a.i. monocrotophos EC/ha 7, 14 DE, 1 kg a.i. monocrotophos EC/ha 5, 15, 25 DT, 1 kg a.i. chlorpyrifos (20%) + BPMC (11.5%) 35, 45, 55 DT; 1 kg a.i. γ BHC EC/ha at milk, soft and hard dough stage. [c]1 kg a.i. carbofuran G/ha, SI. [d]1980 - 0.75 kg a.i. γ BHC EC/ha milk stage (rice bug), 2 fields. [e]1976 - 0.75 kg a.i. monocrotophos EC/ha 25 DT (whorl maggot) and 55 DT (stem borer), all fields, 1977 - 1 kg a.i. diazinon G/ha broadcast 3 DT (whorl maggot), all fields, 1978 - No insecticide applied, 1979 - 0.75 kg a.i. carbaryl WP/ha 5, 15 DT (whorl maggot), all fields. 1980 - 0.75 kg a.i. monocrotophos EC/ha 30 DT (whorl maggot), 0.75 kg a.i. γ BHC EC/ha milk stage (rice bug), both in 2 fields.

Table 20. Yield loss, by growth stage, in transplanted, second rice crop. Manaoag, Pangasinan, 1976-80.

Year	Yield loss[a] (t/ha)			
	Total	Vegetative	Reproductive	Ripening
1976	0.5	0.3	0.2	0.0
1977	0.3	0.3	0.0	0.0
1978	0.8	0.8	0.0	0.0
1979	0.6	0.4	0.1	0.1
1980	0.3	0.3	0.0	0.0
Mean	0.5	0.4	0.07	0.03

[a]No yield loss recorded in seedbed. Yield losses in each growth stage were adjusted proportionally to conform with the total yield loss.

protect a rapidly growing crop against insect pests that attacked immediately after plant emergence. Monocrotophos at 0.25 kg a.i./ha was confirmed in insecticide trials (Annual report for 1979) as the superior chemical for preflowering insect control. The low dosage is less costly than the best granular insecticide and competitive with other chemicals applied as sprays. No seed treatment formulations that would meet safety requirements for small farmer usage are marketed in the Philippines. One spray application would not have the persistence necessary to protect the rapidly growing crop, and three applications (complete control) showed no advantage over two.

Insecticide trials showed that two postflowering applications were necessary to provide an acceptable level of control. In the 1977 trial, applications at 35 and 45 DE occurred too late, allowing the *Heliothis* larval population, which initially colonizes the crop before flowering, to reach the older instars. A dosage of 0.75 kg a.i./ha is not adequate to kill the larger larvae.

To use this low-cost dosage, earlier timing was essential. Application at 25 and 35 DE performed very well in 1978 but not in 1979. Consequently, a compromise timing of 30 and 40 DE, which yielded the same as complete control, was settled on in 1980.

Although decamethrin is the superior insecticide for *Heliothis* control, its high cost is prohibitive to small-scale farmers. Endosulfan is superior to carbaryl at 0.75 kg a.i./ha. The difference in cost

Table 21. Economic evaluation of 2 potential insecticide practices – economic threshold and prophylactic + economic threshold – for transplanted second rice crop. Manaoag, Pangasinan, 1976-80.

Practice	Yield[a] (t/ha)	Cost (t/ha)	Marginal profit ($/ha)	Net returns ($/ha)	Benefit: cost
		1976			
Untreated	2.6 a	0	–	222	–
Economic threshold	3.1 a	55	-17	206	1.4
Prophylactic	3.3 a	90	-9	196	1.4
		1977			
Untreated	1.9 a	0	–	156	–
Economic threshold	2.0 a	22	-32	144	0.9
Prophylactic	2.1 a	35	-4	139	1.1
		1978			
Untreated	1.4 b	0	–	121	–
Economic threshold	1.4 b	0	0	121	0.0
Prophylactic	2.2 a	35	29	150	3.7
		1979			
Untreated	2.9 a	0	–	239	–
Economic threshold	3.2 a	19	15	254	3.3
Prophylactic	3.4 a	35	2	256	3.0
		1980			
Untreated	2.5 a	0	–	206	–
Economic threshold	2.6 a	22	9	198	1.3
Prophylactic	2.7 a	57	-23	174	1.0

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

Table 22. Development of an insecticide recommendation for mungbean after rainfed wetland rice, Manaoag, Pangasinan, 1976-1980.

Year	Variety	Fields (no.)	Insecticide treatment	Application[a] time (DE)	Yield (t/ha)	Insect pests				Insecticide use[f]		
						Flea beetle[b] (% defoliation) 7 DE	Thrips[c] (no./10 terminals) 21 DE	Beanfly[d] (% infested plants) 21 DE	*Heliothis*[e] (% defoliation) 45 DE	Cost[g] ($/ha)	Net returns[h] ($/ha)	Benefit: cost[i]
1976	CES 55	6	Complete[j]	5, 15, 25, 35, 45	0.69 a	14 b	—	30 a	5 a	—	—	—
			Untreated	—	0.19 b	24 b	—	75 b	45 b	0	68	—
			Practice 1[k]	5, 15, 35, 45	0.64 a	12 a	—	28 a	5 a	42	180	7.0
			Practice 2[l]	5, 21, 35, 45	0.90 a	12 a	—	33 a	6 a	58	256	8.1
1977	CES 55	7	Complete[m]	2, 12, 25, 35, 45	1.37 a	2 a	—	10 a	2 a	—	—	—
			Untreated	—	0.08 c	12 b	—	50 b	63 c	0	27	—
			Practice 3[n]	2, 12, 35, 45	0.72 b	3 a	—	10 a	45 b	54	196	8.0
1978	CES 1D-21	4	Complete[o]	−3, 25, 35, 45	1.41 a	3 a	—	22 a	—	—	—	—
			Untreated	—	0.32 b	18 b	—	74 b	—	0	113	—
			Practice 4[p]	2, 12, 25, 35	1.32 a	3 a	—	25 a	—	40	417	16.6
1979	CES 1D-21	4	Complete[q]	2, 9, 16, 25, 35, 45	1.22 a	0 a	0.7 a	12 a	2 a	—	—	—
			Untreated	—	0.48 c	4 c	2.5 b	40 b	20 c	0	166	—
			Practice 4[p]	2, 12, 25, 35	0.82 b	0 a	0.4 a	10 a	5 ab	40	246	5.7
			Practice 5[r]	5, 30	0.75 b	1 b	0.7 a	19 a	6 b	18	242	9.8
1980	CES 1D-21	4	Complete[q]	2, 9, 16, 25, 35, 45	1.25 a	1 a	0.1 a	0 a	1 a	—	—	—
			Untreated	—	0.43 b	8 c	7.1 c	14 c	31 b	0	150	—
			Practice 6[s]	2, 12, 30, 40	1.20 a	3 b	0.8 b	4 b	5 a	54	362	9.5

[a]DE = days after crop emergence. December plantings, high tillage. Separation of means in columns within a year by Duncan's multiple range test at the 5% level. [b]*Medythia suturalis*. [c]*Thrips palmi*. [d]*Ophiomyia phaseoli*. [e]*Heliothis armigera*. [f]Based on 1976 prices, $1 = P7.30, 1 workhour (h) = $0.14, 1 kg mungbean = $0.62, share tenant farmers. [g]Insecticide cost = chemical + 9% interest (3%/month × 3 months) + labor for application (16 h/ha for knapsack spraying). [h][Yield - 44% (17% harvesters' share less 33% of the remainder for landlords' share] × mungbean price - insecticide cost. [i]Marginal benefit-cost ratio calculated after subtracting yield of untreated check from each treatment. Insecticide cost = chemical + labor only. [j]Monocrotophos EC 5, 15, 25, 35 days after seedling emergence (DE) (0.25 kg a.i./ha), 45 DE (0.75 kg a.i./ha). [k]0.25 kg a.i. monocrotophos EC/ha. [l]Monocrotophos EC 5, 25, 35 DE (0.25 kg a.i./ha), 45 DE (0.75 kg a.i./ha). [m]0.5 kg a.i. monocrotophos/ha 2, 12 DE, 1 kg a.i. endosulfan EC/ha 25, 35, 45 DE. [n]0.25 kg a.i. monocrotophos EC/ha 2, 12 DE; 0.75 kg a.i. endosulfan EC/ha 35, 45 DE. [o]1% carbofuran (seed treatment), 0.05 kg a.i. decamethrin EC/ha 25, 35, 45 DE. [p]0.25 kg a.i. monocrotophos EC/ha 2, 12 DE; 0.75 kg a.i. carbaryl WP/ha 25, 35 DE. [q]0.5 kg a.i. monocrotophos EC/ha 2, 9, 16 DE, 0.03 kg a.i. decamethrin EC/ha 25, 35, 45 DE. [r]0.5 kg a.i. dimethoate EC/ha 5 DE, 0.75 kg a.i. carbaryl WP/ha 30 DE. [s]0.25 kg a.i. monocrotophos EC/ha 2, 12 DE, 0.75 kg a.i. endosulfan EC/ha 30, 40 DE.

Table 23. Yield loss by growth stage for mungbean planted in December under high tillage. Manaoag, Pangasinan, 1976-80.

Year	Yield loss[a] (t/ha)		
	Total	Preflowering	Postflowering
1976	0.50	0.10	0.40
1977	1.29	0.15	1.14
1978	1.09	0.88	0.21
1979	0.74	0.30	0.44
1980	0.82	0.25	0.57
Mean	0.89	0.32	0.57

[a]Yield losses in each growth stage were adjusted proportionally to conform with total yield loss.

between the two is more than made up for in net returns, since mungbean commands four times the price of rice. The recommended practice costs $54/ha, giving a benefit-cost ratio of 9.5.

Effect of planting time and insect control and tillage practices on mungbean insects. Mungbean after wetland rice can be planted from October to January in rainfed Pangasinan. The recommended 4 insecticide sprays (0.25 kg a.i. monocrotophos/ha 2 and 12 DE and 0.75 kg a.i. endosulfan EC/ha 30 and 40 DE) were evaluated in mungbean sown into stubble and stubble-free fields at 1-month intervals. In earlier experiments (Annual report for 1978), erect rice stubble suppressed several preflowering mungbean insects, and species population densities changed during the wet-to-dry transition.

Only treatments that gave protection during both preflowering and postflowering stages were included. Yield losses for each growth stage were computed separately as the difference between each treatment and complete control. Total yield loss was computed as the difference between complete control and untreated check.

Control practices. Complete control gave the highest yields in November and December plantings (Table 24). Waterlogged soils and cloudy weather in October and drought stress in January caused low yields of those plantings. The November and December crops were able to compensate for insect damage during preflowering. Yields in plots protected during postflowering were not significantly different from those in the complete-protection plots. The November planting, which was under less postflowering insect pressure (particularly from *Heliothis*), was able to compensate for damage at either preflowering or postflowering.

The October planting recorded the highest *Thrips palmi* and *Heliothis armigera* populations and had high numbers of flea beetle *Medythia suturalis* and leaf miner *Stomopteryx subsecivella*. The November planting had the highest bean pod borer *Maruca testulalis* and aphid *Aphis craccivora* populations, as well as high leafhopper *Amrasca biguttula biguttula*. The December planting had moderate populations of all pests. The January planting had the highest number of beanfly *Ophymyia phaseoli* and high flea beetle and leaf miner populations.

Because most farmers plant mungbean in December, the January planting would have been expected to register the highest insect populations. But leafhopper and bean pod borer were not detected. The absence of bean pod borer in the October planting probably resulted from superior competition from *Heliothis*, which also attacks the flowers.

Tillage practice. Significant reductions occurred in beanfly, thrips, leafhopper, and aphid populations in stubble planting. In the October and January plantings, zero-tillage yields were significantly higher than high-tillage yield. Control of thrips by rice stubble was responsible for the yield increase in the October planting, and its control of beanfly for the increase in the January planting.

The recommended practice developed in 1976-80 for December plantings performed well in November and December plantings. The recommended practice could be improved for *Heliothis* control in the October planting, but zero tillage gave adequate yields in spite of suboptimal *Heliothis* control.

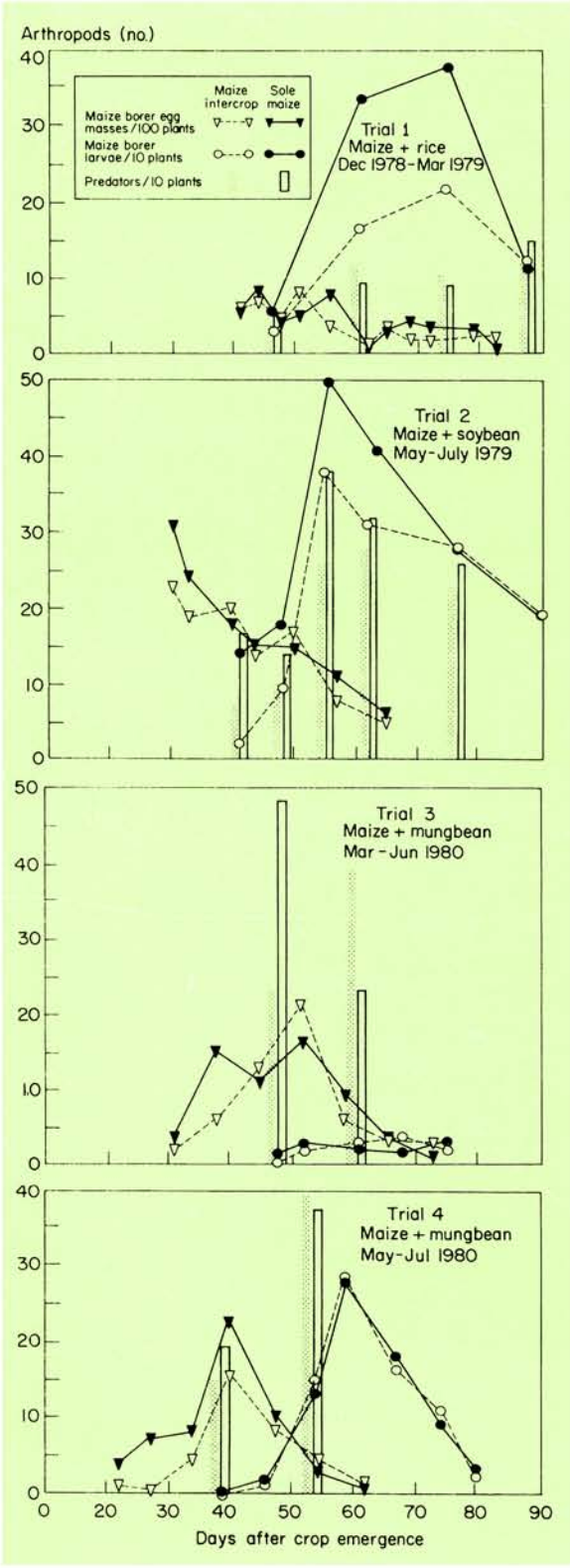
The recommended practice gave the least yield in the January planting, in spite of no recorded deficiencies in insect control.

Maize intercropping and Oriental maize borer. The suppressing effect of intercropped maize on the Oriental maize borer *Ostrinia furnacalis* occurs at oviposition, when fewer eggs are laid, and after oviposition, with greater larval mortality (Annual reports for 1973 and 1975). More egg masses occur per plant in dense maize stands. Four field experiments in 1978-80 used equal maize plant populations per hectare in single-crop (0.75-m rows) and intercrop (1.5-m rows) patterns designed to test

Table 24. Effect of planting time and tillage method on development of an insect control recommendation for CES 1D-21 mungbean planted after rainfed wetland rice.[a] Manaoag, Pangasinan, 1980-81.

Insecticide protection	Flea beetle[b] no. holes/plant 14 DE		Beanfly[c] infested plants (%) 25 DE		Thrips[d] (no./35 leafbud tips) 25 DE		Leaf miner[e] (no. tunnels/35 plants) 25 DE		Leafhopper[f] (no./35 plants) 25 DE		Aphid[g] infestation (grade) 25 DE		*Maruca*[h] infested flowers (%) 35 DE		*Heliothis*[i] larvae (no./35 plants) 45 DE		Yield[j] (t/ha)	
	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT	ZT	HT
October planting																		
Complete[k]	8 a	8 a	0 a	0 a	18 a	23 b	30 a	33 a	0 a	0 a	1.0 a	10.0 a	0	0	1 a	0 a	0.73 a	0.52 ab
Postflowering	9 a	14 a	4 b	19 c	24 b	122 c	48 a	40 a	0.3 a	3 c	1.7 a	3.0 ab	0	0	2 a	0 a	0.48 bc	0.24 de
Preflowering	11 a	14 a	0 a	1 a	12 a	26 b	28 a	24 a	0 a	0 a	1.0 a	10.0 a	0	0	28 d	25 cd	0.36 cd	0.28 de
Untreated	10 a	14 a	5 b	19 c	26 b	127 c	65 a	39 a	0.3 a	3 c	3.7 b	3.7 b	0	0	18 c	20 c	0.23 de	0.09 e
Recommended[l]	7 a	12 a	0 a	0 a	15 a	26 b	42 a	49 a	0.3 a	1 b	1.0 a	1.0 a	0	0	7 bc	5 b	0.54 ab	0.34 cd
November planting																		
Complete[k]	2 a	1 a	0 a	3 ab	3 a	7 d	0.3 ab	0 a	1 a	1 a	1.0 a	1.0 a	0 a	1 ab	0 a	0 a	0.97 a	0.96 a
Postflowering	8 cd	7 cd	2 ab	16 cd	4 ab	8 d	0 a	0.3 a	1 a	1 a	1.0 a	2.3 b	1 ab	2 abc	0 a	0 a	0.93 ab	0.90 ab
Preflowering	3 abc	2 ab	0 a	1 a	6 cd	8 d	3 bc	2 bc	2 b	7 c	1.0 a	1.0 a	14 d	12 d	3 b	3 b	0.95 a	0.67 ab
Untreated	11 d	8 cd	9 c	24 d	7 d	12 e	6 c	4 c	2 b	7 c	2.3 b	6.3 c	15 d	18 d	4 b	2 ab	0.57 c	0.43 c
Recommended[l]	6 bcd	5 bc	1 a	6 bc	5 abcd	7 d	1 ab	1 ab	1 a	1 a	1.0 a	1.0 a	4 c	4 c	0 a	1 ab	0.63 abc	0.70 ab
December planting																		
Complete[k]	0 a	0 a	0 a	0 a	6 a	6 a	0 a	0 a	0 a	0 a	1.0 a	1.0 a	0 a	0 a	0 a	0 a	1.19 ab	1.25 a
Postflowering	2 c	3 c	3 b	11 c	5 a	10 a	0 a	4 b	1 b	5 c	2.5 b	3.5 b	0 a	0 a	1 a	1 a	1.04 ab	0.97 abc
Preflowering	1 b	1 b	0 a	3 b	5 a	7 a	4 b	0.3 a	0 a	0.5 a	1.0 a	1.0 a	5 bc	5 bc	4 b	4 b	0.54 cde	0.62 cd
Untreated	6 cd	7 d	2 b	14 c	7 a	13 a	4 b	5 b	2 b	7 c	2.0 b	4.0 b	7 bc	8 c	5 b	5 b	0.45 e	0.43 e
Recommended[l]	1 b	1 b	0 a	4 b	6 a	9 a	0 a	1 a	0 a	0 a	1.0 a	1.0 a	5 bc	3 ab	1 a	1 a	0.91 abc	1.20 ab
January planting																		
Complete[k]	11 a	12 a	6 a	6 a	8 a	11 a	0 a	1 a	0	0	1.0 a	1.0 c	0	0	0 a	0 a	0.60 a	0.54 ab
Postflowering	17 ab	20 b	5 a	46 bc	24 b	23 b	0 a	0 a	0	0	1.0 a	1.0 a	0	0	0 a	0 a	0.25 c	0.11 d
Preflowering	12 a	11 a	0 a	7 a	12 a	13 a	61 c	57 c	0	0	4.3 b	4.3 b	0	0	0 a	0 a	0.25 c	0.24 c
Untreated	18 ab	23 b	26 b	56 c	27 b	31 b	56 c	71 c	0	0	4.3 b	5.0 b	0	0	2 b	1 b	0.28 c	0.07 d
Recommended[l]	9 a	15 a	4 a	2 a	9 a	18 ab	2 ab	3 b	0	0	1.0 a	1.0 a	0	0	0 a	0.3 a	0.47 b	0.45 b

[a] Av of 4 replications (fields)/ monthly planting. ZT = zero tillage (rice stubble undisturbed), HT = high tillage (field plowed and harrowed). Separation of means in paired columns (tillage practices) within each month by Duncan's multiple range test at the 5% level. [b] *Medythia suturalis*: 35-plant sample. [c] *Ophiomyia phaseoli*: 35-plant dissected. [d] *Thrips palmi*: 35-leaf bud terminals. [e] *Stomopteryx subsecivella*: 35-plant sample. [f] *Amrasca biguttula biguttula*: 35-plant sample. [g] *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 colonies running together. [h] *Maruca testulalis*: 50-flower sample. [i] *Heliothis armigera*: 35-plant sample. [j] 25-m^2 sample. [k] Preflowering: 0.5 kg a.i. monocrotophos EC/ha 2, 9, 16 days after emergence (DE); postflowering 0.03 kg a.i. decamethrin EC/ha 25, 35, 45 DE. 0.25 kg a.i. monocrotophos EC/ha 2, 12 DE; 0.75 kg a.i. endosulfan EC/ha 30, 40 DE.



whether greater larval mortality was due to higher predator populations attracted to the companion crop. The results showed an inconsistent benefit from intercropping between trials and no significant differences in predator quality or quantity between cropping treatments.

The first experiment, December 1978-March 1979, was characterized by very low egg numbers with no difference between intercrop maize + rice and single-crop maize, both at 25,000 plants/ha (Fig. 2). Maize borer larval numbers were significantly higher in the single crop than in the intercrop, but the difference could not be attributed to the presence of predator spiders *Lycosa pseudoannulata, Thomisus cherapunjus, Araneus inustus,* and *Oxyopes javanus* (Table 25).

The May-July 1979 trial (60,000 maize plants/ha) also failed to show a difference in egg numbers between intercrop (maize + soybean) and single-crop maize. Maize borer larval numbers were not

Table 25. Predator populations sampled on maize plants in maize sole crop and intercrop in 4 experiments. IRRI, 1978-80.

Predator	Predators[a] (no./10 plants)	
	Sole crop	Intercrop
	Dec 1978-Mar 1979[b]	
Spiders	6.3	6.8
Total	14.2	14.2
	May-Jul 1979[c]	
Spiders	11.7	11.3
Microspis crocea	11.1	5.5
Total	28.7	21.7
	Mar-Jun 1980[c]	
Solenopsis geminata	16.4	15.5
Microspis crocea	7.4	5.8
Spiders	4.8	5.1
Orius sp.	4.7	4.7
Total	37.3	34.9
	May-Jul 1980[c]	
Solenopsis geminata	11.4	12.7
Microspis crocea	8.9	7.7
Spiders	7.4	6.7
Total	30.5	31.7

[a]Av of 4 replications, 10 plants/replication. [b]Visual counts. [c]Whole-plant enclosure with cage.

2. Comparison of intercropped and sole-cropped maize on Asian corn borer *Ostrinia furnacalis* predators and egg and larval numbers. Predators were collected using whole-plant enclosure traps. IRRI, December 1978–July 1980.

significantly different between treatments. More predators occurred on this crop; the most common was coccinellid egg predator *Microspis crocea* and spiders *L. pseudoannulata, A. inustus,* and *Callitrichia formosana.* Predators were equal in the cropping treatments.

In the third trial at 60,000 maize plants/ha, high egg populations occurred in both intercrop (maize + mungbean) and single crop. The anthocorid egg predator *Orius* sp. was particularly abundant at the peak period of maize borer egg masses. Its abundance and the high incidence of ants and coccinellids greatly suppressed maize borer larval populations, and no difference in larval numbers was evident between treatments.

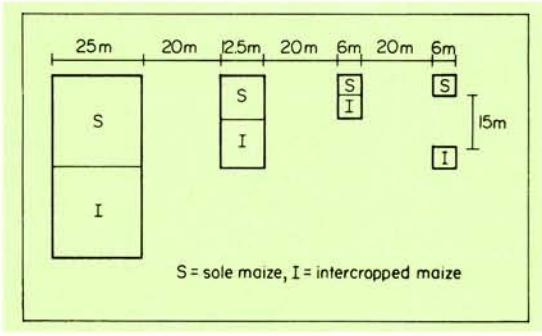
The fourth trial, May-July 1980, produced a significant difference in egg numbers between intercrop (maize + mungbean) and single crop at 60,000 plants/ha. Larval populations were identical in both treatments, in spite of higher initial egg numbers in the single crop. Predator numbers were not significantly different between treatments. The predominant predator, an ant, *Solenopsis geminata,* mainly attacks young larvae and does not occur within the stalks to attack older larvae.

Plot size in the fourth planting was smaller (375 m^2) than in the first three trials (625 m^2). Plots (57-144 m^2) in the 1972-74 trials at IRRI also showed higher egg numbers in single crops.

The plot layout (Fig. 3) replicated in 4 locations at the IRRI farm used 3 plot sizes to compare maize + mungbean intercrop and maize single crop at 40,000 plants/ha. Small single-crop and intercrop maize plots were isolated 15 m apart.

Ovipositing moths showed a progressively greater preference for single-crop maize than for intercropped maize as plot sizes decreased if cropping treatments were together. But when small plots were isolated, egg numbers were equal. More eggs occurred per plant in larger plots.

The greater oviposition per plant in large plots and dense stands shows that maize borer moths are attracted to greater concentrations of their hosts. The host-seeking mechanisms of this night-flying insect are unclear. Migratory moths descending from high altitudes to crop level could be responding to more intense visual or olfactory signals from larger plots or more dense stands. Or, the suppressing effect of the companion crop in an intercrop would mask or dilute these signals.



3. Experimental layout for studying the effect of plot size on the oviposition behavior of Asian corn borer *Ostrinia furnacalis.*

Trials in Batangas Province, Philippines, had shown that earwigs alone can suppress the maize borer (Annual report for 1976). But earwigs are virtually absent in maize at the IRRI farm (their preferred refuge is sugar cane).

However, in the first field trial, when predator populations were low, larval mortality was greater in the intercrop than in the single crop with equal egg populations, despite no apparent difference in predator species composition or number of individuals. The explanation could be the dispersal behavior of first-instar larvae.

Plant-to-plant dispersal of recently hatched larvae occurs when larvae secrete silk strands up to 1.5 m long. When the free end of the strand strikes another plant, a bridge is formed on which the larvae crawls to the next plant. If the prevailing wind is perpendicular to the maize rows, greater mortality occurs in dispersing larvae whose silk strands have to extend as far as 1.5 m to break (as in an intercrop). The larvae are blown away. Larvae also balloon into the air if the strand does not strike another object. If the prevailing wind is parallel to the rows, shorter plant-to-plant distances mean greater larval dispersal.

WEED CONTROL

Agronomy Department

Land preparation for weed control in dry-seeded rice. *Stale-seedbed and zero tillage.* In a dry-seeded wetland rice trial, five different land-preparation methods and five postplanting weed control methods were tested for weed growth.

The five land-preparation methods were 1) one plowing followed by one harrowing, 2) one plowing followed by three harrowings, 3) stale-seedbed and tillage (weeds controlled by harrowing before planting), 4) stale-seedbed and herbicide (weeds controlled with paraquat before planting), and 5) zero tillage with herbicide (weeds controlled with glyphosate before planting).

No herbicide combination controlled *Ipomoea triloba*. To prevent complete yield loss, all plots except those hand weeded were sprayed 35 DE with 2,4-D at 0.75 kg a.i./ha. At 35 DE, total weed weight in unweeded plots was lower in stale-seedbed plots than in plowed-and-harrowed and zero-tillage plots (Table 26). Composition of the weed flora also varied. Broadleaf weeds dominated in stale-seedbed plots and plots with one plowing followed by three harrowings; grasses dominated in reduced and zero-tillage plots.

In all postplanting weed control treatments, at 60 DE, there were significantly less weeds in stale-seedbed plots than in other land-preparation plots (Table 27). In all tillage treatments, two hand weedings gave the best weed control. Time required for hand weeding ranged from 700 work hours/ha in stale-seedbed plots with paraquat to over 2,000 work hours/ha in zero-tillage plots.

In general, in stale-seedbed plots, weed control with herbicides was similar to that with two hand weedings; in plots prepared by other methods, it tended to be inferior. Weed weight was significantly lower in all land-preparation treatments with herbicides than in the untreated check.

No yield was obtained because of severe moisture stress during heading and grain filling.

Time and degree of land preparation. In a dry-seeded wetland trial at IRRI, weed weights in unweeded plots were unaffected by time of land

Table 26. Effect of method of land preparation on the relative dry weight and total weed weight in the unweeded plots of dry-seeded IR50 wetland rice.[a] IRRI, 1981 wet season.

Weed species	Zero tillage	1 plowing + 1 harrowing	1 plowing + 3 harrowings	Stale-seedbed (harrow)	Stale-seedbed (paraquat)
		Relative dry wt			
Melochia concatenata	5.4	23.2	52.0	11.9	13.1
Digitaria sp.	39.4	27.5	10.1	18.0	9.9
Ipomoea triloba	8.5	8.7	19.6	26.4	12.5
Paspalum sp.	20.2	34.7	15.9	2.3	0.8
Commelina diffusa	0.3	3.5	1.3	8.9	28.1
Murdannia nudiflora	0.0	0.0	0.1	9.6	11.6
Others[b]	26.2 (4)	2.4 (8)	1.0 (6)	22.9 (7)	24.0 (8)
		Total weed wt (g/m²)			
	307.2	284.4	287.4	82.2	97.4

[a]Av of 3 replications. [b]Number of species indicated in parentheses.

Table 27. Total weed weight 60 days after emergence, as affected by land preparation methods and postplanting weed-control techniques.[a] IRRI, 1981 wet season.

Land preparation method	Total weed wt (g/m²)				
	No weeding	Butachlor + propanil	Pendimethalin + propanil	Thiobencarb + propanil	2 hand weedings
Zero tillage	1037.2 a	230.8 a	226.6 a	255.6 a	90.6 a
1 plowing + 1 harrowing	1091.8 a	169.4 a	118.6 ab	415.6 a	97.6 a
1 plowing + 3 harrowings	818.0 ab	250.0 ab	164.8 ab	302.4 a	46.2 ab
Stale-seedbed (harrow)	293.6 bc	64.0 b	132.6 ab	15.4 b	18.0 bc
Stale-seedbed (paraquat)	215.0 c	37.8 b	45.0 b	40.4 b	10.6 c

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. 2,4-D was applied to all plots (35 days after emergence) except those that were hand weeded.

preparation. However, there were differences in the composition of the weed flora. When land was prepared by plowing and harrowing in February, *I. triloba* made up 57.2% of the weed flora by weight, *Digitaria* sp. 1.2%. When land was prepared in May, *I. triloba* made up 22.3% of the weed flora, *Digitaria* sp. 25.8%. The effectiveness of herbicides in dry-seeded rice is likely to depend on the time of land preparation.

At the Solana outreach sites, in Amulung, Cagayan Valley, there was a significant decrease in *Cynodon dactylon* and a significant increase in *Echinochloa colona* in dry-seeded rice when land was prepared at the start of the dry season rather than at the start of the wet season.

There was a decrease in *Ipomoea aquatica* and an increase in *E. colona* in dry-seeded rice when land was prepared by two plowings followed by three harrowings at the start of the rainy season rather than by one plowing and two harrowings. Increased land preparation also reduced weed weight.

Effect of tillage, fertilizer, and weed control methods on weed growth. A long-term trial of three cropping patterns, initiated in 1979, was continued in 1981.

Continuous transplanted irrigated rice. Two tillage levels (minimum tillage, 1 plowing followed by 1 harrowing 1 week later; and conventional tillage, 1 plowing followed by 3 harrowings at weekly intervals) and 3 nitrogen levels (0, 40, and 80 kg/ha in the wet season and 0, 60, and 120 kg/ha in the dry) are being tested. Six weed control treatments are being evaluated under each nitrogen level.

In croppings 7 (dry season) and 8 (wet season) land preparation and nitrogen level had little effect on weed flora 40 days after transplanting (DT). *Echinochloa* spp. (primarily *Echinochloa glabrescens*) were the dominant weeds. Minor weeds were *Cyperus difformis*, *Monochoria vaginalis*, *Paspalum paspalodes*, and *Fimbristylis littoralis*.

Nitrogen application resulted in a significant increase in weed weight. Weed weights were not significantly different at medium and high nitrogen levels.

At all nitrogen levels weed growth was less in minimum-tillage plots than in conventionally tilled plots.

Weed growth was less in the wet-season crop than in the dry-season crop.

In the dry season, weed control with 2,4-D and thiobencarb-2,4-D decreased as nitrogen level increased. In the wet season, at high nitrogen levels all weed control treatments gave poor control.

Weeds caused significant yield losses at all nitrogen levels. Herbicide performance was poorer and yields were lower, especially in conventional-tillage plots at higher nitrogen levels (Table 28).

In the wet season, weeds did not cause a significant yield reduction when no nitrogen was applied. Yield losses were significant and increased as nitrogen level increased. At the highest nitrogen level, yields were significantly lower with thiobencarb-2,4-D in minimum-tillage plots and with 2,4-D in conventional-tillage plots.

One crop of rainfed transplanted rice. Two levels of land preparation were keeping the field free of weeds during the dry season by tilling and preparing the land as soon as there was sufficient water for puddling. Nitrogen levels were 0, 40, and 80 kg N/ha.

Weed weight and composition of weed flora

Table 28. Effect of tillage level, nitrogen level, and weed control treatment on yield of transplanted IR36 rice, 7th crop.[a] IRRI, 1981 dry season.

Weed control method[b]	Yield (t/ha)					
	Minimum tillage			Conventional tillage		
	0 kg N/ha	60 kg N/ha	120 kg N/ha	0 kg N/ha	60 kg N/ha	120 kg N/ha
Rotary weeding fb hand weeding	1.9 a	2.1 ab	2.0 a	2.1 a	1.9 a	1.6 a
2,4-D (0.8 kg a.i./ha)	1.4 ab	0.8 c	0.0 b	1.1 b	0.0 b	0.0 b
Thiobencarb – 2,4-D (1.0-0.5 kg a.i./ha)	1.9 a	1.5 b	1.8 a	2.0 a	0.1 b	0.3 b
Butachlor (1 kg a.i./ha)	2.1 a	2.1 ab	2.4 a	2.2 a	2.0 a	0.2 b
Butachlor (1 kg a.i./ha) fb 2,4-D (0.8 kg a.i./ha)	1.7 a	2.3 a	2.2 a	1.9 a	1.6 a	0.6 b
No weeding	0.9 b	0.0 d	0.0 b	1.4 ab	0.0 b	0.0 b

[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. A spaced dash (–) means that the herbicides were formulated as a proprietary mixture.

were affected by tillage method but not by nitrogen level. Average weed weight in tillage plots was 18.4 g/m^2; in puddled plots, 180.4 g/m^2. Major weeds were *E. colona* in the tillage plots and *P. paspalodes* in puddled plots.

Hand weeding, alone or in combination with herbicides, gave good weed control (Table 29). Butachlor alone failed to control the weeds with either level of land preparation.

Yields were low because of severe moisture stress during crop growth. Yields in hand-weeded plots were not affected by tillage level. In plots kept weed free by tillage during the dry season, the weed population was so small that weed control plots did not yield significantly higher than the unweeded check. With puddled land preparation, hand-weeded plots yielded significantly more than the unweeded check and the treatment with butachlor alone. Butachlor failed to control *P. paspalodes*, and yields of treated plots were not significantly different from those of the unweeded check.

Dry-seeded rice followed by transplanted rice. In the dry-seeded rice crop, the two levels of land preparation used were similar to those used with one rainfed transplanted crop except that land preparation for the second treatment started after the onset of monsoon rains. Nitrogen levels were 0, 60, and 120 kg N/ha for both crops. Rice emerged 3 days earlier in plots tilled during the dry season than in plots prepared at the onset of rains. Stand count was higher and stand more uniform in plots prepared during the dry season.

Total weed weight and weed flora composition were not affected by fertilizer level and were only slightly affected by tillage level. *Melochia concatenata* and *E. colona* were the major weeds. *Panicum repens* appeared late in the season in plots prepared at the start of the rains but was not present in plots kept weed free during the dry season.

All weed control treatments, except butachlor applied alone, gave good weed control (Table 30). Weed control was slightly better when land was

Table 29. Effect of time of land preparation and weed control method on weed weight and yield of rainfed transplanted IR36 rice.[a] IRRI, 1981 wet season.

Weed control method[b]	Time of application[c]	Tillage during the dry season		Tillage after sufficient water for puddling	
		Weed wt (g/m^2)	Yield (t/ha)	Weed wt (g/m^2)	Yield (t/ha)
Butachlor (1 kg a.i./ha) fb hand weeding	PE fb 30 DT	0.0 b	1.7 a	2.1 b	1.5 a
Hand weeding fb 2,4-D (0.8 kg a.i./ha)	15 DT fb 30 DT	0.8 b	1.5 a	8.3 b	1.6 a
1 weeding	21 DT	1.3 b	1.5 a	8.3 b	1.3 a
Butachlor (1 kg a.i./ha)	PE	7.6 a	1.5 a	67.2 a	0.6 b
Unweeded	–	9.2 a	1.4 a	90.2 a	0.6 b

[a] Av of 3 replications and 3 nitrogen levels. Separation of means in a column by Duncan's multiple range test at the 5% level. [b] fb = followed by. [c] PE = preemergence, DT = days after transplanting.

Table 30. Effect of time of land preparation and method of weed control on weed weight at harvest and yield of dry-seeded IR36 rice.[a] IRRI, 1981 wet season.

Weed control method[b]	Time of application[c]	Land preparation during the dry season		Land preparation at the onset of rain	
		Weed wt (g/m^2)	Yield (t/ha)	Weed wt (g/m^2)	Yield (t/ha)
2 weedings	14 fb 35 DE	29.0 b	3.0 a	39.0 c	2.8 a
Butachlor (2 kg a.i./ha) + propanil (3 kg a.i./ha)	8 DE	10.4 c	3.2 a	47.4 c	2.5 a
Butachlor (2 kg a.i./ha) fb propanil (3 kg a.i./ha)	PE fb 8 DE	17.0 b	3.1 a	99.8 b	2.5 a
Butachlor (2 kg a.i./ha) fb hand weeding	PE fb 30 DE	21.2 b	3.0 a	39.6 c	2.6 a
Butachlor (2 kg a.i./ha)	PE	311.8 a	0.2 a	364.0 a	0.0 b
No weeding	–	382.8 a	0.0 b	439.6 a	0.0 b

[a] Av of 3 replications and 3 nitrogen levels. Separation of means in a column by Duncan's multiple range test at the 5% level. [b] + indicates the herbicides were tank-mixed; fb = followed by. [c] DE = days after emergence, PE = preemergence.

prepared during the dry season than when it was prepared at the onset of rains. Yields were slightly lower when land was prepared at the start of rains. With adequate weed control, fertilized plots produced significantly higher yields than unfertilized plots. In no-weeding plots and those treated with butachlor alone, increased fertilizer rates did not significantly increase yields because of intense weed competition.

In the transplanted rice crop, *E. glabrescens*, *C. difformis*, *E. colona*, and *Leptochloa chinensis* were the major weeds. Tillage method and nitrogen level for dry-seeded rice had no effect on weed flora nor on weed weight in transplanted rice.

Weed control was excellent with one hand weeding, 2,4-D followed by propanil, and the combination of 2,4-D and butachlor with hand weeding. Weed control with butachlor was lowest and decreased as nitrogen level increased.

In general, combination treatments were superior to hand weeding alone or butachlor alone and yields tended to increase as nitrogen levels increased (Table 31).

Effect of nitrogen and weed control practices in dry-seeded rice followed by transplanted rice. In a trial at IRRI, major weeds in the unweeded plots of dry-seeded rice, 35 days after emergence, were *Cyperus rotundus*, *C. dactylon*, *E. colona*, and *Rottboellia exaltata*. Total weed weight was significantly higher in dry-seeded rice with 100 kg N/ha than with no nitrogen. Nitrogen level had little effect on the composition of the weed flora, although *R. exaltata* increased as nitrogen level increased and there was less *C. rotundus* at the highest nitrogen level than at other levels.

Nitrogen uptake by rice increased in the hand-weeded plots as the level of nitrogen increased. In the unweeded plots, nitrogen uptake by weeds increased as the level of nitrogen increased (Table 32). At the lowest level of nitrogen in the unweeded plots, there was a significant difference between nitrogen taken up by rice and that taken up by

Table 31. Effect of time of land preparation in dry-seeded rice, nitrogen level, and weed control treatment on grain yield of transplanted IR36 rice.[a] IRRI, 1981 wet season.

Weed control method[b]	Grain yield (t/ha)					
	Land preparation during dry season			Land preparation at the onset of rain		
	0 kg N/ha	60 kg N/ha	120 kg N/ha	0 kg N/ha	60 kg N/ha	120 kg N/ha
2,4-D (0.8 kg a.i./ha) fb hand weeding	1.8 a	2.7 a	3.0 a	1.3 c	2.5 a	2.2 ab
Butachlor (2 kg a.i./ha) fb hand weeding	1.6 a	2.6 a	2.9 ab	1.8 a	2.0 b	2.0 ab
2,4-D (0.8 kg a.i./ha) fb propanil (3 kg a.i./ha)	1.6 a	2.2 b	2.6 bc	1.6 ab	2.1 b	2.4 a
1 weeding	1.1 b	1.6 c	2.6 bc	1.6 ab	1.7 c	2.0 ab
Butachlor (2 kg a.i./ha)	1.9 a	1.6 c	2.4 c	1.5 ab	1.0 d	1.6 c
No weeding	0.4 c	0.0 d	0.0 d	0.0 d	0.0 e	0.0 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.

Table 32. Nitrogen uptake of rice and weeds at 35 days after crop emergence (DE), as affected by nitrogen levels and method of weed control.[a] IRRI, 1981 wet season.

N level (kg/ha)	Weed control method[b]	Nitrogen uptake (kg/ha)		
		Rice	Weeds	Difference
0	No weeding	24.2 a	5.8 a	18.4*
	2 weedings (14 fb 35 DE)	19.8 a	0.0 a	19.8*
35	No weeding	21.7 a	10.9 a	10.8
	2 weedings	24.2 a	0.0 a	24.2**
65	No weeding	29.5 a	11.2 a	18.3*
	2 weedings	28.3 a	0.0 a	28.3**
100	No weeding	13.4 b	15.0 a	1.6
	2 weedings	40.8 a	0.0 b	40.8**

[a] Av of 3 replications. Separation of means in a column, within each nitrogen level, by Duncan's multiple range test at the 5% level. [b] fb = followed by.

weeds. At the highest nitrogen level, there was no significant difference between nitrogen taken up by rice and weeds. This was reflected in yield. Weeds caused a significant reduction in yield at the highest nitrogen level; when no nitrogen was applied, yield differences were not significant.

The major weeds in transplanted rice at 35 DT were *C. rotundus*, *F. littoralis*, *E. colona*, and *Ludwigia octovalvis*. The coefficient of similarity of weed flora growing with dry-seeded rice and transplanted rice was 45.0.

Weed weights in the transplanted rice crop were unaffected by previous nitrogen levels and weed control treatments applied to dry-seeded crop had no residual effect on the weed flora in the transplanted crop.

Yields of transplanted rice did not differ significantly with weed control method or nitrogen level used in the dry-seeded crop. Weeding in the transplanted crop resulted in a significant yield increase.

Evaluation of farmers' weed control practices. In Alcala-Amulung, hand weeding was done 15 and 30 DT in 6 randomly selected irrigated fields planted to IR36. The average yield increase of 0.5 t/ha (0-1.2 t/ha), was equivalent to 13.3% of the yield obtained by the farmer.

In a similar trial in Solana, in 5 rainfed fields planted to traditional cultivar Wagwag, the average yield increase of 0.9 t/ha was equivalent to 69% of the yield obtained by the farmer.

Yields in farmers' fields using traditional weed control practices were higher in Alcala-Amulung (3.9 t/ha) than in Solana (1.3 t/ha). A higher level of weed control is used in the irrigated area than in the rainfed area. Only one farmer in the irrigated area did no weeding; only one of the five farmers in the rainfed area did.

Weed control in mungbean before rice. The major weed in the Solana, Cagayan Valley, experimental area was *E. colona*. At 20 DE, the best weed control method was hand weeding (Table 33). All weed control treatments reduced dry weight of weeds significantly. All weed control treatments, except interrow cultivation and one hoe weeding, gave yields that were significantly higher than the unweeded check. The highest yields and the greatest returns to weeding were with interrow cultivation followed by hand weeding and two hand weedings. Returns from one hand weeding, the practice used by the majority of the farmers, were considerably lower. The lowest returns to weeding were with treatments that yielded the lowest.

Effect of tillage on weed growth. Farmers in Solana, Cagayan Valley, frequently plant mungbean using zero tillage. Zero-tillage plots had greater weed growth than conventional tillage (two plowings and three harrowings) (204 vs 124 g/m^2), and they had a different composition of weed flora. Major weeds in the zero-tillage plots were *C. dactylon*, 62% of weed weight; *E. colona*, 15%; and *C. rotundus*, 10%. Major weeds in conventional-

Table 33. Effect of method of weed control on weed weight, mungbean yield, and returns to weeding.[a] Solana, Cagayan, Philippines, 1981 wet season.

Treatment[b]	Time of application[c] (DE)	Weed wt 20 DE (g/m^2)	Yield (t/ha)	Return to weeding ($)
Interrow cultivation fb hand weeding	13 fb 21	17.6 b	1.8 a	499
2 hand weedings	13 fb 21	5.2 c	1.8 a	503
1 hand weeding	13	5.4 c	1.5 bc	375
Hoe weeding fb hand weeding	13 fb 21	27.6 b	1.5 bc	264
2 hoe weedings	13 fb 21	21.8 b	1.4 cd	310
Butachlor (1 kg a.i./ha) fb hoe weeding	PE fb 21	28.4 b	1.4 cd	310
Butachlor (1 kg a.i./ha)	PE	24.2 b	1.3 cd	260
Interrow cultivation	13	23.2 b	1.2 de	201
1 hoe weeding	13	20.0 b	1.2 de	193
Unweeded	–	63.2 a	0.9 e	–

[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. [c] DE = days after emergence, PE = preemergence.

tillage plots were *E. colona*, 59%; *Melochia* sp., 15%; and *C. rotundus*, 10%. *C. dactylon* accounted for only 2% of total weed weight.

Yields were higher in weeded conventional-tillage plots (1.2 t/ha) than in weeded zero-tillage plots (0.7 t/ha). In conventional-tillage plots weeds caused a significant yield reduction. But in zero-tillage plots, despite their higher weights, weeds had no effect on yields. This could be attributed to the predominance, in conventional-tillage plots, of the annual *E. colona*, which is taller and more competitive for light than the perennial *C. dactylon*, which was predominant in zero-tillage plots.

Competitive ability of mungbean cultivars. Eight mungbean cultivars were tested for competitive ability against weeds in the early 1980 dry season. Dominant weed species in the experimental area were *C. rotundus* and *Digitaria* spp.

There was no significant difference in the competitive abilities of cultivars against weeds, based on total weed weight at harvest. Average weed weight in unweeded plots at harvest was 149 g/m^2.

Weed competition caused a significant reduction in yield, number of pods per plant, pod length, and number of seeds per pod. It significantly reduced the weight of 100 seeds in 4 cultivars (Table 34) but not in others. In the 1980 wet season (Annual report for 1981), pod length, number of seeds per pod, and weight of 100 seeds were unaffected by weed competition.

As in the wet season, weeds caused a significant yield reduction in all cultivars except CES ID-21.

Competitive ability of rice cultivars. Two tall traditional (Binato and Peta) and two short modern (IR32 and IR52) rice cultivars were tested under transplanted irrigated conditions for competitive ability against a mixed weed community. The dominant weed species in the experimental area was *E. glabrescens*. Other weeds were *Scirpus maritimus*, *M. vaginalis*, *C. difformis*, and *Scirpus supinus*.

Dry weed weights were unaffected by rice cultivar at all sampling dates. Maximum weights of *E. glabrescens*, *S. supinus*, and *M. vaginalis* were recorded at 6 weeks after transplanting (WT), those of other weed species at 9 WT. Weeds were most competitive with rice cultivars between 6 and 9 WT.

Weed competition significantly reduced tiller number, leaf area index (LAI), and plant dry matter. Except at 3 WT, crop growth rate in all cultivars was reduced by weed competition (Fig. 4). Crop growth rate was greatest at 9 WT and it increased most rapidly between 6 and 9 WT, when weeds were most competitive.

Table 34. Weight of 100 seeds of mungbean cultivars, as affected by degree of weeding.[a] IRRI, 1980 dry season.

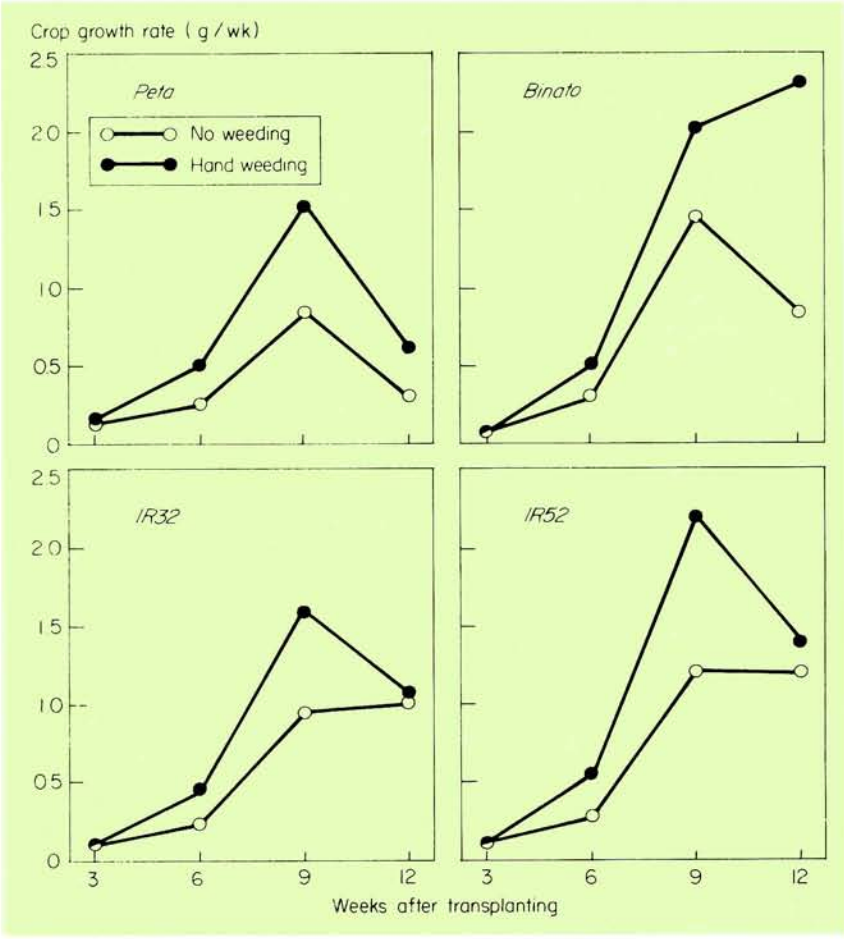
Cultivar	100-seed wt (g)		
	No weeding	1 weeding	2 weedings
Bhacti	6.52 b	7.32 a	7.01 ab
EG Glabrous #3	6.40 b	7.01 a	7.10 a
CES 14	6.26 a	6.41 a	6.45 a
CES 55	6.20 b	7.26 a	7.38 a
EGMG-174-3	5.90 b	6.75 a	6.63 a
CES 1D-21	5.11 a	5.14 a	4.81 a
CES IT-2	4.31 a	4.13 a	3.77 a
CES X-10	4.03 a	4.31 a	4.12 a

[a] Av of 3 replications. Separation of means in a row by Duncan's multiple range test at the 5% level.

Even though weed weights did not differ significantly among cultivars, the cultivars responded differently to weed competition. Reduction in yield due to weeds was not significant in the tall cultivars; yield losses in the short cultivars were significant (Table 35). Probably, because functional leaves of tall cultivars are above the weed canopy, photosynthetic activity was not affected by shading. Short cultivars suffered from shading. Also, modern cultivars that mature earlier had weed competition for a proportionately longer time than tall cultivars. Thus, the tall, longer growth duration cultivars had a longer period to compensate for weed competition.

Response of weed species to flooding. *Melochia concatenata*. Seeds of *M. concatenata* planted in pots in the greenhouse were subjected to different watering regimes. Soil was kept well drained, saturated, or flooded to depths of 2, 4, and 6 cm at 0, 7, 14, 21, and 28 DE.

When flooding occurred immediately after planting, no seeds germinated. Flooding 7 DE significantly reduced plant survival (Table 36). More plants survived at shallower flooding depths but differences were not significant. At 14 DE, flooding at 2 cm had no effect on plant survival. With deeper flooding depths, plant survival was significantly



4. Crop growth rate of different rice cultivars at different stages of crop growth as affected by weeding regime (av of 4 replications). IRRI, 1981 dry season.

lower. Later flooding had no effect on plant survival.

Flooding at 7 and 14 DE resulted in a significant reduction in plant height. Later flooding had little effect on plant height.

Shoot and root dry weights of surviving plants were not significantly affected by time or depth of flooding.

Cyperus rotundus. Tubers collected from upland and lowland fields in Iloilo and placed in soil in trays in the IRRI greenhouse were kept flooded with 6 cm water for 0, 30, 60, 90, and 120 days, then grown under well-drained conditions for 1 month.

Emergence of upland tubers was significantly reduced by length of submergence; emergence of lowland tubers was unaffected (Table 37). Significantly more upland tubers planted immediately after collection emerged. After 30 days' submergence, there was no significant difference in emergence between collection sites. Significantly less upland tubers emerged when the length of submergence was 60 days or longer.

Length of submergence had no effect on number of shoots produced per plant. Significantly fewer off-shoots were produced by upland tubers as

Table 35. Grain yield of rice cultivars, as affected by weeding regime.[a] IRRI, 1981 dry season.

Cultivar	Grain yield (t/ha)		
	Hand weeding	No weeding	Difference
Peta	2.05 b	1.62 ab	0.44
Binato	2.67 b	2.05 a	0.61
IR32	4.32 a	0.80 b	3.52**
IR52	4.57 a	1.45 ab	3.12**

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

Table 36. Survival of *Melochia concatenata* as affected by time and depth of flooding.[a] IRRI, 1981 wet season.

Time of flooding (DE[b])	Survival (%) at depth of		
	2 cm	4 cm	6 cm
0	0.0 c	0.0 d	0.0 c
7	27.5 b	17.5 c	7.5 c
14	95.0 a	52.5 b	42.5 b
21	97.5 a	100.0 a	95.0 a
28	100.0 a	92.5 a	95.0 a

[a]Av of 4 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]DE = days after emergence.

length of submergence increased. Lowland tubers had no reduction in off-shoot production with increasing submergence.

Plants produced by lowland tubers were significantly taller than those produced by upland tubers. Length of submergence had no effect on height of plants produced by upland tubers. Variation in height of plants produced by lowland tubers was not related to length of submergence. The tallest plants were produced by tubers that had been submerged for 90 days and the shortest by those that had not been submerged.

Shoot, tuber, root, and total dry weight of plants produced by lowland tubers were significantly larger than those of plants produced by upland tubers. Shoot dry weight and total dry weight decreased significantly as length of submergence increased.

Echinochloa colona. Seeds of 12 ecotypes of *E. colona* collected from different areas in the Philippines were subjected to different depths of flooding. Variations in germination were observed among ecotypes and between watering regimes. At all depths of water except 12 cm, germination was highest with the IRRI ecotype with a green seed coat (78%) and lowest with the Batangas ecotype (24%). At 12-cm water depth, germination was highest with the Zamboanga del Sur ecotype. Increasing water depth resulted in a significant reduction in germination of all ecotypes except those collected in Cagayan Valley, Leyte, Bukidnon, Zamboanga del Sur, and IRRI (red seed coat).

When flooding was done 10 days after seeding, heights of surviving plants were not significantly reduced by 4-cm water depth (Table 38). Significant reductions in plant height were observed for 5 ecotypes when water was 8 cm deep and plant heights of all ecotypes, except the one collected in Pangasinan, were significantly reduced at 12-cm water depth.

Effect of herbicides on azolla. All herbicides used were deleterious to azolla that had been inoculated into plots immediately after transplanting, causing a significant reduction in fresh weight at 30 DT (Table 39). With herbicide application at 4 DT, 2,4-D caused the least reduction in growth; with application at 21 DT, propanil was more detrimental.

It appears that herbicides are counterproductive for weed control when rice is to be inoculated with azolla. Weeds will have to be controlled by other means, such as by the suppressive effect of azolla itself, by hand weeding, or by rotary weeding — which can also be used to incorporate azolla into the soil.

Interaction between weeds and rats. Rat damage in transplanted rice grown on a rainfed, bunded toposequence was more severe in weedy than in weed-free plots. There was a highly significant correlation between rat damage and dry weed weight at harvest. Rats damaged weedy plots first, moving to adjacent weeded plots when the food supply in the weedy plots was exhausted. However, rat damage varied from field to field, even in adjacent fields.

Rat damage resulted in an overestimation of yield loss due to weeds. In some instances, rats completely destroyed the weedy check crop, leav-

Table 37. Effect of length of submergence on *Cyperus rotundus* (*F* tests for all parameters measured).[a] IRRI, 1981 wet season.

Parameter	Emergence (%)	Shoots (no.)	Offshoots (no.)	Plant ht (cm)	Dry wt (g)			
					Shoot	Root	Tuber	Total
Ecotype (C)	**	ns	ns	**	**	*	**	**
Length of submergence (D)	**	ns	ns	ns	**	ns	ns	*
C x D	**	ns	*	**	ns	ns	ns	ns

[a]ns = not significant.

Table 38. Effect of depth of flooding on plant heights of *Echinochloa colona* ecotypes 20 days after seeding.[a] IRRI, 1981 wet season.

Ecotype	Plant ht (cm)			
	0 cm	4 cm	8 cm	12 cm
Cagayan Valley	19.0 a	15.7 ab	13.2 b	8.1 c
Pangasinan	21.8 a	21.2 a	21.5 a	18.2 a
Nueva Ecija	20.0 a	19.7 a	17.9 a	9.0 b
IRRI (green[b])	16.0 a	15.2 a	12.3 ab	9.5 b
IRRI (red[b])	17.8 a	16.4 a	14.1 ab	10.4 b
Batangas	17.1 a	15.4 a	9.0 b	7.3 b
Camarines Sur	16.3 a	17.5 a	16.5 a	8.3 b
Iloilo	22.3 a	21.3 a	18.0 ab	13.3 b
Leyte	16.8 a	15.3 a	10.2 b	9.2 b
Bukidnon	17.3 a	15.3 a	7.8 b	7.7 b
Zamboanga del Sur	13.4 a	11.7 a	13.1 a	7.8 b
South Cotabato	21.7 a	18.6 a	11.4 b	11.5 b

[a]Av of 4 replications. Separation of means in a row by Duncan's multiple range test at the 5% level. [b]Color of seed coat.

Table 39. Fresh weight of azolla 30 days after transplanting, as affected by herbicide application.[a] IRRI, 1980 wet season.

Treatment[b]	Rate of application (kg a.i.[c]/ha)	Time of application (DT[d])	Azolla fresh wt (g/m^2)
Thiobencarb	1.0	4	478.0 d
Propanil	3.0	21	536.3 d
Piperophos - 2,4-D	1.5	4	667.7 cd
Butachlor	1.0	4	814.3 cd
2,4-D liquid	0.5	21	1420.6 bc
2,4-D granular	0.8	4	1660.3 b
Untreated	–	–	2840.0 a

[a]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [b]A spaced dash (–) indicates that the herbicides were formulated as a proprietary mixture. [c]Active ingredient. [d]Days after transplanting.

ing no basis for comparison in experiments of improved weed control technology.

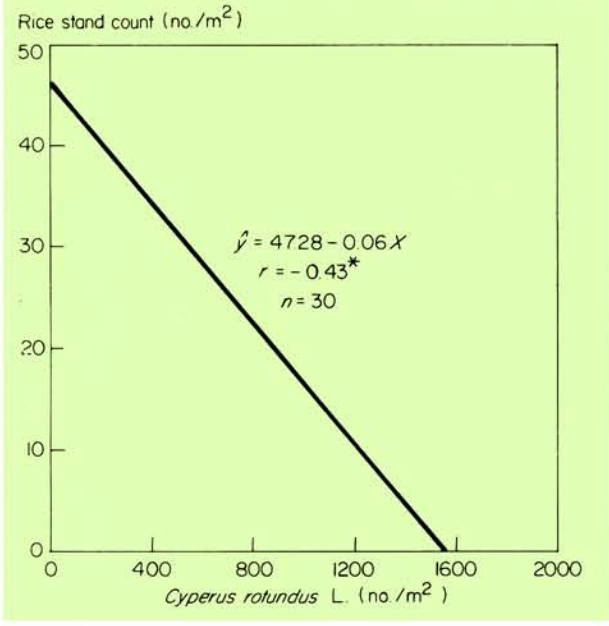
Allelopathy between rice and weeds. A possible instance of allelopathy between rice and weeds was observed in dry-seeded rainfed rice at IRRI. One week after rice emergence there was a negative linear relationship between rice stand count and *C. rotundus* density (Fig. 5). As the density of *C. rotundus* increased, the rice stand decreased. Further studies are planned.

Herbicide screening in upland crops. New preemergence herbicides were evaluated in some upland crops during the wet season. The principal weeds were *Rottboellia exaltata* and *Echinochloa colona*. Weeds were sampled for dry matter yield at flowering.

All herbicides adequately controlled *E. colona*. Only pendimethalin, PPG 844, and MC 10108 provided reasonable control of *R. exaltata* (Table 40). Alachlor, butachlor, and thiobencarb were ineffective.

Because of shading by tall maize and leafy mungbean plants, *R. exaltata* infestations on those plots did not vary significantly among herbicide treatments, and weed population in untreated plots was minimal. Consequently, there were no significant yield increases in maize and mungbean due to treatment (Table 41).

R. exaltata incidence was high in plots planted to less competitive soybean and peanut crops. Weed weights were numerically very high in untreated soybean and peanut plots and in plots treated with



5. Effect of *Cyperus rotundus* density on stand of dry-seeded rice 1 week after emergence. IRRI, 1980 wet season.

alachlor, butachlor, and thiobencarb. As a result, peanut yields in plots treated with those herbicides and in the untreated control plots were significantly lower than yields in plots with the other treatments. Soybean yields did not differ significantly among herbicide treatments and between herbicide treatments and untreated control. Yields in plots treated with PPG 844, pendimethalin, and MC 10104 were comparable to yields in hand-weeded plots and, in general, were higher.

Mungbean and soybean were slightly to moderately susceptible to MC 10108 and pendimethalin. Mungbean was very slightly damaged by alachlor and butachlor. Soybean was slightly damaged by PPG 844. Maize and peanut were tolerant of all herbicides.

HERBICIDE APPLIED RESEARCH TRIAL

Rice Production Training and Research Department

Yields from trials at both sites in Pangasinan showed no difference among treatments. All treatment plots performed better than the unweeded control (Table 42). In South Cotabato, plots treated with pendimethalin fb oxadiazon had the

Table 40. Effects of new preemergence herbicides on weed control and on tolerance of upland crops. IRRI, 1981 wet season.

Treatment	Rate (kg a.i.[a]/ha)	Weed wt[b] (g/m²)				Visual toxicity rating[c]			
		Maize	Mungbean	Soybean	Peanut	Maize	Mungbean	Soybean	Peanut
2 hand weedings	check	3 a	1 a	1 a	10 a	0	0	0	0
PPG 844	1.0	4 a	4 a	128 bc	268 b	0	0	2	0
Pendimethalin	2.0	1 a	5 a	45 ab	12 a	0	6	4	0
MC 10108	0.5	18 ab	47 ab	57 bc	362 b	0	3	3	0
Butachlor	2.0	43 ab	177 ab	457 c	465 b	0	2	0	0
Alachlor	2.0	50 ab	73 ab	330 c	440 b	0	2	0	0
Thiobencarb	3.0	80 ab	42 ab	202 bc	653 b	0	0	0	0
Untreated check	–	86 b	214 b	404 c	262 b	0	0	0	0

[a]Active ingredient. [b]Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. [c]Rated 1 week after crop emergence on a scale of 0-10: 0 = no toxicity and 10 = complete kill.

Table 41. Effects of preemergence liquid herbicides on grain yield of upland crops grown under rainfed condition. IRRI, 1981 wet season.

Treatment	Rate (kg a.i.[a]/ha)	Yield[b] (t/ha)			
		Maize	Mungbean	Soybean	Peanut
2 hand weedings	check	2.9 a	1.6 a	1.1 a	1.8 a
PPG 844	1.0	2.8 a	1.5 ab	0.8 abc	1.1 b
Pendimethalin	2.0	2.9 a	1.1 ab	0.8 abc	1.3 ab
MC 10108	0.5	1.8 a	1.4 ab	0.9 ab	0.9 b
Butachlor	2.0	2.4 a	1.1 ab	0.1 d	0.8 c
Alachlor	2.0	2.7 a	0.9 b	0.4 cd	0.4 c
Thiobencarb	3.0	1.8 a	1.4 ab	0.4 bcd	0.2 c
Untreated	–	2.5 a	1.2 ab	0.6 bcd	0.2 c

[a] Active ingredient. [b] Av of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level.

Table 42. Grain yields of IR36 in plots direct-seeded in dry soil at the start of the rainy season and treated with 8 different herbicides and herbicide combinations, compared with those in hand-weeded plots and the unweeded control, 1981 wet season.

Treatment	Grain yield[a] (t/ha)			
	Koronadal, South Cotabato	Malasiqui, Pangasinan	Ajuy, Iloilo	Pangasinan
Butachlor	4.2 bc	5.8 a	3.5 b	4.4 ab
Pendimethalin fb 1 hand-weeding	4.3 bc	5.6 a	3.8 b	3.8 ab
Pendimethalin fb 2,4-D	3.6 d	6.0 a	4.3 ab	4.3 ab
Pendimethalin fb oxadiazon	6.4 a	5.5 a	5.3 ab	4.1 ab
Propanil	3.9 cd	5.4 a	5.4 ab	4.7 a
Butachlor + propanil	4.0 cd	5.5 a	4.2 ab	4.0 ab
Thiobencarb + propanil	3.9 cd	6.3 a	4.3 ab	3.8 ab
Pendimethalin + propanil	4.6 b	5.9 a	4.5 ab	3.5 ab
3 hand weedings	4.7 b	5.7 a	6.0 a	4.5 ab
Unweeded control	1.6 e	1.6 b	1.3 c	3.2 b

[a] Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level.

highest yield (6.4 t/ha), better than the hand-weeded control (4.7 t/ha). Yields from other treatments were similar. In Iloilo, the highest yield was from the hand-weeded control plot (6.0 t/ha); the lowest yield was from the unweeded control (1.3 t/ha). Yields from all plots with chemical treatment were better than those from the unweeded control but lower than those from the hand weeded; they ranged from 3.5 t/ha for butachlor to 5.4 t/ha for propanil.

Cropping systems program

Selecting and testing cultivars for rice-based cropping patterns

Multiple Cropping, Plant Breeding, and Rice Production Training and Research Departments and Deepwater Rice Project-Thailand

RICE VARIETY YIELD TRIALS **458**
- Early-maturing dry-seeded rice **458**
  - Stratum 1, first planting **458**
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RICE VARIETY YIELD TRIALS

Multiple Cropping Department

The identification of rice varieties with higher yield potential than local varieties has the highest priority at the Solana test site. In 1981 variety testing was emphasized.

Early-maturing dry-seeded rice. *Stratum 1, first planting*. Yields ranged from 3.92 to 0.75 t/ha (Table 1). Two entries yielded 28 and 20% higher than the local variety Wag-wag-aga although yields were not significantly different. The advantage, in kilograms per day, of the two highest yielders favors an earlier maturing variety to the farmer's variety if crop intensification is to be considered. IR4829-89-2 and IR9830-26-3-3 had yield advantages of 13.74 and 14.02 kg/day.

Regression analysis showed that 53% of the yield variation was due to number of tillers per linear meter, height, and number of days to maturity. Diseases, insects, lodging, seedling vigor, and wind damage did not correlate with yield.

Stratum 1, second planting. The same cultivars seeded 34 days later had a 49% yield advantage. IR9830-26-3-3 (3.53 t/ha) and IR4829-89-2 (3.92 t/ha) gave consistently high yields regardless of planting date.

Diseases, insects, and lodging correlated negatively with yield. Regression analysis showed that at least 43% of yield differences could be accounted for by tiller number, height, and maturity.

Average yields between the first and second plantings showed a significant relationship (r = 0.4495) (Fig. 1). This indicates that the performances of the most promising entries were stable enough to warrant trials on dry-seeded rice with only one planting.

Stratum 1, ratoon crop. All varieties were tested for ratoon potential. Only the ratoon crop of the early planting produced grain. Two entries failed to produce any ratoon yield (Wag-wag-aga and Hashikalmi). Average yield was 0.82 t/ha. Four introduced cultivars and a recommended variety gave yields of more than 1 t/ha (Table 2). Simple linear correlation analysis showed that average yield of the main crop had no significant effect on ratoon yield (r =0.2504).

Stratum 2, first planting. Yields averaged 2.72 t/ha and ranged from 0.60 to 3.84 t/ha. IR9830-26-3-3 and IR13429-150-3-2-1-2 outyielded IR52, the recommended check. IR9830-26-3-3, the top yielder in stratum 1, outyielded farmers' variety Wag-wag-aga by 36% and had a 54% yield advantage over IR36 and 12% over IR52 (Table 3).

Stratum 2, second planting. Yields ranged from 1.67 t/ha for Hashikalmi to 3.34 t/ha for IR52. IR9830-26-3-3 ranked sixth (3.16 t/ha); IR13429-150-3-2-1-2, third (3.28 t/ha); and IR21015-174-3-3, second (3.31 t/ha). Average yields of the 7 highest yielders were 8% higher than the yield of Wag-wag-aga and 66% higher than that of RD19.

Early transplanted rice. *Stratum 2, first planting*. Average yields of transplanted rice (TPR) cultivars were 16% higher than the first planting of dry-seeded rice (DSR) and 12% higher than the second planting in the same stratum. IR9752-1-2-1 gave the highest yield (3.99 t/ha) and Hashikalmi the lowest (2.12 t/ha). Four promising entries closely followed IR9752-1-2-1: IR19728-6-3-2-2-3 (3.77 t/ha), IR8608-167-1-2 (3.61 t/ha), IR19728-8-3-2-3-3 (3.57 t/ha), and IR9729-67-3 (2.54 t/ha). The top 5 yielders gave 7-23% yield advantages over IR52, IR46, RD19, and Wag-wag-aga (Table 3).

Stratum 2, second planting. IR46 (4.54 t/ha) and IR52 (3.94 t/ha) were the two highest yielders. IR46 had a yield advantage of 45% over IR9752-1-2-1 and 53% over IR19791-12-1-2-2-2, the highest yielders in the first planting, and a 51% yield advantage over Wag-wag-aga and 87% over RD19 (Table 4).

Midseason transplanted rice. *Stratum 2, first planting*. Yields averaged 2.17 t/ha and ranged from 0 to 3.24 t/ha. Habiganj Aman 1 was not harvested because of grain spoilage after flooding. Only IR10781-75-3-2 and C168 yielded more than 3 t/ha. The highest yielder among the check cultivars was IR46 (2.80 t/ha), followed by UPL Ri 3 (2.60 t/ha) and IR52 (2.59 t/ha).

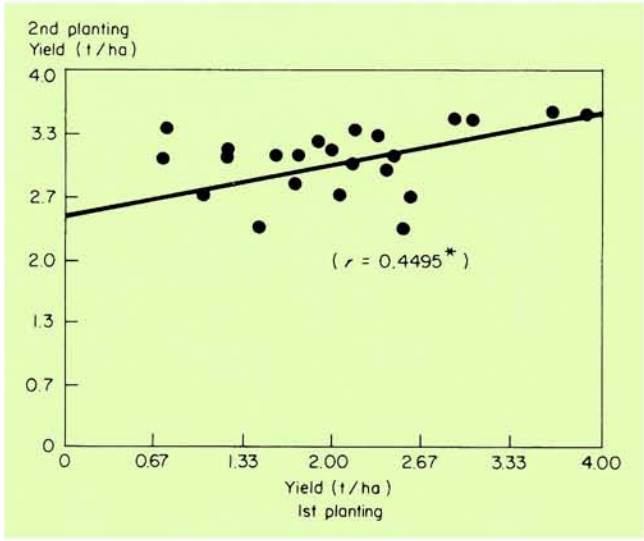
Stratum 2, second planting. Performance of the same cultivars was comparatively low, with an average yield difference of 49% from the first planting. Wag-wag Tawataw, which ranked 26th in the 1st planting, ranked third with 2.19 t/ha. Its yield was 14% lower than that of BR10 and 3% lower than that of C186. IR52, the recommended check variety, ranked fourth with 2.15 t/ha (Table 5).

Combined regression analysis of first- and second-planting yields indicates a significant relationship (r = 0.4500) (Fig. 2).

Table 1. Yield and agronomic parameters of 18 early-maturing and 4 check cultivars evaluated under rainfed dry-seeded condition at 2 planting dates, stratum 1, Solana, Cagayan, Philippines, 1981 wet season.[a]

Cultivar	Yield (t/ha)			Plant ht (cm)			Productive tillers/mm			Lodging rating[b]		
	1st	2nd	Av	1st	2nd	Av	1st	2nd	Av	1st	2nd	Av
IR4829-89-2	3.92 a	3.52 a	3.72	107.0 b	90.0 c	98.5	68 bcd	87 abc	78	1.7 ef	3.0 b	2.4
IR9830-26-3-3	3.66 a	3.53 a	3.60	91.7 c	85.3 cde	88.5	83 ab	99 a	91	1.0 f	1.0 c	1.0
Wag-wag-aga (check)	3.06 ab	3.46 a	3.26	152.0 a	147.3 a	149.6	70 bcd	58 d	64	9.0 a	3.0 b	6.0
IR21015-182-3-2	2.39 bc	3.47 a	2.91	82.0 efgh	83.7 cde	82.9	74 abcd	90 abc	82	3.0 de	1.0 c	2.0
IR21015-210-2-1	2.34 bcd	3.31 ab	2.83	84.7 def	82.3 cde	83.5	75 abcd	91 abc	83	1.0 f	1.0 c	1.0
IR13429-150-3-2-1-2	2.18 bcde	3.36 a	2.77	83.3 defg	75.0 de	79.2	81 abc	92 ab	87	1.0 f	2.3 bc	1.7
IR15496-219-2-3-2	2.45 bc	3.09 ab	2.77	81.7 efgh	75.0 de	78.4	79 abc	104 a	92	1.0 f	1.0 c	1.0
IR52 (check)	2.42 bc	2.96 ab	2.69	92.0 c	84.3 cde	88.2	98 a	92 abc	95	1.0 f	2.3 bc	1.7
IR13471-23-2-1-3-2-2	2.59 bc	2.65 ab	2.62	75.3 ijk	80.7 cde	78.0	84 ab	98 a	91	5.7 b	1.7 bc	3.7
IR9761-19-1	2.17 bcde	3.01 ab	2.59	74.3 jk	81.0 cde	77.7	87 ab	86 abc	87	2.3 def	1.0 c	1.7
IR13240-82-2-3-2-3-1	2.0 bcde	3.16 ab	2.58	71.3 kl	84.0 cde	77.7	72 abcd	105 a	89	1.0 f	1.0 c	1.0
IR21015-180-3-3	1.90 cde	3.24 ab	2.57	86.7 cde	87.3 cd	87.0	74 abcd	96 abc	85	1.7 ef	1.7 bc	1.7
IR9129-209-2-2-2-3	2.54 bc	2.31 b	2.43	76.7 hijk	84.0 cde	80.4	72 abcd	86 abc	79	3.7 cd	2.3 bc	3.0
IR8608-298-3-1-1-2	1.75 cdef	3.08 ab	2.42	76.7 hijk	83.7 cde	80.2	91 ab	99 a	95	5.0 abc	1.7 bc	3.4
IR21015-174-3-3	2.06 bcde	2.70 ab	2.38	88.7 cd	86.0 cde	87.4	70 bcd	88 abc	79	1.0 f	1.7 bc	1.4
IR21015-121-2-2	1.59 cdef	3.11 ab	2.35	92.0 c	89.3 c	90.7	83 abc	99 a	91	1.7 ef	2.3 bc	2.0
Chandina	1.73 cdef	2.81 ab	2.27	66.7 l	73.7 e	70.2	91 ab	88 abc	90	2.3 def	1.7 bc	2.0
IR36 (check)	1.23 def	3.13 ab	2.18	61.3 m	75.0 de	68.2	80 abc	92 abc	86	1.0 f	2.3 bc	1.7
IR8608-139-1-1-3	1.23 def	3.08 ab	2.16	78.3 ghij	89.0 c	83.7	49 d	87 abc	68	3.0 de	1.7 bc	2.4
IR9209-217-1-2-2	0.77 f	3.38 a	2.08	77.0 jk	85.0 cde	81.0	73 abcd	82 abc	78	1.7 ef	1.7 bc	1.7
IR19575-85-2-2-3	0.75 f	3.07 ab	1.91	75.0 ijk	81.3 cde	78.2	73 abcd	89 abc	81	9.0 a	1.0 c	5.0
RD 19 (check)	1.48 cdef	2.34 b	1.91	109.3 b	107.7 b	108.5	73 abcd	69 bcd	71	1.0 f	9.0 a	5.0
IR13384-79-2	1.04 ef	2.69 ab	1.87	79.3 fghij	78.7 cde	79.0	89 ab	105 a	97	1.7 ef	2.7 b	2.2
Hashikalmi	0.76 f	1.16 c	0.96	81.0 efghi	83.0 cde	82.0	56 cd	66 cd	61	9.0 a	9.0 a	9.0
Av	2.00	2.98	2.49	85.0	103.0	85.8	77	90	83	4.5	2.4	2.7
CV(%)	19.30	17.12	—	3.7	4.0	—	17.8	15.0	—	29.7	25.3	—

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Maturities ranged from 94 to 121 days for the early maturing and 106 to 164 days for the check cultivars. [b]0 = no lodging, 9 = all plants lodged.



1. Relationship between yield of 24 dry-seeded rice cultivars during the 1st and 2nd planting, stratum 2, Solana, Tuguegarao, Cagayan, Philippines, 1981 wet season.

Table 2. Ratoon yield and plant height of 18 early-maturing and 4 check cultivars evaluated under rainfed dry-seeded condition, 1st planting, stratum 1, Solana, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

Yield rank	Cultivar	Yield (t/ha)	Maturity[b] (days)	Plant ht (cm)
1	IR13471-23-2-1-3-2-2	1.37 a	124 f	65.7 bc
2	IR13129-150-3-2-1-2	1.23 ab	142 cde	60.7 cd
3	IR21015-180-3-3	1.16 abc	136 def	68.3 ab
4	IR21015-174-3-3	1.14 abcd	142 cde	62.7 bcd
5	IR52 (check)	1.04 abcde	136 def	63.7 bcd
6	IR21015-210-2-1	0.92 bcdef	139 cde	63.0 bcd
7	IR21015-121-2-2	0.87 bcdef	142 cde	65.3 bcd
8	IR36 (check)	0.83 bcdef	136 def	53.0 gh
9	IR9761-19-1	0.82 bcdef	124 f	60.7 cd
10	IR13384-79-2	0.81 bcdef	136 def	61.0 cd
11	IR9830-26-3-3	0.79 cdef	142 cde	61.7 cd
12	IR8608-298-3-1-1-2	0.76 cdef	124 f	63.0 bcd
13	IR4829-89-2	0.72 cdef	151 bc	73.7 a
14	IR9129-209-2-2-2-3	0.71 def	124 f	59.3 cdef
15	RD 19 (check)	0.70 def	157 b	51.3 h
16	IR8608-139-1-1-3	0.70 def	130 ef	59.7 cde
17	IR13240-82-2-3-2-3-1	0.66 ef	142 cde	53.3 fgh
18	IR15496-219-2-3-2	0.63 ef	145 cd	53.7 efgh
19	IR21015-182-3-2	0.60 ef	124 f	54.3 efgh
20	IR9209-217-1-2-2	0.54 f	160 b	59.0 defg
21	Chandina	0.52 f	124 f	52.0 h
22	IR19575-85-2-2-3	0.51 f	160 b	61.7 cd
23	Wag-wag-aga[c] (check)	–	–	–
24	Hashikalmi[c]	–	–	–
	Av	0.82	138	60.3
	CV (%)	17.29	16.0	5.5

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]Recorded from the day after the main crop emergence. [c]Produced no ratoon.

Table 3. Yield and agronomic characteristics of 18 early-maturing and 4 check cultivars evaluated under rainfed dry-seeded conditions, 1st and 2nd planting, stratum 2, Solana, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

Yield rank	Cultivar	Yield (t/ha)			Plant ht (cm)			Seedling vigor[b]		
		1st	2nd	Av	1st	2nd	Av	1st	2nd	Av
1	IR9830-26-3-3	3.84 a	3.16 abcd	3.50	91.3 c	92.3 d	91.8	2.3 ab	2.3 efg	2.3
2	IR13429-150-3-2-1-2	3.67 ab	3.28 ab	3.48	79.3 ghijk	83.0 ghijk	81.2	3.0 ab	4.3 abcd	3.7
3	IR52 (check)	3.42 abcd	3.34 a	3.38	88.3 cdef	91.3 de	89.8	1.7 b	1.7 g	1.7
4	IR4829-89-2	3.35 abcde	3.23 abc	3.29	111.0 b	109.3 c	110.2	2.0 b	2.3 efg	2.2
5	IR21015-182-3-2	3.04 abcdefg	3.31 a	3.18	82.0 efghij	84.3 fghi	83.2	2.0 ab	1.7 g	1.9
6	IR21015-174-3-3	3.48 abc	2.67 abcde	3.08	89.0 cdef	92.3 d	90.7	3.7 ab	3.3 bcdefg	3.5
7	IR21015-180-3-3	3.28 abcdef	2.75 abcde	3.02	90.3 cd	92.3 d	91.3	2.7 ab	2.3 efg	2.5
8	IR8608-139-1-1-3	2.56 defgh	3.24 abc	2.90	83.7 cdefgh	87.7 defg	85.7	2.7 ab	2.0 fg	2.4
9	Wag-wag-aga (check)	2.82 bcdefgh	2.87 abcde	2.85	141.3 a	144.0 a	142.7	3.0 b	2.7 defg	2.9
10	IR13240-82-2-3-2-3-1	3.03 abcdefg	2.65 abcde	2.84	74.0 jk	78.3 kl	76.2	4.3 a	5.7 a	5.0
11	IR15496-219-2-3-2	2.87 bcdefgh	2.82 abcde	2.83	85.7 cdefg	87.3 defg	86.5	3.3 ab	4.7 abc	4.0
12	IR13471-23-2-1-3-2-2	2.50 efgh	2.96 abcde	2.73	81.7 efghij	83.7 ghij	82.7	1.7 b	2.0 fg	1.9
13	IR21015-210-2-1	2.82 bcdefgh	2.75 abcde	2.79	85.7 cdefg	89.0 def	87.4	2.3 ab	5.0 ab	3.7
14	IR36 (check)	2.49 efgh	2.84 abcde	2.67	74.7 ijk	74.0 l	74.4	1.7 b	1.7 g	1.7
15	IR9761-19-1	2.72 cdefgh	2.55 abcdef	2.64	81.0 fghijk	80.3 ijk	80.7	3.3 ab	2.7 defg	3.0
16	IR9209-217-1-2-2	2.42 fgh	2.84 abcde	2.63	82.3 defghi	87.0 efg	84.7	3.0 ab	4.0 abcde	3.5
17	IR21015-121-2-2	2.77 cdefgh	2.32 efg	2.55	89.3 cde	92.3 d	90.1	3.0 ab	3.0 cdefg	3.0
18	IR9129-209-2-2-2-3	2.20 gh	2.73 abcde	2.47	78.3 ghijk	78.7 jkl	78.5	2.0 b	2.0 fg	2.0
19	IR19575-85-2-2-3	2.40 fgh	2.42 def	2.41	80.0 ghijk	85.0 fghi	82.5	2.3 ab	2.3 efg	2.3
20	IR8608-298-3-1-1-2	2.30 gh	2.51 bcdef	2.41	81.7 efghij	80.3 ijk	81.0	2.3 ab	2.7 defg	2.5
21	Chandina	2.45 efgh	2.19 efg	2.32	73.3 k	74.3 l	73.8	2.0 b	3.7 bcdef	2.9
22	IR13384-79-2	2.15 gh	2.47 cdef	2.31	84.3 cdefgh	81.0 hijk	83.0	2.3 ab	3.0 cdef	2.7
23	RD 19 (check)	2.04 h	1.87 fg	1.96	115.3 b	120.3 b	117.8	1.7 b	2.3 efg	2.0
24	Hashikalmi	0.60 i	1.67 g	1.14	77.3 hijk	86.0 fgh	81.7	2.7 ab	3.7 bcdef	3.2
	Av	2.72	2.73	2.72	87.5	89.8	88.7	2.5	3.0	2.8
	CV (%)	16.87	14.68	–	4.8	3.1	–	22.2	13.7	–

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Maturities ranged from 94 to 121 days for the early cultivars and from 105 to 190 days for the check cultivars. [b]0 = good vigor, 9 = poor.

Table 4. Yield and agronomic parameters of 16 early maturing and 4 check cultivars evaluated under rainfed transplanted condition, 1st and 2nd planting, stratum 2, Solana, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

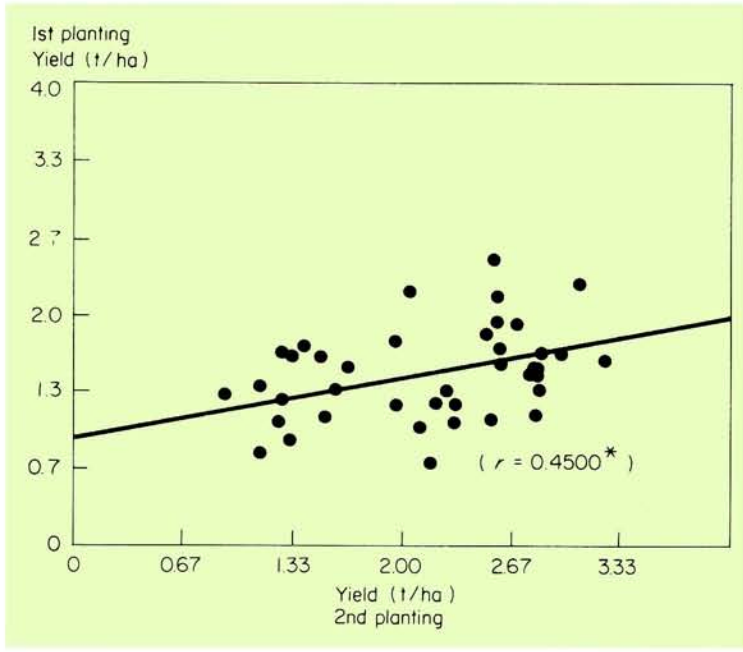
Yield rank (av)	Cultivar	Yield (t/ha)			Plant ht (cm)			Productive tillers/hill			Lodging rating[b]		
		1st	2nd	Av	1st	2nd	Av	1st	2nd	Av	1st	2nd	Av
1	IR46 (check)	3.35 abcde	4.54 a	3.95	93.5 c	101.9 bc	97.7	12 ef	12 abc	12	2.3 cd	3.0 cdef	2.7
2	IR52 (check)	3.46 abcd	3.94 ab	3.70	90.5 cd	97.2 cd	93.9	11 ef	11 bc	11	3.0 c	1.0 f	2.0
3	IR9729-67-3	3.54 abcd	3.70 abc	3.62	85.5 de	89.9 cdef	87.7	14 cdef	11 bc	13	2.3 cd	5.3 bcd	3.8
4	IR9752-1-2-1	3.99 a	3.14 bcd	3.57	87.0 de	89.6 cdef	88.3	11 ef	11 bc	11	6.3 b	1.7 ef	4.0
5	IR8608-167-1-2	3.61 abc	3.26 bcd	3.44	83.4 ef	84.8 defg	84.0	18 abcd	12 abc	15	1.0 d	4.3 bcdef	2.7
6	IR19728-6-3-2-2-3	3.77 ab	2.87 cd	3.32	83.3 ef	81.6 efg	82.5	14 def	10 bc	12	1.0 d	4.3 bcdef	2.7
7	IR19746-28-2-2-3	3.11 bcde	3.21 bcd	3.19	77.4 fg	83.1 efg	80.3	19 abcd	12 abc	16	1.0 d	6.3 abc	3.7
8	IR19728-8-3-2-3-3	3.57 abcd	2.66 d	3.12	82.7 ef	87.0 def	84.9	14 cdef	11 bc	13	3.0 c	7.7 ab	5.4
9	IR19791-12-1-2-2-2	3.21 bcde	2.96 bcd	3.09	74.9 gh	81.8 efg	78.4	19 abc	13 abc	16	1.0 d	1.7 ef	1.4
10	IR8455-78-1-3-3	3.08 bcde	2.96 bcd	3.02	85.1 de	87.4 def	86.3	18 abcd	12 abc	15	1.7 cd	1.7 ef	1.7
11	IR19819-31-2-3-1-1	3.19 bcde	2.83 cd	3.01	69.7 h	71.8 g	70.8	18 abcd	13 abc	16	1.0 d	2.3 def	1.7
12	IR19743-25-2-2-3-1	3.27 bcde	2.80 cd	3.01	80.7 efg	82.3 efg	81.5	17 abcde	13 abc	15	1.7 cd	1.0 f	1.4
13	Wag-wag-aga (check)	3.01 bcde	3.01 bcd	3.01	168.2 a	143.2 a	155.7	9 f	9 c	9	9.0 a	9.0 a	9.0
14	IR19743-46-2-3-3-2	2.91 cdef	2.75 cd	2.83	79.7 fg	84.2 defg	81.0	20 ab	14 ab	17	1.0 d	5.0 bcde	3.0
15	RD19 (check)	3.18 bcde	2.43 d	2.81	113.2 b	111.5 b	112.4	15 bcde	13 abc	14	8.3 a	9.0 a	9.0
16	IR19774-23-2-2-103	2.08 efg	2.94 bcd	2.80	70.2 h	82.0 efg	76.1	22 a	14 ab	18	2.3 cd	1.0 f	1.7
17	IR19794-8-3-1-3-3	3.01 bcde	2.54 d	2.78	74.9 gh	78.7 fg	76.8	20 abc	14 ab	17	1.7 cd	2.3 def	2.0
18	IR19735-5-2-3-2-1	2.86 defg	2.64 d	2.73	75.3 gh	79.7 efg	77.5	16 bcde	13 ab	15	1.7 cd	2.3 def	2.0
19	IR9752-71-3-2	2.26 fg	2.56 d	2.41	69.6 h	71.9 g	70.8	22 a	12 abc	17	1.7 cd	1.0 f	1.4
20	Hashikalmi	2.12 g	1.44 e	1.78	84.5 de	93.8	89.2	14 cdef	15 a	15	9.0 a	9.0 a	9.0
	Av	3.16	2.96	3.06	86.4	89.2	87.8	16	12	14	3.0	3.9	3.5
	C.V. (%)	12.54	17.76	—	4.2	8.1	—	17.0	17.0	—	27.9	26.8	—

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Maturities ranged from 101-109 days for the early-maturing cultivars and 117 to 205 days for the check cultivars. [b]0 = lodging, 9 = all plants lodged.

Table 5. Yield and agronomic parameters of 34 medium-maturing and 8 check cultivars evaluated under rainfed transplanted condition, 1st and 2nd planting, stratum 2, Solana, Tuguegarao, Philippines, 1981 wet season.

Yield rank (av)	Cultivar	Yield (t/ha)			Plant ht			Tillers/hill			Lodging[b]		
		1st	2nd	Av	1st	2nd	Av	1st	2nd	Av	1st	2nd	Av
1	C168	3.09 ab	2.26 ab	2.68	98.7 efghijk	86.7 bcdefghij	92.7	7 bcdef	11 ab	9	1.0 d	3.0 bcd	2.4
2	BR10	2.57 abcdef	2.45 a	2.51	97.0 efghijkl	74.3 efghijklm	85.6	6 def	11 ab	8	1.0 d	3.0 bcd	2.0
3	IR10781-75-3-2	3.24 a	1.58 abcdefghij	2.41	87.0 jklmnopq	71.0 fghijklm	79.0	7 cdef	11 ab	9	1.0 d	3.7 bc	2.4
4	IR52 (check)	2.59 abcdef	2.15 abcd	2.37	88.0 ijklmnop	68.3 ghijklm	78.2	8 abcdef	12 ab	10	1.0 d	1.0 d	1.0
5	BR51-282-8	2.72 abcde	1.93 abcde	2.33	119.0 abcd	87.7 abcdefgh	103.4	7 cdef	9 ab	8	1.7 d	3.0 bcd	2.4
6	BR4	2.98 abc	1.64 abcdefghi	2.31	101.3 defghijk	91.3 abcdefg	96.3	6 ef	11 ab	8	1.7 d	3.0 bcd	2.4
7	IR4819-77-3-2	2.69 abcdef	1.90 abcdefg	2.30	99.0 efghijk	82.3 cdefghijk	90.6	7 bcdef	11 ab	9	1.7 d	3.0 bcd	2.4
8	IR14753-49-2	2.85 abcd	1.64 abcdefghi	2.25	97.3 efghijkl	83.3 cdefghijk	90.3	8 abcdef	11 ab	10	1.0 d	3.0 bcd	2.0
9	BR118-38-17	2.58 abcdef	1.92 abcdef	2.25	107.7 cdefgh	89.7 abcdefgh	98.7	11 ab	11 ab	11	2.3 d	2.3 bcd	2.3
10	BIET 452	2.82 abcd	1.52 bcdefghij	2.17	110.7 bcdefg	101.3 abcd	106.0	9 abcdef	13 ab	11	2.3 d	3.0 bcd	2.6
11	UPL Ri5 (check)	2.52 abcdef	1.81 abcdefg	2.17	104.7 cdefghij	85.0 cdefghij	94.8	7 cde	8 b	8	2.3 d	2.3 bcd	2.3
12	IR46 (check)	2.80 abcde	1.51 bcdefghij	2.16	92.0 ghijklmn	69.3 fghijklm	80.6	8 abcdef	13 ab	11	1.7 d	3.0 bcd	2.4
13	UPL Ri3 (check)	2.60 abcdef	1.67 abcdefghi	2.14	98.0 efghijkl	92.7 abcdef	95.4	6 def	14 ab	10	2.3 d	3.0 bcd	2.6
14	Pajam	2.82 abcde	1.46 bcdefghij	2.14	95.7 fghijklm	82.7 cdefghijk	89.2	8 abcdef	9 ab	8	1.7 d	2.3 bcd	2.0
15	IR8192-166-2-2-3	2.78 abcde	1.47 bcdefghij	2.13	95.3 fghijklm	79.7 defghijkl	87.5	8 abcdef	12 ab	10	2.3 d	3.7 bc	3.0
16	Wag-wag Tawataw (check)	2.05 efghijk	2.19 abc	2.12	123.0 abc	103.7 abc	113.4	6 def	9 b	8	3.0 cd	3.0 bcd	3.0
17	IR13146-45-2-3	2.84 abcd	1.34 cdefghij	2.09	91.7 ghijklmn	87.6 abcdefghi	89.4	8 abcdef	12 ab	10	1.7 d	3.0 bcd	2.4
18	BT 050C-MR-18-1	2.60 abcdef	1.56 abcdefghij	2.08	90.7 hijklmno	81.3 cdefghijk	86.0	7 cdef	12 ab	10	1.7 d	3.0 bcd	2.3
19	Mahsuri	2.81 abcde	1.00 efghij	1.95	107.0 cdefghi	81.0 cdefghijkl	94.0	8 abcdef	11 ab	10	2.3 d	3.0 bcd	2.6
20	CN 540	1.96 fghijkl	1.77 abcdefgh	1.87	120.0 abcd	96.0 abcde	108.0	7 cdef	13 ab	10	3.0 cd	3.0 bcd	3.0
21	IR14632-2-3	2.54 abcdef	1.07 efghij	1.81	90.3 hijklmno	55.0 m	72.6	9 abcde	12 ab	11	1.7 d	4.3 ab	3.0
22	IR13358-85-1-3	2.27 cdefgh	1.32 cdefghij	1.80	77.0 mnopqr	74.0 efghijklm	75.5	8 abcdef	15 a	12	1.0 d	3.0 bcd	2.0
23	BKN-6990-63	2.32 cdefg	1.22 efghij	1.77	128.3 ab	96.3 abcde	112.3	6 ef	14 ab	10	1.7 d	2.3 bcd	2.0
24	IR13365-253-3-2	2.21 defghi	1.23 efghij	1.72	85.3 jklmnopq	64.3 ijklm	74.8	9 abcde	9 ab	9	1.0 d	2.3 bcd	1.6
25	RD19 (check)	2.33 bcdefg	1.00 ghij	1.67	96.0 fghijklm	56.7 m	76.4	9 abcdef	8 b	8	1.7 d	2.3 bcd	2.0
26	Wag-wag-aga (check)	1.67 ghijklm	1.53 bcdefghij	1.60	113.0 abcdef	110.0 a	111.5	8 abcdef	8 b	8	3.0 cd	3.0 bcd	3.0
27	Wag-wag Java (check)	1.96 fghijkl	1.20 efghij	1.58	116.0 abcde	109.3 ab	112.6	5 f	13 ab	9	3.0 cd	3.0 bcd	3.0
28	BR222-B-358	2.11 defghij	1.02 fghij	1.57	106.7 cdefghi	70.7 fghijklm	88.7	10 abc	11 ab	11	5.7 b	3.0 bcd	4.4
29	Baisbish	1.50 ijklm	1.62 abcdefghi	1.56	129.7 a	96.3 abcde	113.0	10 abc	9 b	10	9.0 a	2.3 bcd	5.6
30	IR19735-5-2-3-2-1	1.40 jklm	1.70 abcdefgh	1.55	74.7 nopqr	58.3 lm	66.5	11 ab	13 ab	12	2.3 d	2.3 bcd	2.3
31	IR15429-268-1-2-1	1.33 klm	1.63 abcdefghi	1.48	69.0 qr	55.3 m	62.2	9 abcdef	14 ab	12	1.7 d	1.7 cd	1.7
32	IR9752-71-3-2	1.26 lm	1.66 abcdefghi	1.46	66.0 r	56.7 m	61.4	9 abcdef	11 ab	10	2.3 d	2.3 bcd	2.3
33	Nizersail	1.59 hijklm	1.31 cdefghij	1.45	113.7 abcdef	92.3 abcdef	103.0	10 abc	9 ab	10	4.3 bc	4.3 ab	4.3
34	Yodaya	2.16 defghi	0.70 j	1.43	119.0 abcd	94.3 abcde	106.6	8 abcdef	10 ab	9	5.0 b	4.3 ab	4.6
35	IR19746-28-2-2-3	1.54 hijklm	1.10 efghij	1.32	72.3 opqr	53.0 m	62.6	11 a	13 ab	12	2.3 d	2.3 bcd	2.3
36	IR13429-109-2-2-1	1.26 lm	1.26 defghij	1.26	71.0 pqr	54.0 m	62.5	10 abcde	11 ab	11	5.7 b	2.3 bcd	4.0
37	Shada Pankaish	1.13 m	1.36 bcdefghij	1.25	118.7 abcd	83.0 cdefghijk	100.8	10 abcd	12 ab	11	9.0 a	3.0 bcd	6.0
38	IR9129-192-2	1.25 lm	1.07 efghij	1.16	82.7 klmnopqr	60.3 klm	71.5	10 abcde	10 ab	10	1.7 d	1.7 cd	1.7
39	IR19743-25-2-2-3-1	1.31 lm	0.90 hij	1.11	79.3 lmnopqr	61.3 klm	70.3	10 abcd	10 ab	10	1.0 d	1.7 cd	1.4
40	IR19743-46-2-3-3-2	0.93 m	1.28 defghij	1.11	77.3 mnopqr	63.7 jklm	70.5	10 abc	11 ab	11	1.0 d	1.7 cd	1.4
41	IR19743-40-3-3-2-3	1.13 m	0.79 ij	0.96	71.3 pqr	65.0 hijklm	68.2	11 ab	11 ab	11	2.3 d	3.0 bcd	2.6
42	Habiganj Aman I	—	0.70 j	0.70	—	102.3 abcd	102.3	—	8 b	8	—	5.7 a	5.7
	Av	2.17	1.48	1.82	97.1	79.2	88.2	8	11	10	2.4	2.8	2.6
	CV(%)	17.60	20.77	19.19	10.0	14.7	12.4	23	28	26	20.1	26.8	23.4

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. Maturities ranged from 100 to 133 days for the introduced cultivars and 114-153 days for checks. [b]0 = no lodging, 9 = all plants lodged.



2. Relationship between yield of the 1st and 2nd planting, medium-maturing TPR stratum 2, 1981 wet season, Tuguegarao, Cagayan, Philippines.

EVALUATING DEEPWATER RICES

Multiple Cropping and Plant Breeding Departments, Deepwater Rice Project - Thailand

The Solana site project needs to complete its cropping calendar with a wet-season rice crop. But low-lying fields near the Cagayan River frequently become flooded.

A diagnostic set of 8 key deepwater rices and other varietal types and a set of 271 breeding lines were planted in 3 water strata in a transect from shallow to deep-flooded areas (high to low ground) (Fig. 3).

In the diagnostic set, damage was slight in the rices planted in strata 1 and 2. In stratum 3, which was transplanted on 16 September, the benefit of tolerance for submergence appeared real. FR13A showed by far the best survival of the eight varieties tested.

In the observation nursery, the 271 varieties and lines were planted on 2 planting dates in strata 1 and 2 and on one in stratum 3 (5 plantings). Because all sites were affected by a similar flooding pattern and because the varieties selected should do well in all three strata, survival data were pooled.

Data on survival were compared with results of previous submergence tests on some lines. The lines with good submergence tolerance represented only 30 (11%) of all 271 varieties, but 6 (46%) of the 13 best surviving entries had been found tolerant of flash floods in submergence tests in Thailand and elsewhere (Table 6).

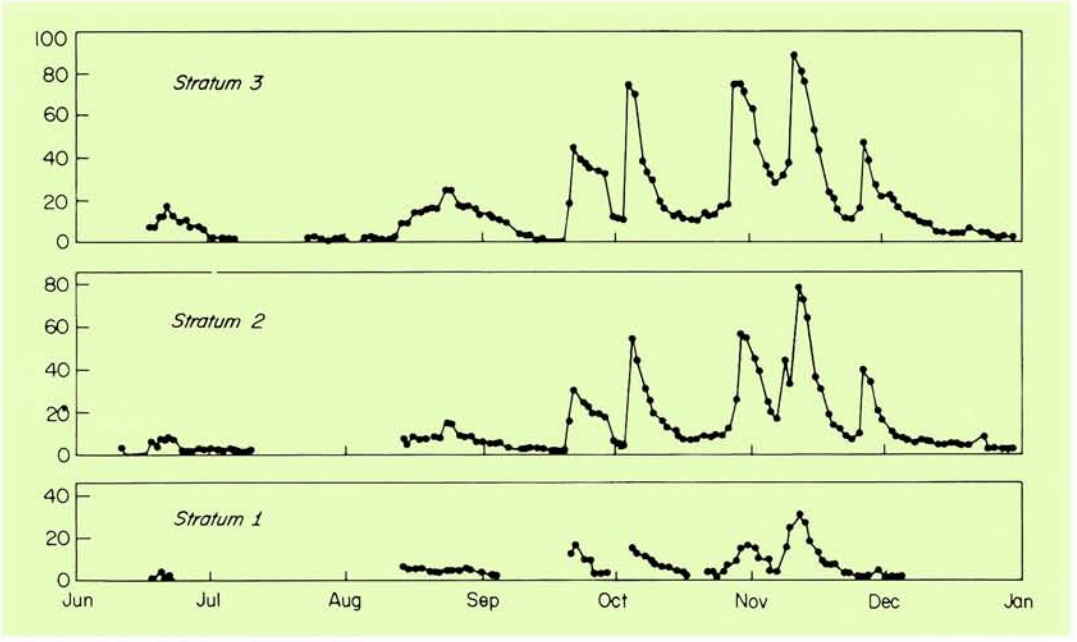
PERFORMANCE OF BANGLADESH VARIETIES

Multiple Cropping Department

In a TPR-mungbean cropping pattern in stratum 2 at Solana, Chandina was planted in two farmers' fields 16 and 17 July 1981 and harvested 25 and 24 September 1981. Only 30 kg N/ha was applied because of flooding at panicle initiation.

Chandina matured 71 days after transplanting, its grain yields at Bauan averaged 5.23 t/ha and at Iraga, 3.94 t/ha (Table 7). The farmer cooperators are planning to plant Chandina next year.

Two rainfed cropping patterns: DSR (Hashikalmi) - TPR (Pajam) and DSR (Hashikalmi) - TPR (Nizersail) - mungbean were tested in stratum 2. These varieties are commonly used in the rainfed



3. Depth of water, Solana, Tuguegarao, Cagayan, Philippines, 1981 rice crop season.

areas of Bangladesh. Planting for both patterns started on 27 May with the onset of rains.

Hashikalmi matured within 107 days after seeding and yielded 2.4 t/ha. In the second rice crop, Pajam (known as Mashuri in some countries) yielded 2.4 t/ha. Total production in the 2-rice crop pattern was 4.8 t/ha (Table 8). In the 3-crop pattern, the second rice crop variety Nizersail, which is photosensitive, has taller plant type, and can yield up to 4.5 t/ha under good management, yielded only 1.3 t/ha because stand establishment in the test was badly affected by flooding. The mungbean crop yielded only 110 kg/ha, for a total crop production of 3.8 t/ha.

The DSR Hashikalmi-TPR Pajam combination appears promising for the lowest part of stratum 2 and probably for the higher portion of stratum 3. Mungbean cannot be grown successfully before rice in these areas because of frequent flooding during the later part of its growth. High yielding dwarf rices do not fit the hydrology in this land topography. The total rice production potential from taller variety combinations may constitute a practical land-use pattern.

Table 6. Deepwater rices with better than 85% survival in 5 plantings in the flood-prone area of strata 1-3 at the Solana cropping systems site in Northern Luzon.

Designation	Background
BKNFR76033-RGA-5[a]	IR4427-70-4/RD19//BKN6987-52-1
BKNFR76109-7-2[a]	IR2053-521-3-3/FR43B
CN540[a]	IR262/Pin Gaew 56
CNL 241[a]	Indian line selection
Dudmona Barisal	Bangladesh line selection
DWCT 134-1-3-1	Deepwater Composite Thailand
IR9288-RGA-252-1-6[a]	Tarao Bao/IR2061-213-2-16//IR34
IR11288-RGA-65-1	IR2071-625-1-252//Leb Mue Nahng 111
IR13146-13-3-3	BG90-2/IR34//IR46
IR4954-K102-2	IR1514A-E597-2/T442-57
IR28930-5T[a]	IR3515-106-2-2-5-3/Goda Heenati//IR48
NPS 136	India line selection
SPR7416-0-155-2	Pin Gaew 56/IR26

[a]With previous record of good tolerance to flash floods.

UPLAND CROP CULTIVARS BEFORE RAINFED WETLAND RICE

Multiple Cropping Department

Alternative cropping patterns at the Solana test site include an upland crop (particularly mungbean) to be planted as the first crop at the onset of the rainy season (late April-early May).

Table 7. Management and performance of transplanted rice (variety Chandina) in a transplanted rice - mungbean[a] pattern at 2 locations. IRRI cropping systems research site at Solana, Tuguegarao, Philippines, 1981.

Observation	Location	
	Bauan	Iraga
Date of transplanting	16 Jul 1981	17 Jul 1981
Seedling age (days)	27	28
Nitrogen (kg/ha)	30	30
Handweedings (no.)	1	None
Insecticide application		
Azodrin, 0.25 kg a.i./ha	2 WT[b]	2 WT[b]
Folidol, 0.75 kg a.i./ha	Postflowering	Postflowering
Harvesting date	25 Sep 1981	24 Sep 1981
Grain yield (t/ha)	5.23	3.94

[a]Data on mungbean crop not yet available. [b]Weeks after transplanting.

Table 8. Results on 2 observational cropping patterns tested at the IRRI cropping systems research site in Solana, Tuguegarao, Philippines, 1981.

Cropping pattern	Observations		
	Date of seeding/ transplanting	Date of harvesting	Yield (t/ha)
Direct-seeded rice (Hashikalmi)	27 May 1981	10 Sep 1981	2.4
Transplanted rice (Pajam)	26 Sep 1981	11 Jan 1981	2.4
Total			4.8
Direct-seeded rice (Hashikalmi)	27 May 1981	10 Sep 1981	2.4
Transplanted rice (Nizersail)	26 Sep 1981	29 Dec 1981	1.3
Mungbean	30 Dec 1981	15 Mar 1981	0.1
Total			3.8

Short-duration upland-crop variety trials grown in 1981 were mungbean (11 entries), cowpea (10), bush sitao (9), green maize (12), and early-maturing field maize (14). Mungbean, cowpea, and bush sitao are reported here. Detailed management data are shown in Table 9.

Rain from 2 weeks before planting to harvest totalled 546.3 mm. Maximum temperatures ranged from 28° to 38.9° C, minimum temperatures from 21.2° to 26.7° C (Fig. 4).

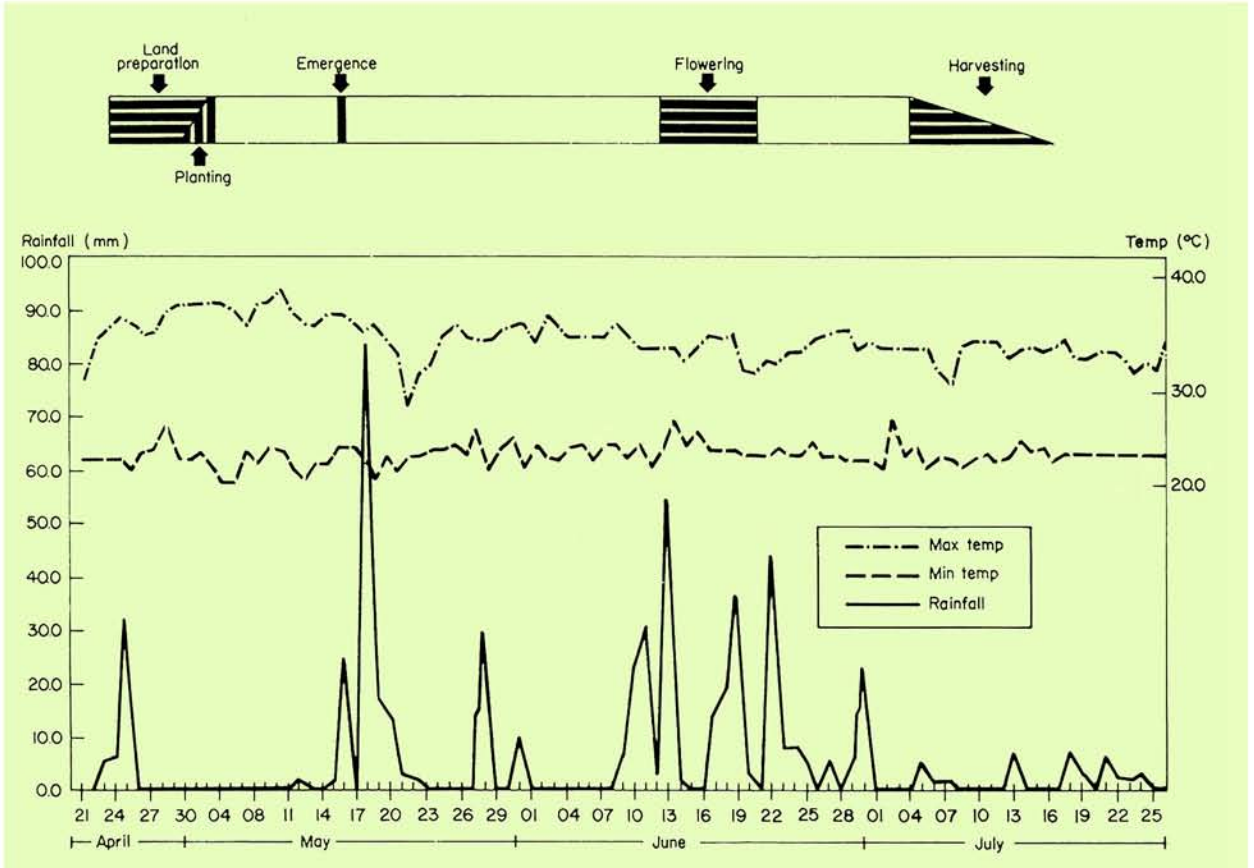
Mungbean. Yields ranged from 0.38 to 1.05 t/ha. Recommended variety Pag-asa 1 yielded 1.05 t/ha; farmers' variety, 1.02 t/ha; H70-16, 0.93 t/ha; MG50-10A (Y), 0.84 t/ha; Dau Mo 0.74 t/ha; and EG MG 174-3, 0.69 t/ha (Table 10). Number of days to flowering did not differ among cultivars, but number of days to maturity showed significant differences, with the farmers' variety the earliest (50 days) and Pag-asa 1 the latest (58 days). Pag-asa 1, Dau Mo, and H70-16 were tolerant of *Cercospora* leaf spot infestation; other entries, including farmers' cultivar, were highly susceptible. No cultivar was resistant to pod borer damage. Regression analysis showed that number of days to maturity, *Cercospora* leaf spot, and plant height were highly related to seed yield ($R^2 = 0.9685$).

Cowpea. The overall performance of cowpea was poor. Only TVx 7-5H yielded more than 1 t/ha; it was followed by TVx 1836-19E (0.88 t/ha), Pelungthay 0.84 t/ha, CP_2-3-1 (0.76 t/ha), CP_4-2-3-1 (0.70 t/ha), and Vita 3 (0.69 t/ha) (Table 11). The lowest yielder was the farmers' variety (0.24 t/ha), followed by V59-41 (0.45 t/ha). Number of days to flowering ranged from 28 to 44; number of days to maturity, 52 to 62. V59-41 was the earliest and Vita 3 the latest. Vita 3 had the tallest plant height and was resistant to both *Cercospora* and pod borer damage. TVx 7-5H and farmers' variety showed only slight tolerance for *Cercospora* and were highly susceptible to pod borer damage.

Table 9. Cultural management in upland-crop variety yield trials before rainfed wetland rice at Solana outreach site, Cagayan, Philippines, 1981 wet season.

Cultural management	Mungbean	Cowpea	Bush sitao
Spacing (cm)	50 x 4.3	50 x 10	50 x 10
Plant population/ha	511,111	200,000	200,000
Land preparation	High tillage[a]	High tillage[a]	High tillage[a]
Date planted	2 May 1981	2 May 1981	30 April 1981
Date emerged	16 May 1981	16 May 1981	16 May 1981
Pesticide applied			
1st application	Azodrin 168	Azodrin 168	Azodrin 168
2nd "	Thiodan EC	Thiodan EC	Thiodan EC
Fungicide applied	None	None	None
Herbicide applied	None	None	None
Hand weedings (no.)	1	1	1
Irrigation	None	None	None
Drainage	Poor	Poor	Poor
Total rainfall (mm)	546.3	546.3	546.3
Date harvested	9 July 1981	9 July 1981	9 July 1981

[a]High tillage consists of 1 plowing followed by 1 harrowing before furrowing.



4. Growth periods of upland crops planted before wetland rice, graphed against daily rainfall and temperature, Solana, Tuguegarao, Cagayan, Philippines, 1981 wet season.

Table 10. Yield and other agronomic characteristics of 11 early mungbean cultivars evaluated before rainfed wetland rice, Solana outreach site, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

Yield rank	Cultivar	Yield (t/ha)	Days to		Plant ht (cm)	CLS[b] rating	Pod[b] borer rating	Plants harvested (no./plot)	Seedling vigor rating[c]
			Flowering	Maturity					
1	Pag-asa 1	1.05 a	29 a	58 a	56.0 b	5.0 b	4.3 a	218 ab	1.0 a
2	Local check	1.02 a	28 a	50 e	62.8 b	9.0 a	5.0 a	229 a	1.0 a
3	H70-16	0.93 ab	28 a	56 ab	64.0 b	7.0 ab	4.3 a	201 abc	1.0 a
4	MG 50-10A-Y	0.84 ab	29 a	51 de	55.7 b	9.0 a	4.3 a	136 e	1.0 a
5	Dau Mo	0.74 abc	29 a	56 ab	75.5 a	6.3 b	4.3 a	180 bcde	1.0 a
6	EG MG 174-3	0.69 abc	28 a	52 cde	60.0 b	9.0 a	4.0 a	151 de	1.0 a
7	CES J-2Y	0.64 bc	29 a	53 cd	56.9 b	9.0 a	5.0 a	163 cde	1.0 a
8	M350	0.60 bc	29 a	51 de	55.9 b	9.0 a	6.3 a	186 abcd	1.0 a
9	CES 55	0.58 bc	29 a	52 cde	59.9 b	9.0 a	5.7 a	134 e	1.0 a
10	CES 1K-25Y	0.55 bc	29 a	54 bc	57.2 b	9.0 a	6.0 a	171 cde	1.0 a
11	CES N-6Y	0.38 c	28 a	52 cde	61.0 b	9.0 a	5.0 a	189 abcd	1.0 a
	Av	0.73	29	53	60.5	8.2	4.9	178	1.0
	CV (%)	21.41	n.s.	2.00	8.90	10.60	n.s	13.00	n.s.

[a]Separation of means in a column by Duncan's multiple range test at the 5% level of probability. n.s. = not significant. [b]1 = resistant, 9 = susceptible. [c]1 = good vigor, 9 = poor, taken 15 days after emergence.

Table 11. Yield and other agronomic characters of 10 determinate cowpea cultivars evaluated before rainfed wetland rice, Solana outreach site, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

Yield rank	Cultivar	Dry bean yield (t/ha)	Days to		Plant ht (cm)	CLS rating[b]	Pod borer rating[b]	Plants harvested (no.)	Seedling vigor rating[c]
			Flowering	Maturity					
1	TVx 7-5H	1.05 a	37 b	58 cd	52.0 c	4.3 bc	7.3 ab	158 ab	1.0 a
2	TVx 1836-19E	0.88 ab	34 bc	61 ab	51.3 c	5.0 abc	3.3 bc	136 abc	1.0 a
3	Pelungthay	0.84 abc	36 b	58 cd	63.3 c	5.7 ab	5.3 abc	148 abc	1.0 a
4	CP_2-3-1	0.78 abcd	30 cd	60 ab	59.1 c	7.0 a	3.3 bc	177 a	1.0 a
5	CP_4-2-3-1	0.70 abcd	29 d	57 d	51.6 c	5.7 ab	5.7 abc	137 abc	1.0 a
6	Vita 3	0.69 abcd	44 a	62 a	116.1 a	1.3 d	1.0 c	128 bc	1.0 a
7	All season	0.68 abcd	29 d	60 ab	50.7 c	5.7 ab	5.0 abc	118 bc	1.0 a
8	Pelungga	0.56 bcd	37 b	59 bc	91.1 b	5.7 ab	5.3 abc	116 bc	1.0 a
9	V59-41	0.45 cd	28 d	52 e	44.8 c	7.3 a	9.0 a	108 cd	1.0 a
10	Local check	0.24 d	38 b	60 abc	95.5 b	3.0 cd	7.0 ab	69 d	1.0 a
	Av	0.69	34	59	67.6	5.1	5.2	130	1.0
	CV (%)	24.74	6.00	2.00	17.00	26.00	22.20	19.00	n.s.

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]1 = resistant, 9 = susceptible. [c]1 = good vigor, 9 = poor vigor. n.s. = not significant at the 5% level of probability.

Table 12. Yield and other agronomic characters of 9 bush sitao cultivars evaluated before rainfed wetland rice, Solana outreach site, Tuguegarao, Cagayan, Philippines, 1981 wet season.[a]

Yield rank	Cultivar	Yield (t/ha)	Days to		Plant ht (cm)	Rust rating[b]	Pod borer rating[b]	Plants harvested (no.)	Seedling vigor rating[c]
			Flowering	Maturity					
1	Bush Sitao #6	1.30 a	28 d	55 b	165.8 a	3.0 ab	2.3 bc	104 bcde	1.0 b
2	Bush Sitao #3	1.23 ab	34 a	59 a	112.4 b	3.3 ab	1.3 c	87 cde	1.3 b
3	EG Bush Sitao #2	1.13 ab	30 b	59 a	75.5 bc	2.3 b	2.0 bc	141 abc	1.0 b
4	Bush Sitao #1	1.07 ab	33 a	57 a	71.3 c	2.7 b	1.7 bc	122 abcd	1.0 b
5	Bush Sitao #7	0.99 ab	28 d	52 c	186.2 a	5.0 ab	4.0 b	163 a	1.0 b
6	Los Baños Bush Sitao #1	0.93 ab	29 c	55 b	60.2 c	4.3 ab	2.0 bc	157 ab	1.0 b
7	UPL Bush Sitao #4	0.51 ab	28 d	54 bc	50.3 c	4.3 ab	2.7 bc	84 de	1.3 b
8	Bush Sitao #4	0.44 ab	28 d	55 bc	43.6 c	3.7 ab	2.7 bc	58 e	1.7 ab
9	UPL Bush Sitao #2	0.34 b	28 d	53 bc	47.8 c	6.7 a	6.3 a	108 bcde	2.3 a
	Av	0.80	30	55	90.3	3.9	2.8	114	1.3
	CV (%)	21.44	1.00	2.00	24.80	11.00	17.10	25.00	21.30

[a]Separation of means in a column by Duncan's multiple range test at the 5% level. [b]1 = resistant, 9 = susceptible. [c]1 = good vigor, 9 = poor. Rating taken 15 days after emergence.

Regression analysis showed that yields were a function of days to flowering, height, and pod borer damage ($R^2 = 0.9855$). There was no significant relationship between yield and number of days to maturity.

Bush sitao. Four cultivars yielded more than 1 t/ha: bush sitao (BS) #6 (1.3 t/ha), BS #3 (1.2 t/ha), BS #2 (1.13 t/ha), and BS #1 (1.07 t/ha) (Table 12). The three lowest yielders were UPL BS #4 (0.51 t/ha), BS #4 (0.44 t/ha), and UPL BS #2 (0.34 t/ha). Low yields may be attributed to poor plant stand in UPL BS #4 and BS #4 and to susceptibility to rust in UPL BS #2. Height ranged from 43 to 166 cm, with BS #6 the tallest and BS #1 the shortest. BS #3, BS #2, and BS #1 were tolerant of pod borer damage. Regression analysis showed that plant height, *Cercospora* leaf spot, and pod borer damage were significantly related to yield ($R^2 = 0.9727$).

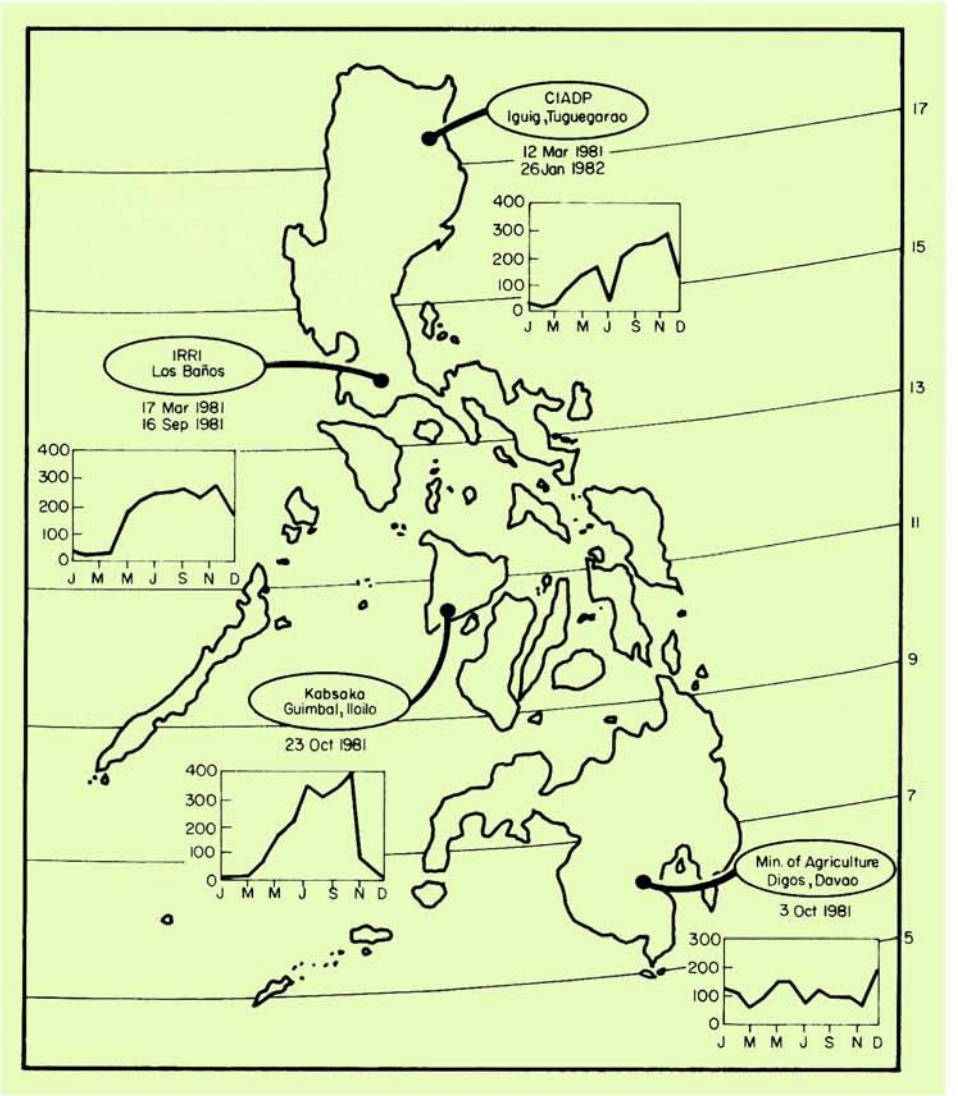
IDENTIFYING HIGH-YIELDING FOOD CROP CULTIVARS

Multiple Cropping Department

The food crops involved in intensive rice-based cropping patterns include mungbean, cowpea, bush sitao, soybean, maize, sorghum, peanut, sweet potato, and sesame. Cultivars are tested at the time a crop fits the cropping system at each research site.

Elite lines and cultivars from the screening program of the University of the Philippines and the Institute of Plant Breeding at Los Baños, Laguna, were used. Upland crop cultivars were selections from materials originally obtained from the breeding programs of the Asian Vegetable Research and Development Center (AVRDC), International Institute of Tropical Agriculture (IITA), International Crops Research Institute for the 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 entries came from IRRI.

Trials were conducted in dryland and wetland fields at the IRRI farm, IRRI cropping systems research sites in Pangasinan and Tuguegarao, and Philippine national cropping systems research sites in Ilocos Sur, Bohol, Cagayan, and Pangasinan (Fig. 5).



5. Dates of planting and rainfall patterns at selected sites, 1981 Cagayan Integrated Agricultural Development Project (CIADP).

Rice. In the 1980-81 dry season, 10 promising early-maturing and 10 medium-maturing selections were dry-seeded under rainfed wetland conditions in Carmen, Bohol, to evaluate yield potential and to identify agronomic characters desirable for crop intensification.

Among the early-maturing selections, IR50 (3.57 t/ha) and IR36 (3.49 t/ha), the recommended varieties for cropping systems research sites, were the top yielders. Average yield of all selections was 2.50 t/ha. The earliest maturing selection, IR9729-67-3 (99 days from seeding), yielded 2.41 t/ha. IR50 matured in 105 days and IR36 in 110 days.

In the medium-maturing selections, IR52 gave the highest yield (6.26 t/ha), followed by IR13423-10-2-3 (6.08 t/ha) and IR13540-56-3-2-1 (6.01 t/ha). IR52 matures in 116 days, IR13423-10-2-3 in 123 days, and IR13540-56-3-2-1 in 114 days after seeding. IR54 ranked fourth (5.87 t/ha). It matures in 123 days. Differences in plant height and 1,000-seed weight among most of the entries were not significant. IR52 was the tallest (88 cm) and had the heaviest 1,000-seed weight (27.7 g).

In the 1981 wet season, the same selections were

dry-seeded in rainfed wetland fields at the IRRI farm and at Vigan, Ilocos Sur. A transplanted rice yield trial was also conducted at Vigan, Ilocos Sur. No yield data were obtained from the trial at IRRI because of severe drought during grain-filling. However, among the early-maturing selections, IR9729-67-3 was the earliest to flower (62 days from seeding). IR50 flowered in 72 days and IR36 in 78.

In Ilocos Sur, the best yielder was IR13429-196-1-2-1 (4.56 t/ha), followed by IR8455-78-1-3-3 (3.55 t/ha), IR19746-28-2-2-2-3 (3.39 t/ha), and IR9752-71-3-2 (3.15 t/ha). These lines matured 88 days after seeding. IR50 yielded 2.48 t/ha and matured in 86 days.

In the transplanted-rice yield trial, IR13429-196-1-2-1 and IR8608-125-3-3 gave the highest yields (4.32 t/ha). IR8608-125-3-3 has shorter plants (80 cm) than IR13429-196-1-2-1 (85 cm). Both lines mature in 105 days. IR9752-71-3-2 yielded 4.0 t/ha and IR50, 3.81 t/ha.

Among medium-maturing selections in the IRRI trial, no entry reached flowering because of drought. In Ilocos Sur, IR54 yielded 4.3 t/ha, IR8192-31-2-1-2, 4.3 t/ha; and IR11248-148-3-2-3-3, 4.0 t/ha. They mature in 110 days. IR52 yielded 3.36 t/ha and IR42, 3.68 t/ha. They mature in 112 days.

Mungbean. In the 1980-81 dry season, two sets of mungbean trials were planted with zero tillage after wetland rice at IRRI. One set consisted of 10 selected cultivars from AVRDC, Taiwan, the other of 13 selections from the Philippine Institute of Plant Breeding (IPB) at Los Baños. The IPB selections also were tested under zero-tillage lowland conditions at the Cagayan Integrated Agricultural Development Project (CIADP) stations in Iguig, Cagayan, and Manaoag, Pangasinan, and under high-tillage upland conditions in San Vicente, Ilocos Sur; Mangaldan, Pangasinan, and Bauan, Tuguegarao.

Among the AVRDC selections, at IRRI, KJ5 gave the highest yield (1.73 t/ha). It has medium seed size (48 g/100 seeds), produces plenty of pods and matures 66 days after planting. Pag-asa 1 (CES 1D-21), the variety recommended for cropping pattern testing, ranked third with 1.32 t/ha. Among the IPB selections, Aa and Pag-asa 1 at 1.6 t/ha, were the outstanding entries. Both cultivars mature in 70 days. They also exhibited resistance to Fusarium stem and root rot, but not to rust.

In Cagayan, CES 55 gave the highest yield (0.50 t/ha). The low yields of Pag-asa 1 (0.22 t/ha) and Aa (0.13 t/ha) could be attributed to moisture stress at flowering. In Manaoag, Pangasinan, yield levels were somewhat higher, despite limited rainfall. CES IT-2 was the highest yielder (1.07 t/ha), CES 2F-1 (Pag-asa 2) the next highest (1 t/ha). Pag-asa 2 matures in 65 days, CES IT-2 a week later. Pag-asa 1 (0.75 t/ha) matures in 64 days. Yield differences may be due to the differences in period of establishment of the trial. The trial in Cagayan was established the first week of February. That in Pangasinan was established the last week of December.

Under high tillage upland conditions in Ilocos Sur, EC MG 174-3 (1.28 t/ha), CES IT-2 (1.27 t/ha), and Pag-asa 2 (1.24 t/ha) were the top yielders. Pag-asa 2 matured the earliest (64 days). Pag-asa 2 and CES IT-2 also exhibited tolerance for powdery mildew and *Cercospora* leaf spot diseases. In Mangaldan, Pangasinan, Pag-asa 2 was also the outstanding entry (1.58 t/ha). It produced more pods per plant and was tolerant of *Cercospora* leaf spot. Average yield of all cultivars was 1.16 t/ha. In Bauan, Tuguegarao, all cultivars yielded more than 1 t/ha. Top yielders were MG 50 10A (G) (1.67 t/ha), Dau Mo (1.5 t/ha), CES U-1 (1.4 t/ha), and CES 55 (1.42 t/ha). Pag-asa 1 (1.32 t/ha) ranked 7th and Pag-asa 2 (1.21 t/ha) ranked 11th. CES U-1 was most tolerant of powdery mildew among the cultivars tested.

In the 1981 wet season, 10 cultivars were evaluated before wetland rice at the IRRI farm and in Bangag, Cagayan. At IRRI, M350 was the highest yielder (0.96 t/ha), Pag-asa 1 the next highest (0.94 t/ha). In Cagayan, Pag-asa 1 (0.84 t/ha) yielded the highest. Yield differences among cultivars within the two locations were not significant. Average yield in the IRRI test was 0.83 t/ha; at Cagayan, 0.50 t/ha. The low yields were attributed to the susceptibility of most entries to *Cercospora* leaf spot disease.

Cowpea. In 1980-81 dry season, 11 indeterminate cultivars were evaluated with zero tillage after wetland rice at IRRI and 6 promising cultivars were tested with zero tillage at the CIADP station in Iguig, Cagayan, and with high tillage in Bauan,

Tuguegarao. Under zero tillage at IRRI, Vita 3 and All Season outyielded EG #2 (the variety used in cropping pattern testing) in both green pod and dry bean production. Vita 3 yielded 7.20 t green pods/ha and 0.71 t dry beans/ha. All Season yielded 6.94 t green pods/ha and 0.50 t dry beans/ha. EG #2 yielded 6.07 t green pods/ha and 0.25 t dry beans/ha. Vita 3 and All Season were also the top yielders in the 1979-80 dry-season test. They exhibit tolerance of Fusarium stem rot disease.

In Cagayan, Vita 3 was also the top yielder of dry beans (0.54 t/ha). Moisture stress after establishment of that trial resulted in low average yield (0.44 t/ha).

Under lowland high-tillage conditions, Vita 4 (1.72 t/ha) and All Season (1.58 t/ha) were the top yielders of dry beans in Bauan, Tuguegarao. EG #2 ranked 4th with 1.44 t/ha. Average yield was quite high (1.42 t/ha) because of favorable growing conditions during critical growth stages.

Two uniform cultivar trials from IITA in Nigeria were also tested under high tillage in IRRI upland fields. Trial 1 consisted of 20 indeterminate cultivars and Trial 2 of 10 determinate cultivars.

Among the indeterminate cultivars, TVx 3380-042E yielded 1.75 t dry beans/ha and Vita 4 1.71 t/ha. Both cultivars significantly outyielded 11 other entries, including local check EG #2 (0.65 t/ha). Average yield of all cultivars was 1.18 t/ha. In the determinate cultivars, no yield data were obtained because of typhoon damage at flowering.

In the 1981 wet season, 9 determinate cultivars were evaluated under high tillage before rainfed wetland rice at IRRI farm and in Bangag, Cagayan.

At IRRI, the top producers of green pods were Cp 4-2-3-1 (5.56 t/ha) and All Season (4.75 t/ha). Both cultivars significantly outyielded all other entries. The top yielders of dry beans were TVx-7-5H (0.7 t/ha) and V59-41 (0.66 t/ha). These cultivars mature in 70 days.

In Bangag, Cagayan, yield differences were not significant. TVx-7-5H was the top yielder (0.78 t dry beans/ha). Average yield of all cultivars was 0.5 t/ha. Vita 3 had the most promising pest and disease resistance.

Bush sitao. Eight promising cultivars of this vegetable legume were evaluated with zero tillage after wetland rice at the IRRI farm during the 1980-81 dry season. BS_4 (MP × 21) was the top producer of green pods (12.40 t/ha), followed by BS_1 (6-14R × AS) (11.80 t/ha). Both cultivars produce smooth pods, a character highly preferred by consumers. BS_1 exhibited more tolerance for Fusarium stem, root rot, and rust. In dry bean yields, BS_1 (Los Baños BS #1 × Co_1) 4-1-1-2 (1.4 t/ha) and EG BS #2 (1.25 t/ha) gave the highest yields. BS_4 (MP × 21) yielded 0.58 t/ha and BS_1 (6-14R × AS) 0.50 t/ha.

During the 1981 wet season, 9 cultivars were tested before wetland rice at the IRRI farm and in Bangag, Cagayan. At IRRI, EG BS #2 (7.48 t green pods/ha) and BS_4 (MP × 21) (5.69 t/ha) significantly outyielded all other entries. BS_1 (6-14R × AS) gave the highest dry bean yield (0.57 t/ha) and was most tolerant of Fusarium stem and root rot. All cultivars matured in less than 70 days. In Bangag, BS_6 (Los Baños BS #1 × Co_1) 4-1-1-1 gave the highest dry bean yield. BS_3 (6-14R × AS) and EG BS_2 ranked second and third.

Soybean. In the 1980-81 dry season, 10 promising cultivars were tested with zero tillage after rainfed wetland rice at the IRRI farm and at the CIADP station in Iguig, Cagayan. The same entries were tested under high-tillage upland conditions in Bauan, Tuguegarao.

Under zero tillage at IRRI, lines 11-4 (2.46 t/ha) and 50106-4-7 (2.2 t/ha) had the highest yields. Clark 63 (1.93 t/ha) and UPL SY-2 (1.6 t/ha), the recommended varieties for cropping pattern testing, ranked third and seventh. In Cagayan, Clark 63 gave the highest yield (1.06 t/ha) followed by line 7024-3 (1.01 t/ha). Both cultivars outyielded all other entries, including UPL SY-2 (0.76 t/ha). Clark 63 also matured a week earlier (83 days) and was more tolerant of rust.

Under upland conditions in Bauan, Tuguegarao, Clark 63 was the top-yielding entry (0.95 t dry beans/ha). It matured in 83 days and showed tolerance for rust.

Peanut. Testing of peanut cultivars with zero tillage after wetland rice started at the IRRI farm in 1980-81. Results showed the possibility of establishing a good peanut crop without cultivation provided soil moisture is sufficient throughout growth, particularly during flowering, to allow penetration of pegs into the soil. During the 1980-81 dry season, the same trial was conducted at the

IRRI farm and at the CIADP Station in Iguig, Cagayan.

At IRRI, the average yield of 10 cultivars tested was 1.32 t/ha. CES 2-25 (1.65 t/ha) was the outstanding entry. Other promising cultivars were CES 102 (1.57 t/ha), UPL PN-2 (1.44 t/ha), and Acc 12 (1.38 t/ha). In Cagayan, average yield of all cultivars was 0.93 t/ha. CES 2-25 also gave the highest yield (1.22 t/ha), followed by PI-118200 (1.17 t/ha), Acc 12 (1.16 t/ha), and M10 (1.09 t/ha). At IRRI, total rainfall during crop growth was 452 mm; in Cagayan, only 4 mm.

Ten cultivars were evaluated under high tillage upland conditions at Bantay, Ilocos Sur; Mangaldan, Pangasinan; and Bauan, Tuguegarao. In Ilocos Sur and Pangasinan, all introduced cultivars were outyielded by the local check (0.72 t/ha). Average yield in both locations was 0.50 t/ha. The promising cultivars were CES 2-25, M10, CES 101, and CES 102. In Tuguegarao, yields averaged 1.71 t/ha. The outstanding entries were CES 103 (1.95 t/ha), CES 102 (1.87 t/ha), M10 (1.85 t/ha), F334-33 (1.82 t/ha), and CES 2-25 (1.82 t/ha).

Field maize. Nine field maize cultivars from the breeding programs of Thailand and the Institute of Plant Breeding at Los Baños, Philippines, were evaluated with zero tillage after wetland rice at the IRRI farm during the 1980-81 dry season. Fourteen cultivars were tested with high tillage under rainfed wetland conditions at Vigan, Ilocos Sur, and Rosales, Pangasinan, and under high tillage upland conditions in Bauan, Tuguegarao.

Under zero tillage, Thai Comp. 1 DMR × Genja Kretek F_3 (2.74 t/ha) and Suwan 2 $(S)C_5F_2$ (2.50 t/ha) had the highest shelled-grain yields. Yield differences among all entries were not significant. Average yield of all cultivars was 2.26 t/ha. Maturities ranged from 95 to 98 days.

In high-tillage wetland conditions in Ilocos Sur, IPB Var 1 yielded 4.42 t/ha, Thai Comp. 1 Early DMR (S) C_4, 4.24 t/ha; and Early DMR Comp. 1, 4.22 t/ha. Yield differences were not significant. The average yield of all cultivars was 3.58 t/ha. In Pangasinan, all cultivars yielded higher than 4 t/ha. IPB Var 1 was the outstanding entry (8.13 t/ha). Thai Comp. 1 Early DMR $(S)C_4$ ranked second with 7.79 t/ha. Average yield of all cultivars was 6.07 t/ha. Maturity ranged from 90 to 95 days. Early DMR Comp. 1 and the local check variety matured the earliest. The high yield levels in Ilocos Sur and Pangasinan can be attributed to favorable growing conditions, especially available irrigation water and high solar radiation.

Under upland conditions in Tuguegarao, the local check variety (2.55 t/ha) significantly outyielded all the introduced cultivars. The highest yielding introduced cultivar was Early DMR Comp. 2 (1.48 t/ha), followed by Phil. DMR Comp. 4 (1.36 t/ha). Average yield was 1.15 t/ha.

In the 1981 wet season, the same cultivars were tested under upland conditions in Koronadal, South Cotabato. The most promising entries were Prolific DMR Comp. 1 and 2. Both cultivars yielded 3.53 t/ha. IPB var 1 ranked 10th with 3 t/ha. Yield differences were not significant.

Eight early-maturing field maize entries composed of hybrids from IITA and composites from IPB were evaluated before wetland rice at the IRRI farm and Tuguegarao. At IRRI, top yielders were Early DMR Comp. 1 (4.99 t/ha), TZE 15 (4.74 t/ha), TZE 17 (4.59 t/ha), and TZE 14 (4.5 t/ha). These composites or hybrids mature in 91-92 days. The lowest yielder was local check Improved Tiniguib (2.97 t/ha), which matured the earliest (90 days). In Tuguegarao, no yield data were obtained because of drought at flowering.

Green maize. In the 1980-81 dry season, seven glutinous and eight sweet maize cultivars were evaluated with zero tillage after wetland rice at the IRRI farm. Glutinous Syn. #4 gave the highest marketable ear yield (2.77 t/ha), Macapuno the next highest (2.54 t/ha). They were harvested 72-75 days after planting. No yield data were obtained in the sweet maize trial because of severe borer damage.

In the 1981 wet season, the cultivars were tested before wetland rice at the IRRI farm and in upland conditions in Koronadal, South Cotabato. Sweet DMR Popn's 31B (5.9 t/ha), 31A (5.37 t/ha), and 31C (5.28 t/ha) were the outstanding sweet maize cultivars at IRRI. They mature in 67 days. In glutinous maize, Los Baños Lagkitan gave the highest marketable ear yield (5.17 t/ha), followed by Glutinous DMR Composite Pop'n 41B (5.5 t/ha) and Glutinous Syn. #41 (5.11 t/ha).

In Cotabato, Sweet DMR Comp. Popn's 31B (1.86 t/ha) and 31A (1.71 t/ha) were also the top yielders of marketable ears among the sweet maize

entries. Glutinous DMR Comp. Pop'n 41A (1.63 t/ha) and Glutinous Syn. #41 (1.53 t/ha) were the outstanding cultivars among the glutinous entries. Sweet maize was more susceptible to downy mildew disease than glutinous maize.

Sorghum. In the 1980-81 dry season, 11 elite lines and cultivars were evaluated with zero tillage after rainfed wetland rice at IRRI. The same lines or cultivars were tested under high-tillage upland conditions in Bauan, Tuguegarao.

At IRRI, UPLB SG 5, the variety used in cropping pattern testing, was the top yielder (3.26 t/ha). It significantly outyielded five entries. Other promising lines were CS 116 (3.23 t/ha), CS 110 (3.07 t/ha), CS 192 (2.93 t/ha), and CS 226 (2.92 t/ha). These lines mature in 88 days.

In Tuguegarao, CS 110 gave the highest yield (2.46 t/ha), followed by CS 226 (2.16 t/ha). CS 226 was more resistant to rust than CS 110.

Sweet potato. In the 1980-81 dry season, 9 cultivars were tested with zero tillage after wetland rice at the IRRI farm and 12 at the CIADP station in Iguig, Cagayan. Eleven cultivars were evaluated under high-tillage upland conditions in Bauan, Tuguegarao.

At IRRI, all cultivars yielded more than 10 t marketable tubers/ha. The highest yielding entry was Tinipay (14.69 t/ha). Catanduanes (13.76 t/ha), Minesuya (12.63 t/ha), and Kinabakab (12.20 t/ha) ranked second, third, and fourth. BNAS 51 (10.40 t/ha), the recommended variety for cropping pattern testing, ranked fifth. Minesuya (6.78 t/ha) and Kinabakab (5.68 t/ha) also produced the highest tip yields. They were also most tolerant of weevil damage. Hinschu (39.1 t/ha) and Quezon 5 (34.5 t/ha) produced the highest vine yields. The high yield levels of all cultivars could be attributed to sufficient moisture and high solar radiation available throughout crop growth.

In Cagayan, BNAS 51 produced the highest marketable tuber yield (7.52 t/ha), Catanduanes the second highest (6.53 t/ha) and Minuras the third (5.84 t/ha). Other promising entries were Tinipay (4.88 t/ha) and Kinabakab (3.90 t/ha).

In Tuguegarao, the outstanding entry was Kinabakag (4.49 t/ha). BNAS 51 gave the lowest yield (0.74 t/ha) because of high weevil damage.

Sesame. During the 1980-81 dry season, a preliminary yield trial of seven sesame cultivars was conducted with zero tillage after wetland rice at the IRRI farm. The most promising entries were Pitsanulok (181 kg seed/ha), Nakornsawan (173 kg/ha), Local Red Variety (145 kg/ha), and Tk 3 (132 kg/ha). These cultivars were also the outstanding entries under high-tillage upland conditions in the 1979-80 dry-season test. They mature 73-77 days after seeding.

SOYBEAN ADAPTATION IN RICE-BASED CROPPING PATTERNS

Multiple Cropping Department

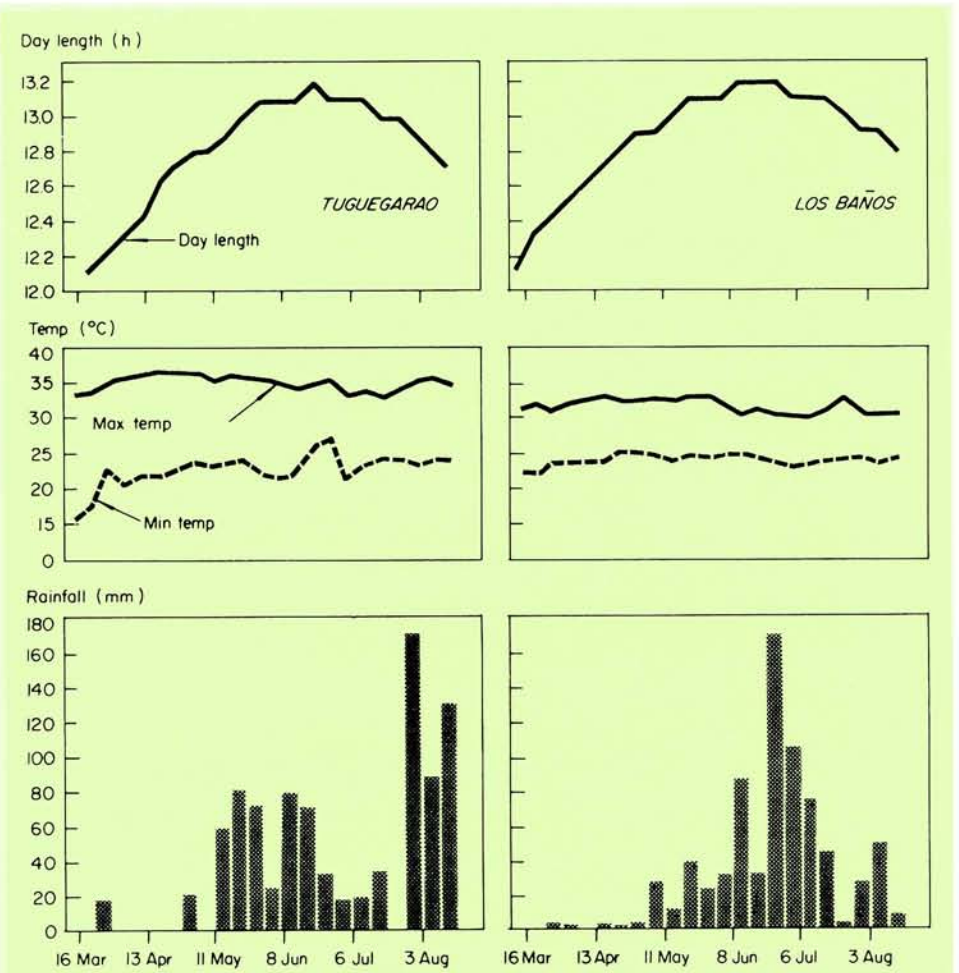
The yield potential of soybeans in tropical areas is reportedly similar to that in temperate regions, but great variability in mean yields among locations shows that exploitation of yield potential requires a better understanding of environmental and management variables.

A number of plant characteristics were measured on 25 soybean cultivars of differing origin, grown at 2 locations before and after rice crops. Factor analysis was used as an interpretive and data-reduction technique to derive composite attributes and to explain the correlations between the original variables in terms of a smaller set of factors.

Before rice. Plantings at Los Baños and Tuguegarao encountered dry-wet monsoon transition environments, with drier conditions during early crop development and excessive moisture later (Fig. 6). The means and ranges of attribute values at each site are listed in Table 13.

Mean seed yields of 1.85 t/ha at Tuguegarao and 2.48 t/ha at Los Baños indicate the potential of soybean in this environment. Yield and selected characteristics of the cultivars are listed in Tables 14 and 15. Cultivars Pb 1, Fitzroy, Clark 63, Tunia, and Improved Pelican were among the top 10 yielders at both locations. Later maturing cultivars IGH23, L-114, and Jupiter were low yielding at both locations and also produced poorer quality seed. Early varieties TK-5, Williams, Clark 63, UPLSY-2, and SL-6 escaped the adverse effects of excessive moisture. They were harvested 88 days after seeding.

Although day length values did not show detectable changes between the locations, number of days to flowering was not identical for all cultivars.



6. Weekly mean maximum + minimum temperatures, weekly total rainfall and weekly mean day length at Tuguegarao and Los Baños, Philippines, 1981.

Table 13. Means and ranges of values at 3 sites, 1981-82.

Variable	Mar-Aug 1981				Oct 1981-Jan 1982	
	Los Baños		Tuguegarao		Digos	
	Mean	Range	Mean	Range	Mean	Range
Days to harvest	99	78-119	104	86-147	86	78- 94
Days to first flower	28	19- 44	29	21- 51	29	24- 42
Grain filling period (R5-R8) (days)	49	33- 65	44	21- 66	43	33- 54
Plant height at R1 (cm)	35	18- 70	51	28-105	46	26- 94
Plant height at R8 (cm)	73	22-130	100	46-140	73	30-123
Seed yield (t/ha)	2.5	1.2- 3.5	1.9	1.0- 3.0	2.3	1.5- 3.1
Node no. at R1	8.4	5.5-13.9	7.4	3.4-14.6	9.2	5.6-16.2
Node no. at R8	13.9	7.4-22.5	13.8	6.9-22.3	13.9	7.0-20.6
100 seed weight (g)	15.3	7.9-21.5	15.6	5.8-19.5	17.2	7.0-23.1
Phytodaylength (h)	12.9	12.1-13.2	12.8	12.1-13.2	12.0	11.9-12.2
Max temp (°C)	31.6	30.5-33.1	35.0	33.0-36.5	24.0	22.5-24.8
Min temp (°C)	23.7	21.5-25.1	22.8	17.0-27.5	23.4	21.9-24.4

Table 14. Yield and selected characteristics of soybean cultivars at Los Baños, Mar-Jul 1981.

Yield rank	Cultivar	Yield (t/ha)	Days to R1	Grain filling period (days)	Days to harvest	Height at R1 (cm)	Height at harvest (cm)	Node no. at R1	Node no. at harvest	100 seed wt (g)	Pods per plant	Lodging score rating[a]
1	Pb. 1	3.403	26	44	93	30.2	67.6	7.6	14.3	14.1	56	1.5
2	Nuwara Eliya	3.301	37	35	92	48.2	95.4	11.0	18.2	10.6	48	3.5
3	Fitzroy	3.152	22	65	108	21.3	79.0	6.5	16.8	14.4	62	1.0
4	Improved Pelican	2.981	28	65	114	28.8	110.3	8.1	20.7	14.3	64	1.75
5	Tunia	2.954	24	61	110	22.0	70.0	6.8	14.8	20.7	34	1.0
6	Davis	2.950	20	56	93	20.9	30.4	6.4	10.4	19.8	43	1.0
7	Multivar 80	2.902	22	48	92	22.5	101.7	6.9	14.3	15.6	28	2.0
8	Clark 63	2.802	25	46	84	29.6	59.9	8.3	12.0	17.9	35	1.5
9	Orba	2.760	28	49	94	38.7	72.4	8.7	15.4	15.5	48	3.25
10	F76-8827	2.641	20	54	94	19.2	22.2	6.3	7.8	21.5	39	1.0
11	Ecuador	2.638	35	56	114	44.8	57.2	9.7	10.8	14.2	53	1.0
12	UF-VI (BP2)	2.586	24	59	118	29.7	130.2	8.0	22.5	13.4	65	3.0
13	ACC. 2120	2.505	44	40	108	69.7	116.2	13.9	19.8	7.9	98	4.0
14	UPLSY-2	2.375	24	46	86	28.5	71.3	7.6	13.7	19.2	35	1.25
15	SJ-2	2.370	29	44	94	38.7	79.6	8.1	14.7	15.4	52	2.5
16	L-114	2.321	36	57	119	47.6	98.7	9.9	19.3	13.1	71	1.25
17	Alamo	2.112	38	45	109	43.9	57.4	10.5	10.8	12.7	48	1.5
18	TK-5	2.103	29	34	78	39.6	59.6	8.7	11.0	15.6	40	1.5
19	Williams	1.992	20	39	83	19.6	55.5	6.1	13.0	20.2	32	1.0
20	SL-6	1.947	25	41	84	31.2	54.6	7.5	11.0	12.0	29	1.5
21	30290-11-11	1.805	30	46	95	40.0	86.4	8.4	13.9	18.1	33	3.25
22	Bossier	1.714	19	58	92	17.7	23.5	5.5	7.4	19.5	25	1.0
23	Jupiter	1.665	40	45	118	59.2	71.8	10.8	11.3	10.9	47	1.0
24	IGH-23	1.532	38	52	118	52.8	75.0	10.6	12.0	10.5	44	1.0
25	Caribe	0.142	32	56	151	36.6	194.3	10.0	25.2	7.3	43	4.5

[a] Lodging score rating: 1 = all plants erect; 5 = all plants lodged.

Table 15. Yield and selected characteristics of soybean cultivars at Tuguegarao, Mar-Aug 1981.

Yield rank	Cultivar	Yield (t/ha)	Days to R1	Grain-filling period (days)	Days to harvest	Ht at R1 (cm)	Ht at harvest (cm)	Nodes (no.)		100-seed wt (g)	Pods (no./plant)	Lodging score rating[a]
								At R1	At harvest			
1	SL-6	2.910	28	36	88	58.2	95.2	7.5	10.6	19.0	30	2.0
2	UPLSY-2	2.635	28	34	87	50.6	91.3	7.3	12.7	18.8	31	2.0
3	Pb-1	2.580	27	38	90	47.0	103.9	7.4	14.2	16.9	36	2.0
4	Clark 63	2.535	28	37	87	51.2	96.8	8.3	12.9	14.0	35	2.0
5	UF-VI (BP2)	2.395	27	47	111	48.9	140.0	7.3	20.8	14.4	58	3.0
6	Tunia	2.295	24	52	106	28.2	91.4	4.8	15.5	19.5	36	2.0
7	Ecuador	2.220	34	45	120	59.1	98.4	8.9	10.3	14.9	37	1.0
8	Alamo	2.185	32	64	112	50.2	104.4	8.5	11.2	15.0	34	2.0
9	Improved Pelican	2.180	29	49	106	46.5	115.4	7.2	17.5	13.3	42	3.0
10	Fitzroy	2.125	22	57	109	31.8	92.5	4.0	16.0	13.8	48	1.0
11	30290-11-11	1.980	31	38	92	60.3	107.9	9.1	12.3	19.5	21	2.0
12	Orba	1.790	28	57	108	49.8	111.3	7.4	16.4	16.5	59	3.0
13	Bossier	1.665	22	42	90	32.7	55.1	8.8	7.5	17.1	23	1.0
14	TK-5	1.660	29	36	86	56.0	97.3	3.5	11.7	15.0	21	2.0
15	Nuwara Eliya	1.650	34	34	97	52.4	126.7	9.1	20.1	10.0	50	2.0
16	SJ-2	1.640	29	39	106	45.6	122.1	6.8	17.9	14.0	44	2.0
17	Davis	1.600	21	43	91	32.1	54.4	3.4	7.7	18.2	29	1.0
18	Multivar 80	1.370	22	34	90	39.8	121.3	5.6	16.5	15.3	41	2.0
19	Jupiter	1.320	26	66	141	46.0	104.1	7.0	11.6	16.3	54	1.0
20	F76-8827	1.265	22	46	94	28.2	46.2	4.4	6.9	18.7	39	1.0
21	Williams	1.265	21	39	87	31.9	53.5	3.5	11.0	18.8	26	1.0
22	IGH 23	1.181	46	60	147	102.2	118.5	12.1	13.7	15.8	43	2.0
23	ACC 2120	1.036	51	21	108	105.4	130.2	14.6	15.8	5.8	82	3.0
24	L-114	0.953	41	48	133	69.7	132.4	11.1	22.3	14.5	53	2.0
25	Caribe	–	31	–	(190)	49.1	(119.9)	9.9	(21)	–	–	4.5

[a] 1 = all plants erect, 5 = all plants lodged.

Flowering was delayed in later maturing cultivars IGH23, Acc. 2120, and L-114 at Tuguegarao.

The 13 plant variables used in the factor analysis are listed in Table 16 and the simple correlation coefficients for the Los Baños crops are presented in Table 17.

Factor interpretation. At Los Baños, 4 factors accounted for 86% of the total variance (Table 18). Because of high loadings on days from emergence to first flower R1 (DR1), main stem node number at R1 (NDR1), and plant height at R1 (HTR1), factor 1, which accounted for 42% of the total variance, was interpreted as expressing vegetative growth phase (VGP). Factor 2, accounting for 24% of the total variance, was interpreted as expressing indeterminancy (INDT) because of high loadings on HT18 and ND18. Factor 3 was interpreted as expressing reproductive growth duration (RGD) because of high loadings on DR15 and DR58. Factor 4 expressed nodulation (NOD). VGP and INDT were dominant.

At Tuguegarao, 4 factors accounted for 81% of the total variance (Table 19). The factor matrix showed a pattern of loadings on the variables similar to that in the Los Baños data. The factors expressing VGP and INDT were again dominant.

Intercorrelation among factors. Correlation coefficients between factors of similar expression

Table 16. Variables and mnemonic codes included in the factor analysis.

Variable	Mnemonic code
Days from emergence to 'first flower' R1	DR1
Days from R1 to 'begin pod' (R3)	DR13
Days from R3 to 'begin seed' (R5)	DR35
Days from R1 to R5	DR15
Days from R5 to harvest	DR58
Plant ht at R1	HTR1
Plant ht at R5	HTR5
Increase in height from R1 to harvest	HT18
Main stem node no. at R1	NDR1
Main stem node no. at R5	NDR5
Increase in main stem node no. from R1 to harvest	ND18
Nodule no. per plant	NODN
Nodule dry wt per plant	NODWT
Pod no. per plant	PODPL
No. of branches per plant	BRAPL
Total no. of pod bearing nodes per plant	TNODE
Lodging score rating	LODGSC
100-seed wt	SDWT

Table 17. Simple correlation coefficients between selected variables, Los Baños, Mar-Jul 1981.

Variable[a]	DR1	DR15	DR58	HTR1	NDR1	HT18	ND18	TNODE	NODN	PODPL	BRAPL	LODGSC	SWDT
DR1	1.000	0.44***	0.30*	0.96**	0.95**	-0.08	-0.23	0.40**	0.07	0.55**	0.70**	0.36*	-0.75**
DR15		1.000	0.27	0.40**	0.41**	0.40**	0.32	0.40**	-0.05	0.58**	0.36*	0.10	-0.51**
DR58			1.000	-0.38**	-0.35*	0.26	0.38**	-0.02	0.09	0.16	-0.16	-0.35*	0.22
HTR1				1.000	1.000	-0.08	-0.23	0.45**	0.14	0.55**	0.67**	0.44**	-0.74**
NDR1						-0.01	-0.17	0.53**	0.06	0.60**	0.69**	0.47**	-0.74**
HT18						1.000	0.91**	0.49**	0.09	0.34*	-0.40**	0.43**	-0.17
ND18							1.000	0.53**	0.16	0.39**	-0.51**	0.35*	-0.04
TNODE								1.000	0.11	0.72**	0.29*	0.75**	-0.46**
NODN									1.000	0.17	-0.15	0.23	-0.06
PODPL										1.000	0.35**	0.42**	-0.57**
BRAPL											1.000	0.19	-0.47**
LODGSC												1.000	-0.36*
SDWT													1.000

[a]Refer to table 16 for explanation of codes.

Table 18. Factor loadings[a] of 13 variables on 4 obliquely rotated factors derived from data on 24 soybean cultivars, Los Baños, Mar-July 1981.

Variable[b]	Factor				Communalities h^2
	1	2	3	4	
DR1	0.961				0.92
DR15	0.616		0.569		0.79
DR58			0.885		0.84
HTR1	0.935				0.94
NDR1	0.929				0.93
HT18		0.953			0.88
ND18		0.944			0.97
TNODE		0.718			0.80
NODN				1.000	0.97
PODPL	0.664				0.77
BRAPL	0.862				0.78
LODGSC		0.658			0.86
SDWT	-0.790				0.69
	Variance accounted for (%)				
	42.4	24.2	11.2	7.7	
	Cumulative variance accounted for (%)				
	42.4	66.6	77.9	85.6	

[a]Only values great enough to be considered as characterizing the factor in the biological context are presented. [b]Refer to Table 16 for explanation of codes.

Table 19. Factor loadings[a] of 13 variables on 4 obliquely rotated factors derived from data on 24 soybean cultivars, Tuguegarao, Mar-Jul 1981.

Variable[b]	Factor				Communalities h^2
	1	2	3	4	
DR1	0.948				0.90
DR15			0.754		0.72
DR58			0.627		0.75
HTR1	0.946				0.92
NDR1	0.942				0.88
HT18		0.895			0.80
ND18		0.935			0.92
TNODE	0.690				0.90
NODN				-0.867	0.76
PODPL	0.621				0.77
BRAPL	0.695				0.71
LODGSC	0.598	0.541			0.86
SDWT	-0.672				0.65
	Variance accounted for (%)				
	40.1	20.7	11.6	8.6	
	Cumulative variance accounted for (%)				
	40.1	60.8	72.4	81.0	

[a]Only those values great enough to be considered as characterizing the factor in the biological context are presented. [b]Refer to Table 18 for explanation of codes.

extracted separately at each location were highly significant (Table 20). The similar factor-loading patterns at the two locations and the strong correlation between factors of similar expression from each location, suggest that environments in Los Baños and Tuguegarao were not sufficiently different to alter expression of plant characteristics in the cultivars tested.

Factors associated with yield. Regression analysis (Table 21) indicated that VGP was the dominant factor explaining yield variability at both locations. INDT and RGD attributes also were

Table 20. Intercorrelations of factors extracted from Los Baños and Tuguegarao experiments,[a] Mar-Aug 1981.

Los Baños	Tuguegarao			
	Factor 1 VGP	Factor 2 INDT	Factor 3 RGD	Factor 4 NOD
Factor 1 – VGP	0.945**	-0.403	0.080	-0.137
Factor 2 – INDT	-0.197	0.978**	-0.141	0.029
Factor 3 – RDG	-0.413	-0.066	0.885**	0.117
Factor 4 – NOD	-0.203	-0.113	-0.157	-0.660*

[a]VGP = vegetative growth phase, INDT = indeterminancy, RDG = reproductive growth duration, NOD = nodulation.

Table 21. Regression statistics from PROC GLM (excluding replication dummy coefficients).

Variable	Regression coefficient	Std. error	F value
Los Baños (Mar-Jul 1981)			
INDT	0.122	0.077	2.56
VGP SQ.	-0.203	0.054	14.58**
VGP x RGD	-0.460	0.114	16.33**
Tuguegarao			
RGD	-0.244	0.063	15.15**
VGP SQ.	-0.166	0.034	23.67**
VGP x INDT	-0.235	0.089	6.97*
VGP x NOD	-0.154	0.073	4.45*
Davao			
INDT SQ	-0.086	0.037	5.28*
PD x NOD	-0.142	0.053	6.97*

*, ** = significant at 0.05 and 0.01 probability levels, respectively.

associated by way of interactions with yield variation.

Early-maturing cultivars that do not exhibit excessive vegetative growth appeared best suited for the prerice environment.

After rice. The postrice planting at IRRI did not experience the expected wet-dry transition environment but was wet throughout. Typhoon 64 days after emergence resulted in almost complete defoliation when all cultivars had reached R5 stage (Fig. 7). Yields were drastically reduced, the effect being more severe on later maturing cultivars.

In Digos, Davao, the environment was comparatively drier and the crop did not encounter excessive wetness. With slightly different daylength values, number of days to flowering in most cultivars was not changed but the total crop duration was much less than the prerice plantings. Yield and selected characteristics of the cultivars are presented in Table 22. Earlier flowering, determinate cultivars from higher latitudes (Davis and F76-8827) were among the low yielders because of curtailed vegetative growth. Eight of the 10 top yielders were cultivars originating from lower latitudes. However, vegetative growth of most cultivars was satisfactory during the short-day season, and the positive correlation between yield and node number was significant.

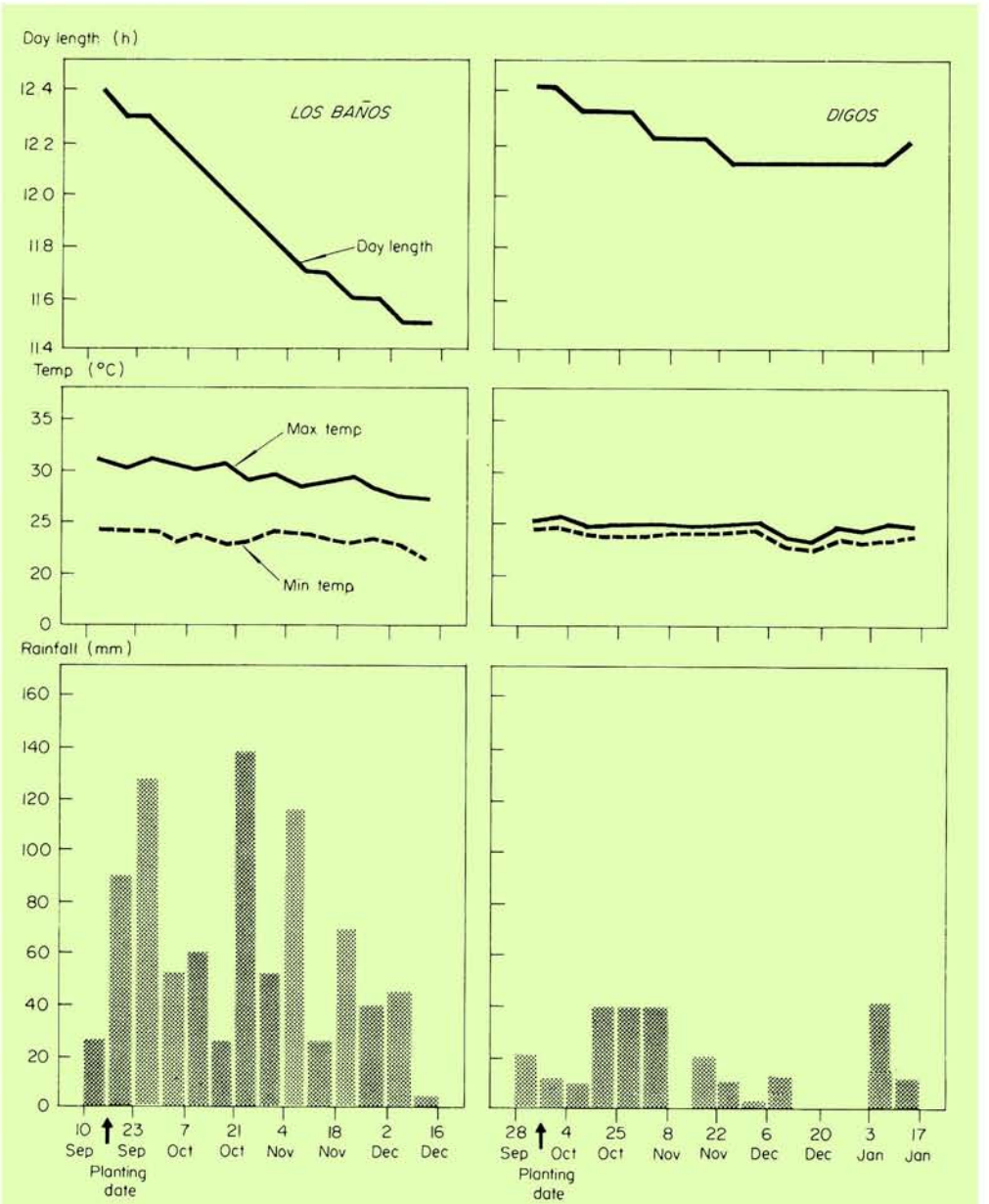
Four factors accounted for 78% of the total variability in the 17 measured attributes (Table 23). Because of high loadings on DR1, HTR1, and NDR1, factor 1 could be interpreted as expressing VGP. Alternatively high loadings on PODPL and TNODE suggest an alternate interpretation such as fruiting potential (FP). Factor 2, accounting for 16% of total variability, was interpreted as expressing INDT because of high loadings on HT18 and ND18. Factor 3 was interpreted as expressing pod set duration (PSD) because of high loading on DR35 and factor 4 as expressing nodulation (NOD). These four factors accounted for most of the variance, with VGP as the most important. Their composition and that of the factors extracted from the two prerice environments were not very similar, indicating that environmental differences altered phenotypic expression.

Regression analyses did not explain as much of the seed yield variation as the classification models (Table 24).

SCREENING SORGHUMS FOR DORMANCY

Multiple Cropping Department

An important constraint in sorghum is its lack of dormancy. When favorable conditions exist (3 or more days of continuous rain), grains (hard dough



7. Weekly mean maximum and minimum temperatures, weekly total rainfall, and weekly mean day length at Los Baños and Davao, Philippines, 1981-82.

stage or older) will germinate in the head in the field.

In 1981, 630 cultivars from the USA and Africa were tested for dormancy. Each cultivar was planted in 2-× 4-m rows, with 50 cm between rows. Flowering time was tagged at 25% anthesis and heads were harvested 30, 35, 40, 45, and 50 days after flowering. An immediate germination test used the petri dish method. After 5 days, percentage germination was computed (Table 25).

Table 22. Yield and selected characteristics of soybean cultivars at Davao, October 1981-January 1982.

Yield rank	Cultivar	Yield (t/ha)	Days to R1	Grain-filling period (days)	Days to harvest	Ht at R1 (cm)	Ht at harvest (cm)	Nodes (no.)		100-seed wt (g)	Pods (no./plant)	Lodging score
								At R1	At harvest			
1	SL-6	3.14	26	40	80	40	57	8.7	11.6	21.4	39	1.0
2	30290-11-11	2.82	29	43	84	44	70	9.2	12.7	23.1	41	1.0
3	Acc. 2120	2.67	42	33	89	94	123	16.2	20.6	7.0	122	4.8
4	Tunia	2.66	25	43	84	38	55	9.9	15.1	20.2	44	1.0
5	UFVI-BP2	2.51	28	47	89	53	103	9.0	16.1	18.5	47	2.0
6	Nuwara Eliya	2.50	33	33	83	48	98	9.3	16.4	10.0	56	4.5
7	Orba	2.50	28	48	83	40	69	9.7	14.3	19.1	62	1.0
8	Improved Pelican	2.48	29	46	88	50	91	9.5	16.9	16.0	62	2.0
9	SJ-2	2.45	29	38	86	60	96	9.2	15.3	17.2	58	2.0
10	TK-5	2.45	29	44	83	45	58	7.9	12.6	21.9	33	1.0
11	Multivar 80	2.35	28	45	84	54	97	9.7	14.2	17.9	45	1.5
12	UPLSY-2	2.35	27	44	79	34	63	8.3	15.0	19.5	38	1.0
13	Alamo	2.28	39	37	88	57	69	10.0	11.7	14.4	45	2.0
14	Pb-1	2.21	27	43	83	39	55	9.8	13.3	14.4	64	1.0
15	Ecuador	2.17	31	42	91	45	67	9.6	12.2	14.5	44	1.0
16	Bossier	2.16	28	38	85	47	65	8.8	10.9	18.0	45	1.0
17	Clark 63	2.14	28	42	83	46	66	9.0	12.7	18.1	33	1.5
18	Fitzroy	2.12	25	48	91	31	63	8.5	14.4	16.6	51	1.0
19	Williams	2.00	24	47	90	36	63	9.5	16.1	20.0	43	1.0
20	L-114	2.00	30	46	93	47	85	8.9	16.1	16.8	50	2.0
21	Davis	1.95	25	54	86	27	33	6.8	8.8	19.0	32	1.0
22	Jupiter	1.92	29	47	94	42	56	7.8	9.7	17.4	28	1.0
23	IGH-23	1.82	41	37	91	73	94	10.8	14.5	14.9	48	2.5
24	Caribe	1.71	29	39	94	41	99	8.8	19.1	12.9	69	4.0
25	F76-8827	1.54	24	54	85	26	30	5.6	7.0	18.1	25	1.0

[a] 1 = all plants erect, 5 = all plants lodged.

Table 23. Factor loadings[a] of 17 variables on 4 obliquely rotated factors derived from data on 25 soybean cultivars, Davao, Oct 1981-Jan 1982.

Variable	Factor				Communalities h^2
	1	2	3	4	
DR1	0.818				0.81
DR13		0.605			0.56
DR35			0.926		0.80
DR58	-0.605		-0.542		0.79
HTR1	0.874				0.83
HTR5	0.592	0.406			0.79
NDR1	0.982				0.85
NDR5	0.707	0.526			0.88
NODN				0.636	0.74
NODWT				0.968	0.88
SDWT	-0.700				0.65
BRAPL		-0.656			0.70
LODGSC	0.671				0.76
PODPL	0.884				0.82
TNODE	0.899				0.74
HT18		0.827			0.79
ND18		0.959			0.92
	Variance accounted for (%)				
	47.4	16.0	7.8	7.1	
	Cumulative variance accounted for (%)				
	47.4	63.4	71.2	78.3	

[a]Only those values great enough to be considered as characterizing the factor in the biological context are presented.

Table 24. Comparison of model and residual mean squares and coefficients of determination (R^2) from classification and regression models used to analyze seed yield data.[a]

	Los Baños		Tuguegarao		Davao	
	df	MS	df	MS	df	MS
Classification model	24	0.5458**	24	0.5875**	25	0.2506**
Residual	23	0.1516	23	0.01343	24	0.0622
R^2	0.79		0.95		0.81	
Regression model	4	1.7755**	5	1.5040**	3	0.7345**
Residual	43	0.2206	42	0.1755	46	0.1208
R^2	0.43		0.51		0.28	

[a]df = degrees of freedom, MS = mean square, ** = significant at 0.01 level of probability.

Table 25. Yield and dormancy of the different sorghum cultivars 30-50 days after flowering (DF), 1981.

Cultivar	Yield (t/ha)	Dormancy (%)				
		30 DF	35 DF	40 DF	45 DF	50 DF
IS 9435	0.67	0	10	29	43	69
IS 2832	2.25	0	10	31	48	65
IS 12299	0.52	0	10	18	36	55
IS 9486	0.90	0	10	31	45	78
IS 9565	1.53	0	10	31	46	59
IS 9548	0.04	0	10	18	29	51
IS 9470	1.81	0	10	33	49	75
IS 9293	0.81	0	21	37	49	78
IS 9479	3.45	0	12	37	47	84
IS 9530[a]	3.17	14	51	–	–	–
IS 14280	1.35	96	–	–	–	–
IS 9252	0.80	95	–	–	–	–

[a]Best selection at Texas A&M.

Table 27. Data on some agronomic characteristics of the test varieties and selections, 1981 wet season.

Variety, selection	Maturity (DS[a])	Plant ht at harvest (cm)	Lodging[b]		
			Antique	Zamboanga del Sur	Pangasinan
IR36	102	96	5.6	1.0	1
IR50	107	110	1.0	1.0	1
IR52	95	89	6.3	1.7	1
IR9708-51-1-2	96	95	7.0	1.7	1
IR9729-67-3	90	94	–	1.0	3
IR9752-1-2-1	98	94	5.0	1.0	1
IR9752-71-5-2	90	85	1.6	1.0	1
IR19728-9-3-2-3-3	93	98	9.0	1.0	9
IR19735-5-2-3-2-1	93	91	7.6	1.0	1
IR19743-40-3-3-2-3	90	92	7.6	1.0	5

[a]DS = no. of days after seeding to harvest. Mean of 3 replications from 8 sites. [b]Scale for lodging based on Standard Evaluation System for Rice, 2nd edition, 1976. No lodging observed in 5 sites. Table shows lodging in 3 sites.

RICE VARIETY APPLIED RESEARCH TRIALS

Rice Production Training and Research Department

The search for a better selection to replace current varieties continued. For the two-crop system of growing rainfed-wetland rice, 3 IRRI varieties and 8 early-maturing promising lines were tested. As a first crop, they were direct-seeded in dry soil before the start of the 1981 rainy season. Data on grain yield from 8 sites in 6 Philippine provinces are shown in Table 26.

IR36 gave as high yields as other varieties and selections in seven of eight sites. IR50 and IR52 performed as well in five of eight sites. IR36, IR50, and IR52 gave the same yields in five of eight sites. IR36 outyielded IR50 and IR52 in 50% of the sites. IR50 and IR52 each had the best yields in 1 site each. They had the same yield in one site, higher than IR36.

All selections had yields as high as the best yields in 2 sites each, at 6.8 and 5.5 t/ha, except IR19743-40-3-3-2-3, which had lower yields. IR9752-1-2-1 outyielded all 3 IRRI varieties in 2 sites in Pangasinan. IR9752-71-5-2 yielded as much as IR36 and better than IR50 and IR54 in Kidapawan and North Cotabato.

No yield differences were found among the varieties and selections in Patnongon, Antique. Yields there were higher than 5.8 t/ha.

Major diseases occurred only at Norala, South Cotabato, where rice was attacked by blast. IR36, IR19728-9-3-2-3-3, IR9752-71-5-2, and IR19735-5-2-3-2-1 had the highest yields in South Cotabato. IR50 (2.5 t/ha) and IR52 (1.4 t/ha) showed susceptibility to blast.

No meaningful analysis or conclusion could be derived from the Pagadian and Zamboanga del Sur sites because of heavy damage by rats.

Applied research trials and multilocation tests. All varieties and selections were harvested in less than 100 days, earlier than IR36 and IR50 (Table 27). The earliest selections were IR9729-67-3 and IR19743-40-3-3-2-3, harvested 90 days after sowing.

Perpetual flooding at Patnongon, contributed to the lodging susceptibility of most varieties and selections. Lodging at Zamboanga del Sur was actually due to rat damage. All other sites reported no lodging.

Cropping systems program

Agronomic management in rice-based cropping patterns

Multiple Cropping and Rice Production Training and Research Departments

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PLANTING DATE FOR TRANSPLANTED RICE

Multiple Cropping Department

In an experiment to determine the optimum date for transplanting rice in stratum 1 at the Solana outreach site, rice seedlings of different ages were transplanted at weekly intervals: 31-day-old seedlings, 2 November (T1); 36-day-old seedlings, 13 November (T2); 34-day-old seedlings, 21 November (T3); 30-day-old seedlings, 28 November (T4).

Experimental plots received two plowings and harrowings. IR36 seedlings were transplanted at 25-cm spacing between hills and rows. Ammonium sulfate was applied at 80 kg N/ha, one-half as basal and one-half at panicle initiation. Cultural practices were similar to those used in the cropping pattern trials.

The effects of planting date on maturity and yield are shown in Table 1. Yield decreased with each planting date. Crops planted later suffered from drought starting in January.

Table 1. Effect of planting time on maturity and yield of IR36 in stratum 1 at Solana, Cagayan, Philippines, 1981.

Planting date	Maturity (days)	Yield[a] (t/ha)
2 November	124	4.1 a
13 November	122	3.7 a
21 November	114	2.6 b
28 November	114	0.4 c
ANOVA		*
CV (%)		10

[a]Separation of means in a column by Duncan's multiple range test at the 1% level.

EFFECT OF SEEDLING AGE AND NUMBER PER HILL ON YIELD

Multiple Cropping Department

A farmer in the area of the Solana outreach site can be plagued by too much and too little water during the same growing season. An experiment in stratum 1 tested the effect of seedling age and number per hill on growth and yield of transplanted IR52.

Wet-bed seedlings aged 30 and 40 days were planted at 2-3, 4-5, and 6-7 seedlings/hill. Ammonium sulfate at 60 kg N/ha was applied, half as basal and half at panicle initiation. Other cultural practices were standard for cropping pattern plots.

Table 2. Effect of number of seedlings per hill and seedling age on plant height at 4 and 6 weeks after transplanting (WT) and at maturity of IR52 planted at 30 and 40 days old.[a] Solana, Cagayan, Philippines, 1981.

Seedlings (no./hill)	Plant ht (cm)					
	4 WT		6 WT		Maturity[b] (days)	
	30 days	40 days	30 days	40 days	30 days	40 days
2-3	62	62	76	74	89	91
4-5	60	64	76	75	90	90 a
6-7	60	62	76	75	91	86 b

[a]Means of 4 replications. [b]Separation of means by Duncan's multiple range test at the 5% level.

Table 3. Effect of seedling age and number of seedlings per hill on number of productive and unproductive tillers, yield, and field duration of IR52 transplanted at 30 and 40 days. Solana, Cagayan, Philippines, 1981.

Seedlings (no.)	Tillers (no.)				Yield[a] (t/ha)		Field duration (days)	
	Productive		Unproductive					
	30 days	40 days	30 days	40 days	30 days	40 days	30 days	40 days
2-3	13.6	11.9	1.4	0.4	3.8	3.1	88	81
4-5	10.9	12.1	0.9	0.7	3.6	3.2	88	81
6-7	11.7	13.3	1.6	0.7	3.5	3.1	88	81
$\bar{X}$	12.1	12.4	1.3	0.6	3.6 a	3.1 b	88	81

[a]Means of 4 replications. Yield differences significant at the 5% level.

Plant height 4 and 6 weeks after transplanting (WT) did not differ significantly (Table 2). At maturity, the 40-day-old seedlings were taller when fewer seedlings per hill had been planted. The number of productive tillers per hill was not affected significantly by seedling age nor by number of seedlings per hill (Table 3). Grain yield was not affected by the number of seedlings per hill, but yield of 30-day-old seedlings was about 0.5 t/ha higher than yield of 40-day-old seedlings. The 40-day-old seedlings were harvested 7 days ahead of the 30-day-old seedlings.

EFFECT OF SEEDBED FERTILIZATION ON SEEDLING VIGOR

Multiple Cropping Department

Farmers in the Solana outreach site area raise seedlings in dry beds because of insufficient water. Seedlings in dry seedbeds are usually short and sometimes suffer from floods. Fertilizer application could produce tall and vigorous seedlings with improved survival against flooding.

An experiment was conducted to determine the optimum rates for applying nitrogen, phosphorus, or potassium, to enhance seedling growth. The effect of seedbed fertilization on yield also was examined.

IR52 and RD17 seeds were soaked in water for 24 hours, then incubated for 48 hours. Seedbed fertilizer treatments (kilograms per hectare of N-P_2O_5-K2O) consisted of: 0-0-0, 20-0-0, 20-20-0, 20-20-20, and 40-20-20. For 40-20-20, half the nitrogen was applied at sowing and half 2 weeks after emergence. In the other treatments, all the fertilizer was incorporated in the soil before sowing.

At 48 days after emergence, seedlings were transplanted to stratum 2. All treatments received 60 kg N/ha applied in equal splits at planting and 40 days after transplanting.

The effects of seedbed fertilization on seedling vigor are shown in Table 4. Application of 20 kg N/ha increased seedling vigor of IR52 and RD17 for 2-3 weeks after emergence. Phosphorus and potassium had no effect. RD17 seedlings were more vigorous when the nitrogen rate was doubled. However, by 2 and 4 weeks after transplanting, seedlings from different treatments looked similar.

Table 4. Effect of seedbed fertilization on seedling vigor of 2 rice varieties at different seedling ages.[a] Solana, Cagayan, Philippines, 1981.

Nitrogen (kg/ha)				Seedling vigor[b]			
N	P_2O_5	K_2O		2 WE	4 WE	2 WT	3 WT
				IR52			
0	0	0		3.7	5.0	3	1
20	0	0		1.7	3.0	3	1
20	20	0		3.0	3.0	3	1
20	20	20		3.0	3.0	3	1
40	20	20		3.0	2.3	3	1
			$\bar{X}$	2.9	3.3	3	1
				RD17			
0	0	0		5.0	5.0	1	1
20	0	0		2.3	3.0	1	1
20	20	0		2.3	3.0	1	1
20	20	20		2.3	3.0	1	1
40	20	20		1.7	1.7	1	1
			$\bar{X}$	2.7	3.1	1	1
				Mean across variety			
0	0	0		4.4	5.0	2	1
20	0	0		2.0	3.0	2	1
20	20	0		2.6	3.0	2	1
20	20	20		2.6	2.3	2	1
40	20	20		2.3	2.6	2	1

[a] Av of 3 replications. [b] Seedling vigor rating: 1 = most vigorous, 3 = average, 5 = least vigorous. WE= weeks after emergence in seedbed, WT = weeks after transplanting.

Table 5. Effect of seedbed fertilization on plant height at different seedling stages and on root length at 48 days after emergence (DE).[a] Solana, Cagayan, Philippines, 1981.

Nitrogen (kg/ha)			Plant ht (cm)			Root length (cm) (48 DE)	Grain yield (t/ha)
N	P_2O_5	K_2O	48 DE	2 WT	3 WT		
				IR52			
0	0	0	63	44.7 e	56.7 bc	6.7	4.2
20	0	0	85	47.0 de	53.3 c	7.7	3.9
20	20	0	79	48.3 de	53.3 c	9.0	4.0
20	20	20	89	46.0 de	59.3 b	7.7	4.2
40	20	20	94	51.0 bcd	55.3 bc	7.0	4.2
		$\bar{X}$	(82)	(47.4)	(55.6)	(7.6) b	(4.1)
				RD17			
0	0	0	65	50.0 cd	57.0 bc	9.7	3.9
20	0	0	86	56.3 a	64.7 a	7.7	3.8
20	20	0	87	56.7 a	65.0 a	7.3	3.6
20	20	20	84	53.7 abc	67.7 a	9.0	3.8
40	20	20	97	55.3 ab	66.3 a	8.7	3.5
		$\bar{X}$	(83.8)	(54.4)	(64.1)	(8.5) a	(3.7)
				Fertilizer mean across variety			
0	0	0	64.0 c	47.4 b	56.8 c	8.2	4.0
20	0	0	85.5 b	51.6 ab	59.0 bc	7.7	3.8
20	20	0	83.0 b	52.5 a	59.2 bc	8.1	3.8
20	20	20	86.5 b	49.8 ab	63.5 a	8.4	4.0
40	20	20	95.5 a	53.1 a	60.8 ab	7.8^{ns}	3.8^{ns}

[a]Means of 3 replications. Separation of means in a column by Duncan's multiple range test at the 5% level. WT = weeks after transplanting.

Table 6. Effects of time of application of 60 kg N/ha on number of productive tillers and yield of dry-seeded IR52 in 2 strata, Solana, Cagayan, Philippines, 1981.

Time of application[a]	Productive tillers (no./m)		Grain yield (t/ha)	
	Stratum 1	Stratum 2	Stratum 1[b]	Stratum 2
1/3 B + 1/3 30 D + 1/3 PI	133	101	3.82 abc	2.49
1/2 20 D + 1/2 PI	139	80	3.70 abc	2.31
2/3 20 D + 1/3 PI	131	89	3.67 bc	2.62
1/2 40 D + 1/2 PI	147	90	4.20 ab	2.45
1/2 B + 1/2 20 D	126	102	3.62 c	2.12
2/3 B + 1/3 20 D	131	96	3.56 c	2.22
1/2 B + 1/2 40 D	147	105	4.12 abc	2.38
1/2 B + 1/2 PI	134	90	4.32 a	2.14
1/3 B + 2/3 40 D	135	100	4.01 abc	2.62
CV (%)	11	21	10	12

[a]B = basal at planting, D = days after planting, PI = panicle initiation. [b]Separation of means by Duncan's multiple range test at the 5% level.

Before transplanting, seedlings that received 20 kg N/ha in the seedbed were more than 2 cm taller than those that were not fertilized (Table 5). Doubling the nitrogen rate increased seedling height by 10 cm. Application of phosphorus and potassium did not affect seedling height.

The effect of 20 kg N/ha seedbed fertilization on plant height was exhibited until 2-4 weeks after transplanting. RD17 seedlings were taller than IR52 seedlings. Fertilizer had no effect on seedling root length. Tillering and yields of IR52 and RD19 were not affected either. IR52 yielded about 0.5 t/ha more than RD17.

TIME OF NITROGEN APPLICATION ON DRY-SEEDED RICE

Multiple Cropping Department

Dry-seeded rainfed rice is a relatively new technology at the Solana outreach site. Farmers in the area usually grow one rice crop per year using local varieties and the traditional random transplanting method. Of the major plant nutrients, nitrogen is quite deficient. In a study to evaluate the effect of time of nitrogen application on yield and yield components of dry-seeded rice, two experimental fields representing strata 1 and 2 were plowed with an animal-drawn plow and harrowed in mid-May. IR52 was drilled in furrows spaced 30 cm apart at 100 kg seed/ha. Fertilizer at 60 kg N/ha was applied in split doses at different growth stages.

The number of productive tillers and yield were greater in stratum 1 than in stratum 2 (Table 6). Typhoon Rubing in September, when the plants were flowering, caused about 30% damage in stratum 2. Time of nitrogen application did not significantly affect yield in stratum 2. In stratum 1, yield increased when nitrogen was applied as basal plus topdressing at later growth stages. The yield was highest with 50% basal nitrogen application plus 50% topdressing at panicle initiation.

EFFECT OF RATE AND TIME OF NITROGEN APPLICATION ON IR52

Multiple Cropping Department

Trial crops were grown in farmers' fields at the Solana outreach site to determine the best time and rate of nitrogen fertilizer application on wet-seeded and transplanted rice.

Wet-seeded trial. A stratum 1 plot was plowed and harrowed three times. Pregerminated IR52 seeds were sown at 100 kg/ha. Nitrogen was applied at planting (basal), at 20 days after emergence, and at panicle initiation. Rates of ammonium sulfate were 25, 50, and 75 kg N/ha. Plant height and number of tillers were recorded 4 and 6 weeks after emergence and at maturity. Yield was determined at 14% moisture.

Time and rate of nitrogen application did not significantly affect height or tillering. Plants that received 25 kg N/ha yielded 1 t/ha more than those unfertilized (Table 7). Higher nitrogen rates tended to increase yield and three split applications tended

Table 7. Effect of nitrogen rate on plant height, tillering, and yield of wet-seeded IR52 across 3 application times, stratum 1, Solana, Cagayan, Philippines, 1981 wet season.

Application rate (kg/ha)	Plant ht (cm)			Tillers (no./m²)		Grain yield (t/ha)
	4 (WE)	6 (WE)	Maturity	Productive	Unproductive	
Control (no nitrogen)	30.8	57.5	68.5	377	0.7	1.61
25	32.2	66.6	76.2	408	0.0	2.70
50	32.8	67.4	76.1	478	1.3	2.55
75	33.7	69.3	78.4	433	2.2	2.92
CV (%)	6.0	6.0	6.9	18.0	–	23.0

Table 8. Effects of time of nitrogen application on plant height, tillering, and grain yield of wet-seeded IR52 across 3 nitrogen rates, stratum 1, Solana, Cagayan, Philippines, 1981 wet season.

Time of nitrogen application[a]			Plant ht[b] (cm)			Tillers (no./m²)		Grain yield (t/ha)
Basal	20 DE	PI	4 WE	6 WE	Maturity	Productive	Unproductive	
Control (no nitrogen)			30.8	57.5	68.5	377	0.7	1.61
0	1/2	1/2	33.2	69.4	77.2	430	0.0	2.57
0	2/3	1/3	32.2	66.8	76.8	480	1.2	2.67
1/3	1/3	1/3	33.2	67.1	76.8	409	2.3	2.94
		CV	6.0	6.0	6.9	18	–	23.00

[a]DE = days after crop emergence. [b]WE = weeks after crop emergence.

to be better than two split applications (Table 8). However, yield differences were not significant.

Transplanted trial. A stratum 2 plot was prepared like the wet-seeded plot, with the same nitrogen treatments. Height and tillering of transplanted IR52 increased with 25 kg N/ha (Table 9). Plants fertilized with 25 kg N/ha yielded 1 t/ha more than unfertilized plants. Yield further increased by 0.7 t/ha with 75 kg N/ha. The time of nitrogen application did not significantly affect plant height, tillering, and yield.

RELAY CROPPING — DRY-SEEDED RICE IN MUNGBEAN

Multiple Cropping Department

Mungbean planting dates range across April and May at the Solana outreach site because of variable rainfall. When mungbean planting is delayed beyond mid-May, the establishment of a second-crop dry-seeded rice can be delayed, exposing it to the flood risk in October and November. Relay cropping rice in mungbean offers a way for early establishment of the second rice crop.

Farmer's local implements and tools were used.

The experimental plot was plowed twice, then harrowed until a good soil bed was attained to prepare it for mungbean (CES ID-21). Furrows (50 cm apart) were constructed with a carabao-drawn plot. Mungbean was drill-seeded in furrows at 25, 21, and 17 kg/ha and covered with soil with a tooth-peg harrow.

As mungbean approached maturity, furrows were made between the rows with a carabao-drawn wooden plot. The relay dry-seeded rice crop (IR52) was planted 1 week before first priming, immediately after first priming, and immediately after second priming at 100 kg seeds/ha drilled in furrows and covered by hand labor. Fertilizer at 60 kg N/ha was applied to rice in equal splits at maximum tillering and panicle initiation. Insects were controlled with Azodrin 202R (0.25 kg a.i./ha), sprayed twice at the vegetative stage and Folidol

Table 10. Effect of mungbean seeding rate and time of dry-seeded rice (DSR) planting on mungbean plant stand and grain yield, Solana, Cagayan, Philippines, 1981.

Mungbean seeding rate (kg/ha)	Plants (no.)		Grain yield (kg/ha)
	Linear m of row at 7 DE	m^2 at harvest[a]	
DSR planted 1 week before 1st priming			
25	23.7	326 a	446.5
21	16.9	136 c	309.25
17	11.6	213 bc	335.75
$\bar{X}$	(17.4)	(225)	(363.83)
DSR planted immediately after 1st priming			
25	19.7	125 c	253.50
21	16.8	165 c	395.75
17	12.8	169 c	376.25
$\bar{X}$	(16.4)	(153)	(341.83)
DSR planted immediately after 2nd priming			
25	19.5	315 ab	500.00
21	18.9	226 abc	425.75
17	12.8	151 c	318.00
$\bar{X}$	(17.1)	(230.7)	(414.58)
Seeding rate mean			
25	20.9 a	255 a	400.00
21	17.2 ab	176 b	376.91
17	12.4 b	178 b	343.33

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

Table 9. Effects of nitrogen rates on plant height, tillering, and grain yield of transplanted IR52 across 3 application times, stratum 2, Solana outreach site, Cagayan, Philippines, 1981 wet season.[a]

Application rate (kg/ha)	Plant ht (cm)			Tillers (no./hill)		Grain yield (t/ha)
	4 WT	6 WT	Maturity	Productive	Unproductive	
0	30.8 b	56.5 d	80.2 b	8.6 b	0.9 b	2.03 c
25	34.6 a	62.2 bc	90.8 a	10.7 a	1.2 a	2.80 abc
50	33.6 ab	64.8 b	89.8 a	10.7 a	1.2 a	3.08 ab
75	32.4 ab	71.0 a	88.7 a	10.8 a	1.3 a	3.48 a
CV	9.8	5.0	6.2	13.1	44.0	15.60

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

Table 11. Effect of mungbean seeding rates and time of dry-seeded rice (DSR) planting on rice yield components and yield, Solana outreach site, Cagayan, Philippines, 1981.[a]

Mungbean seeding rate (kg/ha)	Tillers (no./10 plants)		Panicle length (cm)	Ht at maturity (cm)	Yield (t/ha)
	Productive	Unproductive			
	DSR planted 1 week before 1st priming				
25	176	2.0	23.5	82.3	3.50
21	176	3.0	23.3	85.3	3.32
17	174	1.0	22.0	84.8	3.15
$\bar{X}$	(175.3)	(2.0)	(22.9) a	(84.1) b	(3.32)
	DSR planted immediately after 1st priming				
25	160	3.0	22.5	85.0	3.32
21	169	2.0	23.3	87.8	3.37
17	168	2.0	22.3	85.0	3.17
$\bar{X}$	(165.7)	(2.3)	(22.7) a	(85.9) b	(3.29)
	DSR planted immediately after 2nd priming				
25	148	3.0	21.5	93.3	3.55
21	154	3.0	21.8	89.8	3.70
17	148	3.0	21.3	93.8	3.47
$\bar{X}$	(150)	(3.0)	(21.5) b	(92.3) a	(3.57)
	Seeding rate mean				
25	161.3 b	2.6	22.5	86.8	3.45
21	166.3 a	2.6	22.8	87.6	3.46
17	163.3 a	1.6	21.8	87.8	3.26

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

(0.75 kg a.i./ha), sprayed once at the reproductive stage. Hand weeding was done before seeding and at 30 days after emergence.

The effects of mungbean seeding rate and time of planting dry-seeded rice on mungbean stand and yield are shown in Table 10. At 7 days after emergence, the highest plant stand had been obtained from 25 kg seed/ha. Yield increased as seeding rate increased.

Relay-planting of rice did not significantly affect mungbean yield. And, mungbean seeding rate and time of rice planting did not affect rice plant and weed populations in the rice.

Rice yields did not vary significantly with time of planting (Table 11). Seeding rates of mungbean had no marked effect on yield and yield components of rice. The number of productive tillers declined by 10 per linear meter of row as rice

Table 12. Effect of seeding rate and method on yield of farmers' mungbean crop at Solana outreach site, Cagayan, Philippines, 1981.

Seeding rate (kg/ha)	Seeding method	Mungbean yield (kg/ha)			
		Farmer 1	Farmer 2	Farmer 3	Av[a]
15	Spaced dibbling in rows	642	324	254	406.67 b
15	Continuous seeding in furrow	641	232	256	367.33 b
30	Spaced dibbling in rows	1147	542	389	692.67 a
30	Continuous seeding in furrow	1137	568	550	751.67 a
Av		891.75	416.50	362.25	

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

Table 13. Effect of first-crop nitrogen application on first- and second-crop yields. Iloilo, Philippines, 1979-80.

Second crop nitrogen level (kg/ha)	Grain yield (t/ha)				Mean
	0 kg N/ha	60 kg N/ha	120 kg N/ha	180 kg N/ha	
		First-crop yields			
–	3.54	5.11	5.91	6.45	–
		Second-crop yields			
0	2.67	2.32	2.31	2.76	2.52
35	3.01	3.17	2.95	3.61	3.19
70	3.75	3.72	3.77	3.78	3.76
105	4.71	4.77	4.34	4.57	4.60
140	5.02	4.93	4.88	5.18	5.01
175	5.33	5.03	5.09	5.30	5.19
Mean	4.08	3.99	3.89	4.20	

planting was delayed. At maturity, rice planted last had the tallest plants, but the shortest panicles.

EFFECT OF SEEDING RATE AND METHOD ON MUNGBEAN YIELD

Multiple Cropping Department

Farmers at the Solana outreach site use a low seeding rate (about 15 kg/ha) of mungbean and dibble the seeds at approximately 30- × 15-cm spacing. Yields are generally poor. Trials in farmers' fields tested whether yields of farmers' mungbean crops grown before rainy-season rice could be improved through higher seeding rates (30 kg/ha) and continuous seeding in furrows 30 cm apart. The trials were planted in three farmers' fields between 27 April and 8 May without fertilizer and harvested between 4 and 21 July.

Yields increased significantly with higher seed rates (Table 12). The 30-kg seed rate produced an

Table 14. Analysis of variance on first- and second-crop yields, Iloilo Province, Philippines, 1980.

Source	df	SS	MS
	First crop		
Replication	23	40113970	1744086**
N_1	3	115614102	38538034**
Linear	1		109041314**
Quadratic	1		6351502
Remainder	1		221285
Error	69	169420201	198437
	Second crop		
Replication	3	6627221	
N_2	5	90947810	
Linear	(1)		88187529**
Quadratic	(1)		1827525
Remainder	(3)		932756
Error (a)	15	4238831	
N_1	3	1275651	
Linear	(1)		77445
Quadratic	(1)		981923**
$N_1 \times N_2$	15	1382822	92188
Error (b)	54	5366571	

additional cost-benefit ratio of 22. There was no significant difference in yield between the two seeding methods.

FERTILIZER MANAGEMENT IN A RICE - RICE CROPPING PATTERN

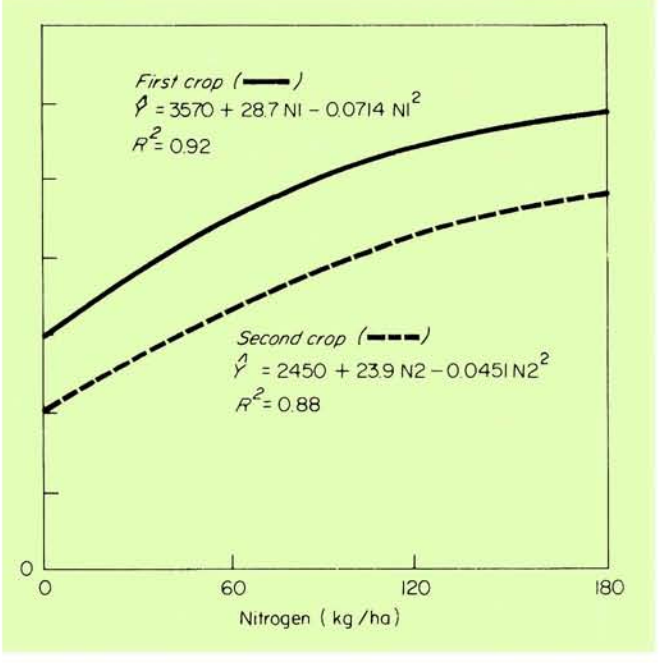
Multiple Cropping Department

Quantified information on residual effects of nitrogen fertilizer is needed to update fertilizer management recommendations where two successive rice crops are grown with supplemental irrigation in a single wet season.

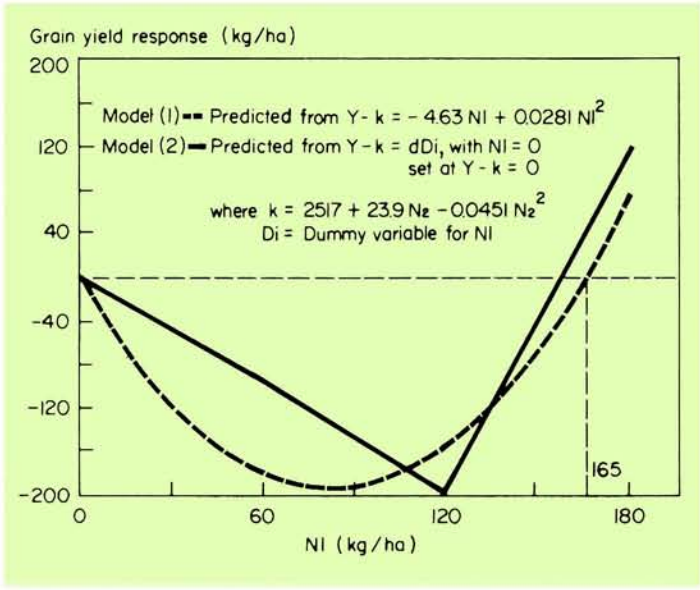
Two successive field experiments were conducted between 29 May and 14 December on an irrigated farmer's field in the major rice-producing area of Iloilo Province, Philippines. The soil, classified as vertisol (pH 6.1, O.C. 1.2%, total N. 0.1%, CEC 44 meq/100 g, 55.4% clay, 37.8% silt, 6.6% sand), belongs to the Santa Rita series.

In both experiments, yields were significantly affected by nitrogen applied directly (Table 13, 14). In the second crop, a significant interaction between N1 and N2 was not obtained, indicating that nitrogen applied to the second crop was not affected by residual nitrogen from the first crop. To summarize the relationship between yield and nitrogen applied to a current crop, quadratic regression models were fitted (Fig. 1). In both regression equations, the intercept term includes the mean of the replication dummy variable coefficients to remove variability across blocks. The mean yield with 0 kg N/ha in the first experiment was 1.1 t/ha higher than yield at 0 kg N/ha in the second experiment. The nitrogen utilization ratio (kilograms of rough rice per kilogram applied nitrogen) was higher in the first crop than in the second.

Residual response in the second crop was evaluated using regression models obtained after removing the effects of second-crop nitrogen application



1. Yield responses of IR36 to varying levels of nitrogen, first and second crops, Iloilo, Philippines, 1981.



2. Yield response of transplanted IR36 to the residual effects of the first-crop nitrogen application (N1). Iloilo, Philippines, 1981 dry season.

(Fig. 2). Yield depressions occurred at 80-130 kg N/ha applied to the first crop and a positive residual response occurred when first-crop nitrogen application exceeded 165 kg N/ha. Using the linear coefficients from the second-crop equation (23.9 kg grain/kg N) and a 100-kg grain yield response at 180 kg N/ha first-crop application, the residual effect was equivalent to about 4 kg N/ha. Calculated nitrogen depression was about 8 kg N/ha.

RESPONSE OF TRANSPLANTED RICE TO MUNGBEAN GREEN MANURE

Multiple Cropping Department

Mungbean is reported to be a promising green manure crop. This study examined growth and yield response of transplanted rice to mungbean green manure plowed under at different growth stages.

There is a time between the initial onset of wet monsoon rains and the accumulation of adequate water for land preparation for transplanted rice when a green manure crop can be grown. The response of transplanted IR36 to a mungbean MG-50 green manure crop incorporated at 20, 30, and 40 days after emergence, with and without 80 kg N/ha applied to the rice crop was evaluated. A fallow plot ahead of rice was the check.

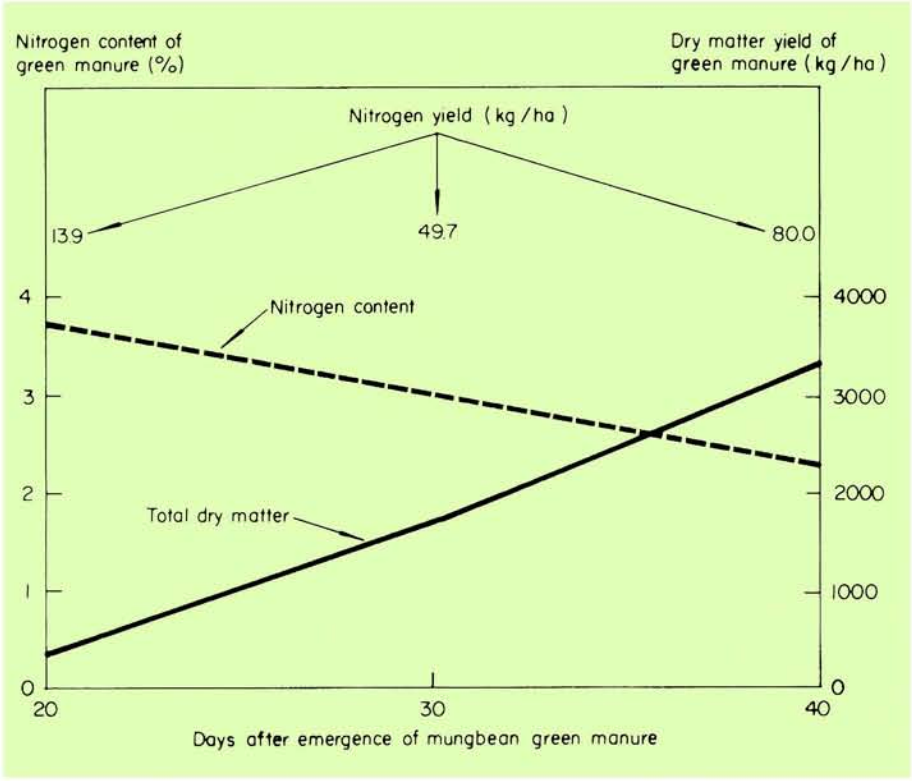
Attributes of green manure. The total dry matter, nitrogen content, and nitrogen yield of mungbean green manure at 20, 30, and 40 days after emergence are summarized in Table 15. Total dry biomass increased significantly with age of green manure. Nitrogen content of plant tissue decreased with green manure age (Fig. 3).

Agronomic attributes of transplanted rice. Num-

Table 15. Total dry matter, percentage of nitrogen, and nitrogen yield of mungbean green manure at various growth stages. IRRI, 1981 wet season.[a]

Green manure growth stage (DE[b])	Total dry matter (kg/ha)	Nitrogen (%)	Nitrogen yield (kg/ha)
20	334.0 a	3.96 a	13.2 a
30	1630.0 b	3.05 b	49.7 b
40	3450.0 c	2.32 c	80.0 c
Mean	1805.0	3.11	47.6
CV (%)	5.7	6.5	11 3

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



3. Nitrogen content, total dry matter, and nitrogen yield of mungbean green manure at different days after emergence.

Table 16. Effect of mungbean green manure on productive tiller counts of transplanted rice. IRRI, 1981 wet season.[a]

Growth stage of green manure (DE[b])	Tillers (no./m²)		
	0 kg N/ha	80 kg N/ha	Mean
Fallow	146	175	161
20	183	220	185
30	183	263	223
40	241	278	260
Mean	188	234	207

CV_a = 15.8%; CV_b = 17.7%

[a]TRT comparison	Mean square
Nitrogen (N)	23436.13*
Green manure (G)	15272.58**
N x G	1250.38

[b]Days after emergence.

Table 17. Effect of green manure and nitrogen rates on plant height at harvest of transplanted rice. IRRI, 1981 wet season.[a]

Growth stage of green manure (DE[b])	Plant ht (cm)		Mean
	0 kg/ha	80 kg/ha	
Fallow	63.4	76.4	69.9
20	67.6	78.8	73.2
30	72.9	86.0	79.5
40	78.2	89.1	83.5
Mean	70.5	83.0	76.5

CV_a = 3.7%; CV_b = 2.4%

[a]TRT comparison	Mean square
Nitrogen (N)	1161.62**
Green manure (G)	305.49**
N x G	2.76

[b]Days after emergence.

ber of productive tillers, plant height, and total dry matter of transplanted rice are shown in Tables 16, 17, and 18. These attributes were significantly influenced by the age at which green manure was incorporated. Productive tiller count, height, and dry matter at harvest also increased consistently at 80 kg N/ha. Analysis of variance showed no interaction between nitrogen and green manure treatments for any attribute.

Nitrogen content. Nitrogen content of rice leaf blades sampled randomly at maximum tillering, panicle initiation, and 20 days after flowering are shown in Figure 4. Mean values for all treatment combinations decreased with age of rice. Nitrogen content at tillering with treatments at 30 and 40 days after emergence (DE) was well within the critical 4.2-5.1%. At panicle initiation, nitrogen content with fallow and the green manure treat-

Table 18. Effect of green manure and nitrogen rates on dry matter of transplanted rice. IRRI, 1981 wet season.[a]

Growth stage of green manure (DE[b])	Dry matter (t/ha)		Mean
	0 kg/ha	80 kg/ha	
Fallow	3.47	6.02	4.75
20	3.75	6.94	5.35
30	4.93	7.35	6.14
40	7.52	9.95	8.74
Mean	4.92	7.57	6.25

CV_a = 20.1%; CV_b = 15.4%

[a]TRT comparison — Mean square

Nitrogen (N)	56.07**
Green manure (G)	24.74**
N x G	0.27

[b]Days after emergence.

Table 19. Effect of green manure and nitrogen fertilization on yield of transplanted rice. IRRI, 1981 wet season.[a]

Growth stage of green manure (DE[b])	Yield (t/ha)		Mean
	0 kg N/ha	80 kg N/ha	
Fallow	1.06	2.25	1.66
20	1.33	2.57	1.95
30	2.01	3.08	2.55
40	2.94	4.26	3.60
Mean	1.84	3.04	2.44

CV_a = 20.1%; CV_b = 15.4%

[a]TRT comparison — Mean square

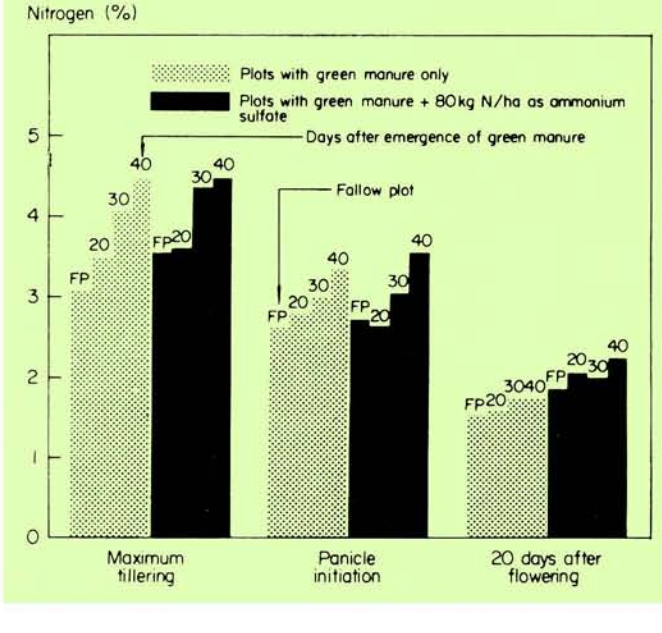
Nitrogen (N)	11.62**
Green manure (G)	5.88**
N x G	0.22

[b]Days after emergence.

ment at 20 days after emergence were close to the critical 2.4-3.4% at panicle initiation, suggesting that soil nitrogen or mineralized green manure, or both, were inadequate. In green manure treatments 30 and 40 DE, nitrogen was adequate with and without applied inorganic nitrogen.

Grain yield and economic returns. Yield increases were proportionately greater in older green manure treatments with and without 80 kg N/ha (Table 19). No interaction between green manure and nitrogen fertilizer was detected.

Yield increments and costs and returns from green manure with or without inorganic nitrogen are summarized in Table 20. Because the analysis of variance showed that green manure and nitrogen fertilizer treatments have additive effects, yield increments from green manure were computed as mean increases above fallow plot yield over nitrogen treatments. Yield increase due to nitrogen fertilizer was regarded as the mean increase over green manure treatments.



4. Changes in nitrogen content at 3 growth stages of rice in response to green manuring and inorganic nitrogen applications.

Table 20. Yield increases and cost and return from green manure (GM) and 80 kg N/ha as ammonium sulfate. IRRI, 1981 wet season.

Growth stage[a] of GM	GM		GM + 80 kg N/ha	
	Yield increase (kg/ha)	Return over cost[b] ($)	Yield increase (kg/ha)	Return over cost[b] ($)
Fallow	–	–	1190	99
20 DE	270	109	1510	56
30 DE	950	13	2020	148
40 DE	1880	180	3200	359

[a]DE = days after emergence. [b]$1 = ₱7.80.

The economic return over cost of green manure seeds or inorganic nitrogen, or both, was derived using these prices:

Item	*Cost ($/kg)*
Rice	0.18
Mungbean seed	0.75
Nitrogen from ammonium sulfate	0.95

Economic return = price of rice per kilogram × yield increment − cost of green manure + (land preparation, weeding, seeding, and insecticide applied to mungbean) and ammonium sulfate.

A negative return was obtained with 20-day-old green manure alone. A return of $12.70 was recorded with incorporation at 30 days after emergence. This increased to $179.61 with 40 DE incorporation. Return over cost of ammonium sulfate alone was $99.23, about 50% lower than that over green manure alone incorporated at 40 days after emergence. Plots with green manure incorporated at 20, 30, and 40 days after emergence plus 80 kg N/ha gave net returns of $56.02, $147.56, $359.36, respectively.

The highest return per unit cost of green manure and inorganic nitrogen was from the combination of green manure incorporated at 40 days after emergence and 80 kg N/ha.

EFFECT OF FIRST-CROP MUNGBEAN ON SECOND-CROP TRANSPLANTED RICE

Multiple Cropping Department

The effects of mungbean management practices on grain yield and yield attributes of a succeeding transplanted rice crop grown in irrigated conditions at IRRI were determined.

Main plot treatments were three mungbean cultivars — CES 1D-21, CES 1T-2, and CES X-10. Three subplots were seed inoculation with *Rhizobium* (M_4 strain), fertilization at 20 kg N/ha at planting, and control (no inoculant, no fertilizer).

All above-ground residues were removed immediately after mungbean harvest. The field was flooded and rotovated twice. Each subplot was divided into two 3.5-m × 3-m plots and planted with IR50. One sub-subplot received no fertilizer and one received 80 kg N, 30 kg P_2O_5, and 30 kg K_2O/ha. Nitrogen was applied in 3 doses — 30 kg at transplanting, 30 kg at maximum tillering, and 20 kg at panicle initiation. Phosphorus and potassium were applied at planting.

Rice yield after the previous mungbean with 20 kg N/ha was 7.5% higher than mungbean with inoculant only and mungbean with no inoculant, no fertilizer (Table 21). Differences in rice yield due to mungbean cultivars were not significant.

Interactions between treatments on the mungbean crop and rates of nitrogen applied to the rice crop were not significant (Table 22). However, beneficial effects of a previous crop of fertilized mungbean were maintained despite individual fertilizer treatments, although the magnitude of difference varied with rate of nitrogen applied.

Rice yield was lowest (3.38 t/ha) in the unfertilized plot of cultivar CES X-10 at zero rice fertilization. It was highest (4.19 t/ha) in the fertilized plot of cultivar CES 1T-2. At 80 kg N/ha, rice grown on previously fertilized mungbean plots yielded more than rice grown on inoculated and uninoculated-unfertilized mungbean crop plots. The highest rice yield (5.96 t/ha) was recorded in the fertilized plot of CES 1D-21 and the lowest (5.48 t/ha) in the

Table 21. Grain yield and other agronomic characters of rice (IR50) transplanted after a mungbean crop with different treatments.[a] IRRI, 1981.

Treatment	Grain yield (t/ha)	Days to		Plant ht (cm)	Tillers (no./m²)	Panicles (no./m²)	Productive tillers (%)	Panicle length (cm)	Grains (total no./ panicle)	Filled grains per panicle		1000-seed wt (g)
		Heading	Maturity							No.	%	
Inoculation	4.65 b	63 a	91 a	79.4 a	414 a	386 a	93.9 a	19.8 a	84.6 a	80 a	95.5 a	20.7 a
20 kg N/ha	5.00 a	63 a	92 a	80.2 a	448 a	414 a	92.6 a	19.9 a	83.5 a	79 a	95.6 a	20.9 a
Control	4.64 b	63 a	92 a	78.4 a	424 a	401 a	95.3 a	19.2 a	79.9 a	76 a	96.2 a	21.5 a

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

Table 22. Effect of a previous mungbean crop on yield and other agronomic characters of transplanted rice crop (IR50). IRRI, 1981.

Treatment[a]	Grain yield (t/ha)	Days to		Plant ht (cm)	Tillers (no./m²)	Panicles (no./m²)	Productive tillers (%)	Panicle length (cm)	Grains (total no./ panicle)	Filled grains (no./panicle)		1000-seed wt (g)
		Heading	Maturity							No.	%	
CES ID-21 + no Fert + no Fert	3.69	62	93	74.0	362	333	92.6	18.5	76	73	98.2	20.7
CES ID-21 + no Fert + Fert II	5.88	62	92	80.6	454	433	96.0	19.6	76	70	93.2	23.8
CES ID-21 + Fert I + no Fert	4.10	63	91	76.7	412	372	91.3	19.8	87	80	94.5	20.7
CES ID-21 + Fert I + Fert II	5.96	63	92	85.3	509	496	97.6	19.9	82	75	93.2	20.5
CES ID-21 + Inoc + no Fert	3.71	63	91	75.0	367	342	93.9	18.7	83	72	94.2	20.3
CES ID-21 + Inoc + Fert II	5.48	62	91	86.0	447	420	94.8	20.3	89	84	94.6	21.0
CES IT-2 + no Fert + no Fert	3.86	63	91	76.3	407	387	95.5	19.4	80	78	97.7	21.2
CES IT-2 + no Fert + Fert II	5.52	62	91	86.6	464	431	93.9	19.3	87	83	97.0	20.4
CES IT-2 + Fert I + no Fert	4.19	63	92	74.3	367	321	88.2	19.4	92	89	98.1	20.9
CES IT-2 + Fert I + Fert II	5.84	63	92	84.3	503	463	93.2	20.1	81	77	96.0	20.0
CES IT-2 + Inoc + no Fert	3.49	63	91	73.7	346	315	91.8	19.2	78	75	97.0	20.4
CES IT-2 + Inoc + Fert II	5.89	62	90	85.3	473	447	95.4	20.5	93	88	94.5	20.9
CES X-10 + no Fert + no Fert	3.38	63	91	71.3	392	373	95.9	18.2	73	66	94.2	21.3
CES X-10 + no Fert + Fert II	5.48	63	90	81.3	461	447	97.9	20.1	89	84	96.8	21.8
CES X-10 + Fert I + no Fert	4.15	63	92	76.3	372	331	89.2	20.5	79	76	97.3	21.5
CES X-10 + Fert I + Fert II	5.76	62	92	84.3	524	499	96.1	19.9	81	77	95.3	21.7
CES X-10 + Inoc + no Fert	3.71	63	92	74.0	364	339	93.6	19.4	80	77	96.8	20.6
CES X-10 + Inoc + Fert II	5.63	62	92	82.6	484	454	94.5	20.6	86	85	96.2	20.9
Mean	4.76	63	91.4	79.3	428	400	94.0	19.6	83	78	95.8	21.0
CV (%) (a)	10.12	1.14	0.89	5.04	9.44	7.72	3.84	6.69	5.62	6.22	3.72	3.86
(b)	9.89	1.10	1.28	6.38	11.07	10.26	4.18	6.06	12.30	13.07	3.34	6.28
(c)	6.85	1.12	0.75	4.50	8.98	7.67	3.78	6.01	12.01	12.99	3.09	3.61

[a]Fert I = 20 kg N applied to the mungbean crop at planting. Inoc = coating of the mungbean seeds. Fert II = 80-30-30 (N - P_2O_5 - K_2O) kg/ha, applied to the succeeding rice crop.

Table 23. Effect of a previous mungbean crop and nitrogen fertilization on leaf nitrogen content at different growth stages of transplanted rice (IR50). IRRI, 1981.

Treatment[a]	Leaf nitrogen content (%)			
	Maximum tillering	Panicle initiation	Flowering	20 days after flowering
CES ID-21 + no Fert + no Fert	3.77	3.03	2.43	1.92
CES ID-21 + no Fert + Fert II	4.01	3.31	2.65	2.05
CES ID-21 + Fert I + no Fert	3.99	3.19	2.51	1.95
CES ID-21 + Fert I + Fert II	4.43	3.63	2.64	2.24
CES ID-21 + Inoc + no Fert	3.99	3.11	2.39	2.06
CES ID-21 + Inoc + Fert II	4.17	3.07	2.64	2.20
CES IT-2 + no Fert + no Fert	3.76	2.89	2.37	1.91
CES IT-2 + no Fert + Fert II	4.11	3.36	2.66	2.09
CES IT-2 + Fert I + no Fert	3.75	3.04	2.40	2.01
CES IT-2 + Fert I + Fert II	4.36	3.42	2.73	2.19
CES IT-2 + Inoc + no Fert	4.21	3.09	2.36	2.00
CES IT-2 + Inoc + Fert II	4.00	3.38	2.53	2.15
CES X-10 + no Fert + no Fert	3.85	2.96	2.44	1.86
CES X-10 + no Fert + Fert II	4.23	3.27	2.44	2.08
CES X-10 + Fert I + no Fert	3.91	3.05	2.42	1.87
CES X-10 + Fert I + Fert II	4.29	3.35	2.75	2.14
CES X-10 + Inoc + no Fert	3.68	2.87	2.47	1.88
CES X-10 + Inoc + Fert II	4.16	3.25	2.72	2.12
Mean	4.04	3.18	2.53	2.04
CV (%) (a)	4.99	6.33	7.75	4.85
(b)	6.34	4.21	5.45	6.84
(c)	4.09	4.18	5.25	4.66

[a]Fert I = 20 kg N applied to the mungbean crop at planting. Inoc = coating of the mungbean seeds. Fert II = 80-30-30 (N-P_2O_5-K_2O) kg/ha applied to the succeeding rice crop.

unfertilized plots of CES X-10 and CES 1D-21.

The higher rice yields after fertilized mungbean seemed to be directly related to the greater availability of nitrogen, as shown by the higher nitrogen leaf index obtained in the fertilized plots at different growth stages of rice (Table 23).

The various treatments on the mungbean crop had no significant effect on the yield attributes of the following rice crop, although there was a numerical increase in plant height and number of tillers and panicles per square meter with 20 kg N/ha (Table 24). At 80 kg N/ha, highly significant increases in plant height, tillers and panicles per square meter, percentage of productive tillers, and panicle length were recorded in the fertilized plot.

ROLLING INJECTOR PLANTER FOR MUNGBEAN AFTER RICE

Multiple Cropping Department

The rolling injection planter (RIP) is a manual seed drill designed for use in zero or reduced tillage

Table 24. Effect of 2 levels of fertilization after a mungbean crop on yield and other agronomic characters of transplanted rice (IR50).[a] IRRI, 1981.

Fertilizer (kg/ha)		Grain yield (t/ha)	Days to		Plant ht (cm)	Tillers (no./m^2)	Panicles (no./m^2)	Productive tillers (%)	Panicle length (cm)	Grains (total no./ panicle)	Filled grains (no./panicle)		1000-seed wt (g)
N	P_2O_5	K_2O		Heading	Maturity							No.	%	
0	0	0	3.81 b	63 a	92 a	74.6 b	377 b	346 b	92.4 b	19.2 b	80.6 a	76 a	96.4 a	20.8 a
80	30	30	5.72 a	63 a	91 a	84.1 a	480 a	454 a	95.4 a	20.0 a	84.8 a	80 a	95.2 a	21.2 a

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



5. Rolling injector planter (RIP).

systems (Fig. 5). It penetrates plant residues and the more variable soil surfaces of untilled plots. The jaws punch a hole into the soil, where the seed is placed.

The rolling injection planter was developed at the International Institute of Tropical Agriculture, using the principle of the hand-operated jab planter. It is designed to achieve a higher rate of injection planting than the one hill-per-second rate achievable with the jab planter. The jab planter itself is much faster than the dibble stick method.

The RIP was compared with slower conventional tillage methods under zero-tillage conditions. Grain yields were equal or superior to those obtained using other tillage and planting methods (Table 25). Minor differences were noted for other agronomic characteristics.

Further improvements to be considered include more uniform seed distribution among hills. The planting points or jaws need to place the seeds in the holes without scattering seeds outside the holes. A simple means of better covering the seeds to

Table 25. Effect of seeding techniques after upland rice on yield and agronomic characteristics of mungbean. IRRI, 1981.

Treatment	Total seed yield (kg/ha)	Total dry matter[a] (kg/ha)	Plant ht (cm)	Plants[a] (no./10-m² sampling area)	Pods (no./plant)	Length of pods (cm)	Seeds (no./pod)	1000-seed wt (g)
High tillage - seed broadcast and covered	1120.0	2160 a	33.4	594.3 a	10.0	8.2	10.4	51.7
Zero tillage - seeded in narrow furrow	1149.4	2590 ab	36.5	427.3 b	13.3	8.4	10.3	52.0
Conventional tillage - row seeding in furrows	1264.9	2670 ab	39.5	422.3 b	13.0	8.1	9.8	53.8
Zero tillage - rolling injector planter	1207.0	2350 a	39.1	426.2 b	12.2	8.4	10.7	54.6
Conventional tillage - rolling injector planter	1304.0	3160 b	41.0	345.8 b	14.4	8.2	10.7	54.8
F value	1.20	3.28*	2.25	10.85*	2.73	0.91	2.41	2.07
CV (%)	11.59	16.18	10.49	12.50	15.66	2.96	4.62	3.71

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

Table 26. Yield and plant stands of soybean relay planted 2 days before harvest of rice.[a] IRRI, 1981.

Treatment	Grain yield (t/ha)	Stand (plants/m²)
Broadcast (unsoaked)		
60 kg/ha	1.31 f	42 g
120 kg/ha	2.12 bc	61 cd
Broadcast (soaked)		
60 kg/ha	1.55 e	47 f
120 kg/ha	2.22 b	64 bc
Drilled (unsoaked)		
60 kg/ha	1.77 d	53 e
120 kg/ha	2.24 b	67 b
Drilled (soaked)		
60 kg/ha	2.02 c	58 d
120 kg/ha	2.61 a	88 a

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

Table 27. Cultural trials of soybean relay planted into puddled flooded rice. IRRI, 1981.

Treatment	Grain yield (t/ha)	Stand (plants/m²)
Broadcast vs drilled	1.80 / 2.16*	53 / 66*
60 kg/ha vs 120 kg/ha	1.66 / 2.30*	50 / 70*
Soaked seed vs unsoaked seed	2.10* / 1.86	66* / 56

*Significant at .05 probability level.

ensure seed protection from birds and rats as well as better contact between seed and soil is needed.

SOYBEAN AFTER FLOODED RICE

Multiple Cropping Department

Relay planting of soybeans 2 days before rice harvest, when water had been drained 7 days earlier, was studied at IRRI farm. Seeding rate of 120 kg/ha gave higher yields than 60 kg/ha in all treatments (Table 26). The overall advantage was 0.64 t/ha (Table 27).

Drilled seed plots yielded significantly higher than broadcast. Soaking seeds for 24 hours outyielded unsoaked seeds. Yield differences were correlated with stand differences between the treatments.

Table 28. Effect of soybean seed placement and prior drainage period of flooded rice soil on plant stand, height, and days to permanent wilting.[a] IRRI, 1981.

Drainage days before soy seeding	Plant stand (%)	Plant ht (cm)	Days to permanent wilting
	Surface placement		
0	62 a	24 a	51 a
3	42 b	26 a	45 b
6	26 c	20 a	39 c
9	8 d	7 b	20 e
	Placement 3 cm (dibble)		
0	55 ab	26 a	50 a
3	81 a	29 a	51 a
6	61 a	24 a	45 b
9	58 a	17 a	35 d

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

In another experiment, soybean seeds were placed on the soil surface or dibbled at different intervals after drainage of puddled rice soil. Dibbling seeds 3 cm deep and covering them generally gave higher plant stands than surface broadcast seed. Several days' delay in seeding produced greater plant heights and extended the time to the permanent wilting point a few more days (Table 28).

EFFECT OF DRAINAGE METHOD AND PLANT DENSITY ON PEANUT

Multiple Cropping Department

Drainage management treatments (flat bed, canal every 1.5 m, and ridge planting) did not affect yield of 3 peanut varieties (UPLPN$_2$, BPI P$_9$, and Kidang) during the wet season at IRRI (Table 29).

Kidang and BPI P$_9$ performed better than UPLPN$_2$ (Table 30, 31). Kidang showed the highest bean yield (Fig. 6).

A population density of 135,000 plants/ha yielded significantly higher than 200,000 and 267,000 plants/ha (Table 32, Fig. 5)

EFFECT OF PLANT DENSITY AND FERTILIZATION ON INTERCROPPED MUNGBEAN, PEANUT, AND MAIZE YIELD

Multiple Cropping Department

Farmers in the humid tropics often grow maize in

Table 29. Yield and other yield components of 3 peanut varieties, as affected by drainage management.[a] IRRI, 1981 wet season.

Drainage management	Yield (kg/ha)	Plant ht 1[b] (cm)	Plant ht 2[c] (cm)	TDM[d] (g/5 plants)	100-seed wt (g)
Flat bed	866.4 a	27.1 a	65.8 a	48.6 a	65.6 b
Canal/1.5 m	892.2 a	26.7 a	65.9 a	47.9 a	68.8 a
Ridge planting	953.6 a	26.4 a	64.1 a	47.5 a	68.4 a

[a]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]Plant height at 40% module formation. [c]Plant height at maturity. [d]Total dry matter.

Table 30. Yield and other plant characters of 3 varieties of peanut under 3 drainage management levels, as affected by varietal differences.[a] IRRI, 1981 wet season.

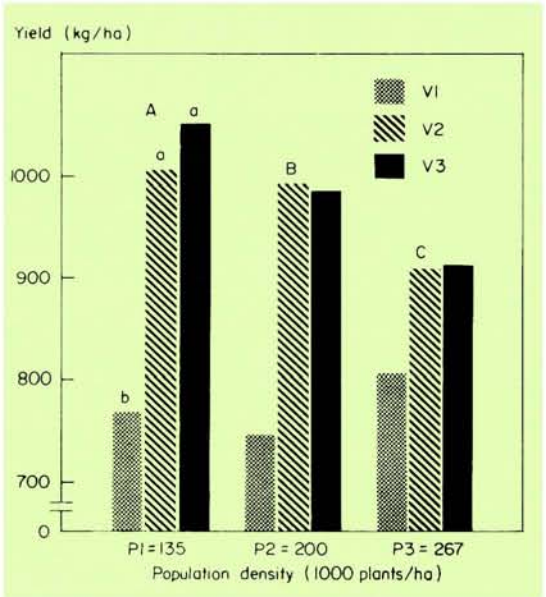
Variety	Yield (kg/ha)	Plant ht 1[b] (cm)	Plant ht 2[c] (cm)	TDM[d] (g/5 plants)	100-seed wt (g)
$UPLPN_2$	769.4 b*	27.6 a	66.0 a	53.2 a	68.2 a
BPI P_9	965.2 a	27.1 a	65.8 a	44.3 b	65.6 b
Kidang	977.7 a	25.5 b	64.1 a	46.6 ab	68.9 a

[a]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]Plant height at 40% module formation stage. [c]Plant height at maturity. [d]Total dry matter.

Table 31. Yield and other plant characters of 3 varieties of peanut under 3 drainage management levels, as affected by plant population. IRRI, 1981 wet season.[a]

Plant density	Yield (kg/ha)	Plant ht 1[b] (cm)	Plant ht 2[c] (cm)	TDM[d] (g/5 plants)	100-seed wt (g)
135,000 plants/ha	936.7 a	26.3 a	64.4 a	49.0 a	68.2 a
200,000 plants/ha	905.3 b*	27.2 a	65.9 a	46.8 a	66.9 a
267,000 plants/ha	870.2 c	26.7 a	65.6 a	48.2 a	67.8 a

[a]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]Plant height at 40% module formation stage. [c]Plant height at maturity. [d]Total dry matter.



6. Yield characteristics due to population density and varietal differences of 3 varieties of peanut (UPLPN2 = V1, BPI P9 = V2, Kidang = V3). IRRI, 1981 wet season (av of 3 replications × 3 drainage managements). Small letters indicate varietal difference significance; capital letters population density.

association with short-duration mungbean and peanut on upland areas where there is not enough water for rainfed rice. The performance of mungbean and peanut intercropped with maize in the wet season and that of mungbean intercropped with maize in the dry season were studied at the IRRI upland farm.

In the wet season, mungbean (CES-1D and MG-50) and peanut ($UPLPN_2$ and Kidang) were intercropped at three plant densities (200,000, 300,000, and 400,000 plants/ha) with SP #1 maize (40,000, 20,000, and 13,333 plants/ha). Maize row spacings were 1, 2, and 3 m. Fertilization was

Table 32. Yield of 3 varieties of peanut under 3 drainage management levels, as affected by population density and varietal difference.[a] IRRI, 1981 wet season.

Variety	Yield (kg/ha)			
	P_1[b]	P_2[c]	P_3[d]	Mean
$UPLPN_2$	764.0	744.0	800.0	769 b*
BPI P_9	1001.0	989.0	905.0	965 a
Kidang	1045.0	983.0	906.0	978 a
Mean	936.7 a	905.3 b	870.3 c	

[a] Av of 3 replications x 3 drainage management levels. Separation of means by Duncan's multiple range test at the 5% level. [b] 135,000 plants/ha. [c] 200,000 plants/ha. [d] 267,000 plants/ha.

60-60-60 kg N, P_2O_5, K_2O/ha, applied all basal or in 2 splits (30-30-30 basal and 30-30-30 kg N, P_2O_5, K_2O/ha 30 days after emergence).

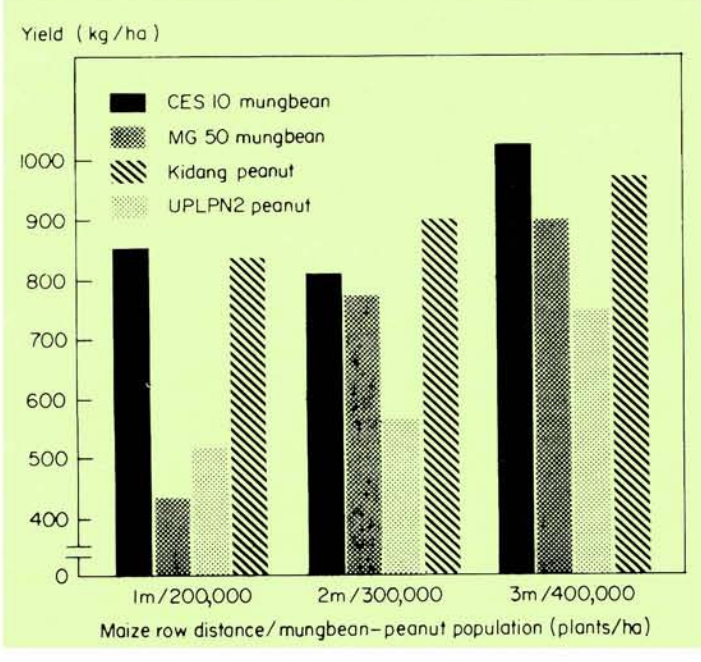
In the dry season, mungbean (CES-1D) at 200,000, 300,000, and 400,000 plants/ha was intercropped with maize (SP #1) at 60,000 and 30,000 plants/ha. Mungbean (400,000 plants/ha) and maize (60,000 plants/ha) as sole crops also were grown. These planting systems were evaluated at (30-30-30, 60-60-60, and 90-60-60 kg N, P_2O_5, K_2O/ha).

In the wet season, the seed yield of all interplanted crops, except Kidang peanut, decreased significantly when plant densities were reduced from 400,000 to 200,000 plants/ha (Fig. 7). Kidang's higher performance was not significantly reduced by increasing maize plant densities. Maize yield was reduced significantly when the plant density was decreased from 40,000 to 13,333 plants/ha. The method of applying 60-60-60 kg N, P_2O_5, K_2O/ha did not significantly affect seed yield of the intercrops or of maize.

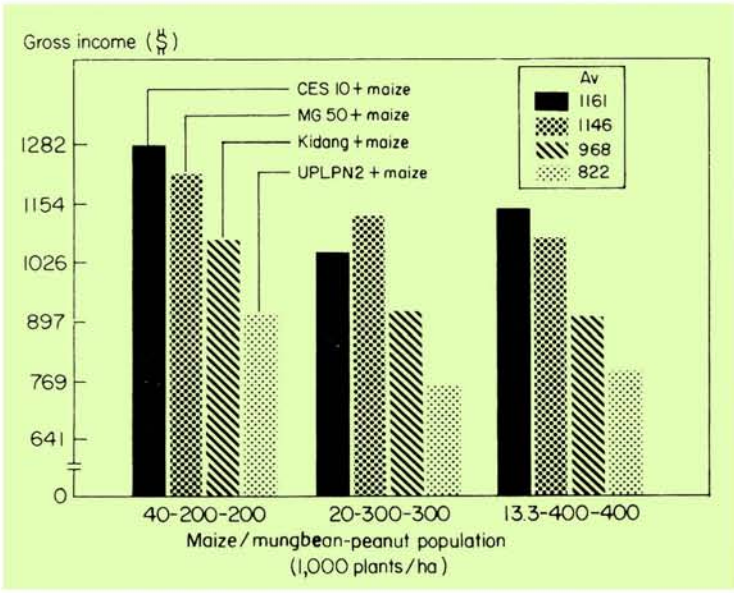
The highest gross income was obtained from intercropping of mungbean at 200,000 plants/ha with maize at 40,000 plants/ha (Fig. 8). CES-1D mungbean gave a higher return than other varieties at this plant density. Peanut cultivar $UPLPN_2$ intercropped with maize gave the lowest return.

In the dry season, mungbean CES-1D at 300,000 and 400,000 plants/ha intercropped with maize yielded similarly to mungbean alone (Table 33). Increasing fertilizer from 30-30-30 N, P_2O_5, K_2O kg/ha to 60-60-60 kg/ha resulted in a significantly higher seed yield of mungbean. There was a significant linear increase in maize yield from 30-30-30 to 90-60-60 N, P_2O_5, K_2O kg/ha at different plant densities (Table 34).

The optimum plant density and fertilizer rate for a mungbean-maize intercrop during the postmonsoon period for a yield advantage over a single crop was 300,000 mungbean plants/ha and 30,000 maize plants/ha at 60-60-60 kg N, P_2O_5, and



7. Yield of intercrops at different maize plant densities. IRRI, 1981 wet season (av of 3 replications).



8. Gross income of different 2-crop combinations under 3 maize row spacings. IRRI, 1981 wet season (av of 3 replications).

Table 33. Yield of CES-1D mung intercropped with SP #1 sweet maize under different fertilizer rates and plant densities.[a] IRRI, December 1981-February 1982.

Fertilizer (kg/ha)			Yield (kg/ha)				
N	P_2O_5	K_2O	P1	P2	P3	P4	Mean
30	30	30	596.2	1170.1	1211.0	1361.9	1084.5 b*
60	60	60	669.1	1332.7	1422.9	1455.4	1220.9 a
90	60	60	670.0	1367.8	1519.9	1631.4	1297.3 a
	Mean		645.1 b*	1290.2 a	1384.2 a	1482.9 a	

[a] Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. P1 = 60,000 maize + 200,000 mung/ha. P2 = 30,000 maize + 300,000 mung/ha. P3 = 30,000 maize + 400,000 mung/ha. P4 = 0 maize + 400,000 mung/ha.

Table 34. Number of marketable ears of SP #1 sweet maize when intercropped with CES-1D mung under different fertilizer rates and plant densities.[a] IRRI, December 1981-February 1982.

Fertilizer (kg/ha)			Marketable ears (no.)				
N	P_2O_5	K_2O	P1	P2	P3	P5	Mean
30	30	30	38,542	21,042	12,292	36,875	27,188 c*
60	60	60	45,000	25,208	18,522	48,375	34,276 b
90	60	60	48,750	27,917	24,315	53,330	38,578 a
Mean			44,097 a*	24,722 b	18,376 b	46,193 a	

[a] Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. P1 = 60,000 maize + 200,000 mungbean/ha. P2 = 30,000 maize + 300,000 mungbean/ha. P3 = 30,000 maize + 400,000 mungbean/ha. P5 = 60,000 maize/ha.

Table 35. Land equivalent ratio (LER) of mungbean (CES-1D)-maize (200,000 mungbean + 60,000 maize) intercropping based on gross income, as affected by plant density and fertilizer rate.

Cropping system	Component		LER
	Maize	Mungbean	
Plant density:			
200,000 mungbean + 60,000 maize	0.95	0.43	1.38
300,000 mungbean + 30,000 maize	0.54	0.87	1.41
400,000 mungbean + 30,000 maize	0.40	0.93	1.33
400,000 mungbean + 0 maize		1.00	
0 mungbean + 60,000 maize	1.00		
Fertilizer rate:			
30-30-30 kg N, P_2O_5, K_2O/ha	0.65	0.67	1.32
60-60-60 kg N, P_2O_5, K_2O/ha	0.61	0.76	1.37
90-60-60 kg N, P_2O_5, K_2O/ha	0.63	0.80	1.43
Mean			1.37

K_2O/ha.

The overall land equivalent ratio of the maize-mungbean combination was 1.37 (Table 35).

EFFECT OF PLANT DENSITY, ROW SPACING, AND CUTTING HEIGHT ON SORGHUM RATOON CROP

Multiple Cropping Department

Sorghum has the inherent ability, after cutting or harvest, to produce new stalks from crown buds of a functioning root system. In tropical areas that receive significant rainfall during the dry season, multiple cropping of one rice crop followed by two sorghum crops (one ratoon) may be possible.

Ratoon cropping reduces land preparation labor and seed costs, shortens turnaround time, and efficiently utilizes soil moisture. Ratoon crops mature early, allowing better utilization of the growing period, thus requiring less irrigation water and less fertilizer. Ratoon plants also are exposed to weed competition, insect infestation, diseases, and bird damage for a shorter time.

Two studies, April-November, at IRRI measured ratooning performance of three grain sorghum cultivars in relation to plant population density, row spacing, and cutting height. The varieties used were UPLB SG5, Cosor 3, and CS 110.

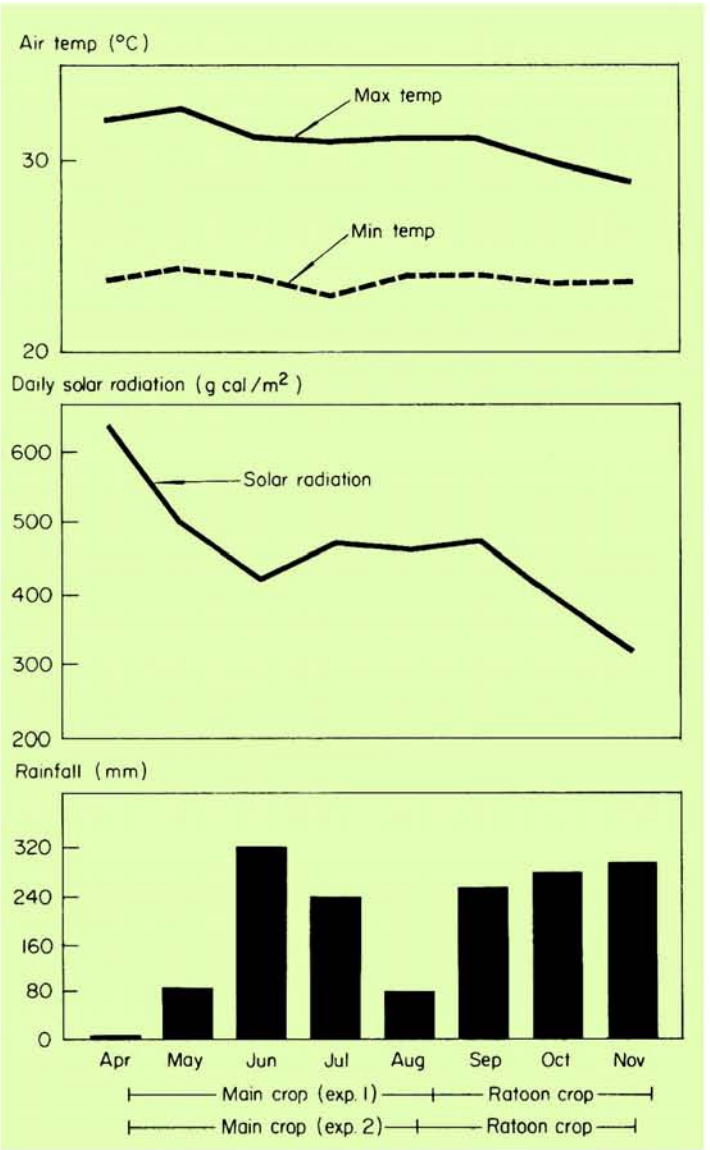
The first experiment used sorghum cultivars in the main plots, plant population per hectare in the subplots, and cutting height in the sub-subplots. The second experiment used Cosor 3 cultivar with plant population per hectare in the main plot, row spacing in the subplot, and cutting height in the sub-subplot. The two experiments had similar levels of management.

Figure 9 shows the rainfall distribution pattern, temperature readings (mean maximum and minimum), and solar radiation pattern from planting of the main crop to harvest of the ratoon crop. A dry spell during August favored harvesting operations and prevented sorghum seeds from sprouting.

Total sorghum yield from experiment 1 averaged 5.8 t/ha, with 59% contributed from the first or main crop and 41% from the ratoon crop. The highest grain yielder for the main crop was Cosor 3, the lowest UPLB SG5 (Table 36). Cultivar yields did not differ significantly in the ratoon crop. The Cosor 3 had the highest combined total grain yield of main and ratoon crops at 6.02 t/ha. All 3 cultivars had a yield reduction from main crop to ratoon crop of about 29%. The inherent capacity of Cosor 3 to produce more ratoon tillers, giving a higher number of panicles per unit area, compensated for its failure to produce the heaviest and longest panicle.

When plant density was increased from 200,000 to 400,000 plants/ha, yield and other agronomic characters of the ratoon crop tended to decrease (Table 37). With an increase in plant density, CS 110 yields tended to decrease and Cosor 3 and UPLB SG5 yields tended to increase (Fig. 10).

Growing a ratoon crop after the main crop's harvest took 20-32 fewer days than growing 2 main



9. Weather conditions during the main and the ratoon crop periods of the experiments at IRRI, Los Baños, 1981 late dry to wet season (Agroclimatic Unit, IRRI, Los Baños, Philippines).

Table 36. Main crop grain yield and some agronomic characters of the ratoon crop of 3 grain sorghum cultivars.[a] IRRI, 1981 wet season.

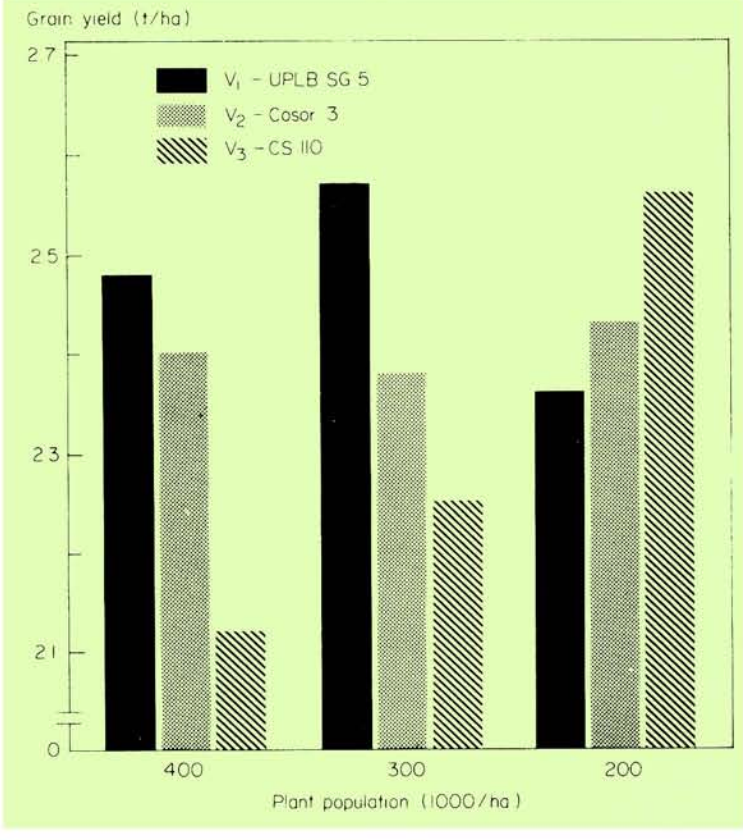
Cultivar	Grain yield (t/ha)			Ratoon crop				
	Main crop	Ratoon crop	Total	Panicle (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
Cosor 3	3.61 a	2.41 a	6.02	101 a	30.0 b	22.2 a	89 c	149.1 b
CS110	3.52 a	2.31 a	5.83	84 b	27.3 b	20.0 b	92 b	151.7 b
UPLB SG 5	3.06 b	2.47 a	5.53	77 b	35.4 a	23.0 a	95 a	156.1 a
Mean	3.40	2.40	5.79					

[a]Mean of 3 populations and 3 cutting heights. Separation of means by Duncan's multiple range test at the 5% level.

Table 37. Main crop grain yield and some agronomic characters[a] of the ratoon crop of 3 grain sorghum cultivars, as influenced by plant density. IRRI, 1981 wet season.

Plant density (1000/ha)	Grain yield (t/ha)			Ratoon crop				
	Main crop	Ratoon crop	Total	Panicles (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
200	3.60 a	2.45 a	6.05	84 a	32.0 a	22.1 a	91 c	152.2 a
300	3.44 a	2.40 a	5.84	90 a	30.5 a	21.5 a	92 b	151.9 a
400	3.15 b	2.33 a	5.48	88 a	30.1 a	21.6 a	93 a	152.8 a

[a]Mean of 3 varieties and 3 cutting heights. Separation of means by Duncan's multiple range test at the 5% level.



10. Grain yield of the ratoon crop of 3 grain sorghum cultivars under 3 plant populations. IRRI, 1981 wet season (av of 4 replications).

crops (Table 38).

The highest cutting level produced the highest ratoon yield (Table 39). The lighter and shorter panicles produced when the cutting height left three nodes above ground level was compensated for by the larger number of panicles per plot at harvest.

In experiment 2, yield and panicle weight and length generally decreased as plant density increased (Table 40). In contrast, the number of panicles per plot increased with plant density. Heavier and longer panicles at 100,000 plants/ha were compensated for by more panicles per unit area at 400,000 plants/ha. Average total yield was 6.62 t/ha, 63% from the main crop and 37% from the ratoon crop.

Higher ratoon yields and panicle numbers also were obtained when the main crop was cut at the

Table 38. Main crop and ratoon crop maturity of 3 grain sorghum cultivars.[a] IRRI, 1981 wet season.

Cultivar	Maturity (days)		Total maturity days		Total days saved
	Main crop	Ratoon crop	2 main crops	Main crop + ratoon crop	
Cosor	109 c	89 c	218	198	20
CS 110	124 a	92 b	248	216	32
UPLB SG 5	117 b	95 a	234	212	22

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

Table 39. Grain yield and some agronomic characters of the ratoon crop of 3 grain sorghum cultivars, as influenced by cutting height.[a] IRRI, 1981 wet season.

Cutting ht	Grain yield (t/ha)	Panicles (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
Ground level	2.38 c	82 c	31.9 a	22.0 a	92 a	151.2 c
1 node above ground level	2.39 b	88 b	31.0 b	21.7 b	92 a	151.6 b
3 nodes above ground level	2.41 a	92 a	29.8 c	21.5 c	92 a	154.0 a

[a]Mean of 3 varieties and 3 populations. Separation of means by Duncan's multiple range test at the 5% level.

Table 40. Main crop grain yield and some agronomic characters of the ratoon crop of Cosor 3 sorghum cultivar, as influenced by 4 plant densities of the main crop.[a] IRRI, 1981 wet season.

Plant density (1000/ha)	Grain yield (t/ha)			Ratoon crop				
	Main crop	Ratoon crop	Total	Panicles (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
100	4.72 a	2.63 a	7.35	60 c	61.2 a	21.4 a	90 c	151.4 a
200	4.38 ab	2.48 a	6.86	92 b	38.4 b	20.6 ab	92 a	147.3 a
300	3.93 abc	2.37 a	6.30	106 a	33.6 b	20.6 ab	91 b	147.2 a
400	3.65 c	2.30 a	5.95	103 a	33.3 b	20.4 b	91 ab	148.3 a
Mean	4.17	2.45	6.62					

[a]Mean of 3 row spacings. Separation of means by Duncan's multiple range test at the 5% level.

Table 41. Grain yield and some agronomic characters of the ratoon crop of Cosor 3 sorghum cultivar, as influenced by cutting height.[a] IRRI, 1981 wet season.

Cutting ht	Grain yield (t/ha)	Panicles (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
Ground level	2.34 b	92 b	28.6 a	21.0 a	91 a	146.8 b
3 nodes above ground level	2.54 a	109 a	26.4 b	20.5 b	91 a	150.3 a

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

third node above ground than when cut at ground level (Table 41).

As row spacing increased from 40 to 80 cm, ratoon grain yield, panicle weight, and number of panicles per plot increased significantly (Table 42).

NITROGEN FERTILIZER EFFICIENCY APPLIED RESEARCH TRIALS

Rice Production Training and Research Department

Efficiency of different methods of applying nitrogen to rice trials continued during the dry and wet seasons. The standard recommended practice, known as best-split application of nitrogen fertilizer in wetland-transplanted rice, was used as one treatment.

In South Cotabato and IRRI (Table 43), in the dry season, there were no differences in yields between treatments nor between any treatment and the check. In two sites in Pampanga, all treatments gave similar yields. However, plow-sole application by carabao gave a lower yield than other tests. All treatments gave better yields than the check plot at both sites.

In the wet season, yield differences between treatments, and between any treatment and the check were not significant at Villasis, Pangasinan (Table 44). At IRRI and South Cotabato, all treatments gave similar yields, higher than those of the control plots.

AZOLLA APPLIED RESEARCH TRIALS

Rice Production Training and Research Department

Azolla trials on irrigated transplanted rice in farmer's fields continued during the dry and wet seasons. The experiments compare an equivalent rate of nitrogen applied as a best split, using commercial fertilizers, with azolla inoculation.

In the dry season at 3 sites, no yield differences were found among treatments, including the different nitrogen rates and the azolla plot (Table 45).

Table 42. Grain yield and some agronomic characters of the ratoon crop of Cosor 3 sorghum cultivar, as influenced by row spacing.[a] IRRI, 1981 wet season.

Row spacing (cm)	Grain yield (t/ha)			Ratoon crop				
	Main crop	Ratoon crop	Total	Panicles (no./plot)	Panicle wt (g)	Panicle length (cm)	Maturity (days after main crop harvest)	Plant ht (cm)
40	4.09 a	2.32 b	6.41	70 c	26.2 b	20.6 a	91 a	147.3 b
60	4.21 a	2.51 a	6.72	104 b	27.1 ab	20.8 a	91 a	149.0 a
80	4.18 a	2.50 a	6.68	127 a	29.3 a	20.7 a	91 a	149.3 a

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

Table 43. Effect of different methods of applying fertilizer at 60 kg N/ha on yield of IR36 under irrigated-transplanted conditions from 4 sites in 3 Philippine provinces.[a] Nitrogen Fertilizer Efficiency Applied Research Trial, 1981 dry season.

Treatment[b]	Barrio 3, Koronadal South Cotabato	Sucap	Apalit, Pampanga	IRRI
PC	5.2 a	4.5 b	4.4 a	4.0 a
PS	5.3 a	5.0 ab	4.7 a	3.6 a
SG	5.5 a	5.5 a	5.3 a	4.2 a
SP	5.3 a	5.3 ab	4.7 a	4.0 a
Ck	4.6 a	3.5 c	3.4 b	4.1 a

[a] Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b] PC = drilling by hand on plow-sole of carabao-drawn native plow. PS = by IRRI-designed hand tractor-drawn plow-sole applicator. SG = urea 45% supergranules or pellets applied between every other 4 hills. SP = split application, 3/4 of nitrogen requirement as basal during final land preparation and 1/4 shortly before panicle initiation of the crop. Ck = check plot, no nitrogen-fertilizer applied.

Table 44. Effect of different methods of applying nitrogen-fertilizer at 60 kg N/ha on yield of IR36 in lowland-irrigated conditions at 3 sites in 3 Philippine provinces. 1981 wet season.

Application method[b]	Yield[a] (t/ha)		
	IRRI, Laguna	Villasis, Pangasinan	Tantangan, South Cotabato
PC	4.1 a	4.9 a	7.3 a
PS	4.5 a	5.6 a	7.0 ab
SG	4.2 a	5.7 a	6.7 ab
SP	4.3 a	4.7 a	6.5 ab
Ck	3.6 b	4.8 a	6.2 b

[a]Mean of 3 replications. Separation of means by Duncan's multiple range test at the 5% level. [b]PC = drilling by hand on plow sole of carabao-drawn Philippine native plow. PS = using the IRRI-designed hand tractor-drawn plow sole applicator. SG = using urea 45% of super-granules applied by hand between every other 4 hills after transplanting. SP = standard best-split application of nitrogen-fertilizer. 3/4 of nitrogen requirement as basal incorporated into the soil during the last harrowing and 1/4 as topdressing applied shortly before panicle initiation of the crop. Ck = check plot, no nitrogen-fertilizer applied.

Table 45. Grain yield of IR36 treated with azolla inoculum and at best-split nitrogen levels in transplanted-irrigated conditions at 3 sites in the Philippines. 1981 dry season.

Treatment[a]	Grain yield[b] (t/ha)		
	Tantangan, South Cotabato	Sucap, Apalit, Pampanga	IRRI
AZ	3.8 ab	4.3 ab	4.0 a
BS 40	3.7 ab	4.2 ab	3.5 ab
BS 60	3.7 ab	4.6 ab	3.7 ab
BS 80	3.8 ab	4.8 a	4.0 a
BS 100	4.0 a	4.7 a	3.8 ab
Ck	3.2 b	4.1 b	3.2 b

[a]AZ = azolla inoculum-treated plots at 2 and 12 days after transplanting (DT), with the former incorporated at 10 DT. BS = nitrogen fertilizer applied best split, 3/4 of the requirement as basal and 1/4 shortly before panicle initiation of the crop at 40, 60, 80, and 100 kg/ha rate. Ck = check plot, no nitrogen-fertilizer applied. [b]Av of 3 replications. Separation of means by Duncan's multiple range test at the 5% level.

Table 46. Grain yield of IR36 treated with *Azolla pinnata* as green manure and at best-split nitrogen levels in transplanted-irrigated fields at 3 sites in the Philippines. 1981 wet season.

Treatment[a]	Yield[b] (t/ha)		
	IRRI, Laguna	Villasis, Pangasinan	Norala, South Cotabato
AZ	2.9 b	5.1 ab	3.9 c
BS 40	3.4 a	5.0 b	3.9 c
BS 60	3.5 a	5.5 a	4.3 b
BS 80	3.7 a	5.0 b	4.2 b
BS 100	3.6 a	4.4 c	4.8 a
Ck	2.8 b	4.3 e	3.2 d

[a]AZ = azolla-inoculated plots at 2 and 12 days after transplanting (DT), the former soil incorporated at 10 DT. BS = nitrogen-fertilizer applied best-split, 3/4 of the requirement applied basal, incorporated into the soil during last harrowing and 1/4 applied shortly before panicle initiation of the crop. Rates are at 40, 60, 80, and 100 kg N/ha. Ck = check plot, no nitrogen-fertilizer applied. [b]Mean of 3 replications. Separation of means by Duncan's multiple range test at the 5% level.

However, yields were higher than the check plot.

In the wet season, azolla-inoculated plots at IRRI gave the same yields as the check plot (Table 46). The best-split nitrogen inorganic fertilizer-treated plots gave the same yield. The trend was similar in South Cotabato. The 40-kg N/ha and azolla-treated plots yielded higher than the check plots but lower than the 60- and 80-kg N/ha plots. Yields were highest with 100 kg N/ha. In Pangasinan, azolla-treated plots yielded much higher than the check plot. At 40, 60, and 80 kg N/ha, yields were similar but lower with 100 kg N/ha best split.

Cropping systems program

Evaluating cropping systems

Agricultural Economics and Rice Production Training and Research Departments

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ECONOMIC EVALUATION OF CROPPING PATTERNS AT SOLANA OUTREACH SITE

Agricultural Economics Department

Cropping pattern trials in the 1980-81 crop year were affected by unusually harsh weather, which destroyed many trials as well as farmers' crops. That severe test helped in determining cropping pattern riskiness and in designing new patterns for testing in 1981-82.

Weather conditions in 1981-82 were more normal and the performance of the pattern trials and of crops cultivated by farmers' traditional practices was consequently better. Fewer crops failed and in general yields were higher.

To accommodate landscape and rainfall variations, farmers in Solana have adopted alternative cropping patterns. The lowland area is commonly planted to a single crop of rice or to mungbean followed by rice. The upland areas have traditionally been planted to one or two crops of maize or to maize followed by an upland crop of mungbean, cowpea, or tobacco.

For cropping pattern testing, IRRI researchers divided the lowland area into three strata on the basis of visual observation, soil analysis, and actual water depth. (See Fig. 1 in Environment description.) Stratum 1 occupies the highest portion of the lowland areas. Stratum 2 represents the transitional area, and stratum 3 the lowest portion. Water is expected to accumulate faster and fields are expected to remain flooded longer on the lower strata 2 and 3.

In stratum 1, three patterns were designed. The first is similar to farmers' traditional mungbean-transplanted rice (TPR) pattern except for varieties used and cultural practices followed. The second pattern, mungbean - TPR - mungbean added a second mungbean crop after rice. In the third pattern — mungbean - dry-seeded rice (DSR) - mungbean — the rice crop was direct seeded rather than transplanted.

In stratum 2, the mungbean - TPR and mungbean - TPR - mungbean patterns were also tested and a first rice crop was substituted for a first mungbean crop in two additional patterns. In one pattern, the first rice crop was dry seeded; in the other, it was transplanted. In stratum 3, only a TPR - TPR pattern was tested.

During testing, some patterns deviated from the original design specifications for crop sequence and time and method of crop establishment. In stratum 1, pattern 3, the DSR crop could not be established because the land was too wet by the time the upland crop was harvested because of a delay in establishment of the mungbean crop. In strata 1 and 2, the mungbean crop in the TPR - TPR - mungbean pattern could not be established, also because the upland crops were harvested late (see Physical and biological environment).

The amount and costs of labor and material inputs used to cultivate crops on experimental plots and farmers' fields were recorded. Seasonal agricultural wage rates were calculated as 5-week moving averages of labor costs reportedly paid by farmer cooperators. Prices paid by local wholesale market vendors during the harvest period of each crop were used to compute gross returns.

The 1981-82 data from experimental pattern trials and records of farmer cooperators' traditional cropping pattern cultivation permit a comparison of 1981-82 pattern performance among crops and cropping patterns and between the research strata and the two strata recognized by farmers that roughly correspond. Performance is measured by individual crop yields and cultivation costs and returns and cropping pattern cultivation costs and returns.

Planned and completed crop plots. Table 1 shows the number of plots planned and successfully harvested in each location.

Mungbean. As a first crop, mungbean had good success in both farmers' and experimental patterns on strata 1 and 2. As a third crop after rice, mungbean planted after December failed because of water stress when rains ended abruptly. Mungbean planted no later than December was more successful.

Transplanted rice. No first-crop TPR failed in either experimental plots or farmers' fields. As a second crop after mungbean, TPR had 100% success on experimental plots and about 96% success on farmers' fields. As a second rice crop, TPR registered losses of about 30% in stratum 2 and of about 15% in stratum 3. Late establishment of the second crop contributed to most TPR losses.

Dry-seeded rice. All DSR plots succeeded in stratum 2. DSR was not tested in the other strata

Table 1. Planned (P) and completed (C) plots in traditional and experimental cropping patterns by stratum, Solana outreach site, 1981-82.

Component crop[a]	Stratum 1		Strata 2 and 3		Total	
	P	C	P	C	P	C
Mungbean before rice						
Traditional	38	29	30	18	68	47
Experimental	15	10	8	5	23	15
Mungbean after rice						
Experimental	9	2	4	1	13	3
TPR first crop						
Traditional[b] (local)	26	26	40	38	66	64
Traditional (MV)	–	–	5	5	5	5
Experimental (2 and 3)	–	–	4/9	4/9	13	13
TPR after mungbean						
Traditional (local)	28	28	30	29	58	57
Traditional (MV)	10	10	–	–	10	10
Experimental	15	15	8	8	23	23
TPR after rice[c]						
Traditional (local)	–	–	5	5	5	5
Experimental (2 and 3)	–	–	9/7	8/6	16	14
DSR first crop						
Experimental	–	–	6	6	6	6

[a]TPR = transplanted rice. DSR = dry-seeded rice. MV = modern variety. [b]Farmers' fallow - TPR (local) and fallow - TPR (MV) patterns. [c]Preceding rice crop is either DSR or TPR.

nor as a second crop because of standing water. The plots were planted to TPR instead.

On the basis of available data, the patterns that appeared most promising were:

Stratum 1	*Stratum 2*	*Stratum 3*
Mung - TPR	Mung - TPR	TPR - TPR
	TPR - TPR	
	DSR - TPR	

Component crop yields. Yields varied widely among the successful plots (Table 2).

Mungbean. Differences between farmers' and experimental plots were notable. First-crop mungbean yields in farmers' plots were about 14% of those in experimental plots in strata 1 and 2. Third-crop mungbean did less well in both strata than first-crop mungbean in experimental patterns, except mungbean - TPR in stratum 2. The failure of plots planted after December explain much of the lower average yield for mungbean planted after rice.

Transplanted rice. Yields ranged widely; farmers' yields averaged 1.0-1.8 t/ha, experimental yields, 1.6-3.7 t/ha. In 1981-82, the farmers' traditional local variety outperformed the farmers' modern variety (1.8 t/ha vs 1.0 t/ha) — perhaps due to farmers' failure to apply chemical fertilizer. The experimental plot performed most poorly as a second crop after rice in strata 2 and 3 because of late establishment of the second crop. It performed best as a second crop after mungbean in stratum 1 and as a first crop in strata 2 and 3.

Dry-seeded rice. As a first crop on stratum 2, where it was tested, DSR was a good performer. Its experimental yields averaged 3.3 t/ha, comparable to yields of experimental TPR after mungbean on stratum 1 and exceeding TPR after mungbean and TPR as a first crop in stratum 2.

Component crop costs and returns. The costs and returns of farmers' and experimental component crops in pattern trials are summarized in Table 2.

Mungbean. Costs of farmers' cultivation averaged one-third to one-half those of experimental cultivation. Average gross returns from farmers' traditional patterns were only 10-20% of those from experimental patterns, except mungbean after rice, whose returns were negative because a large number of plots planted to mungbean after

Table 2. Yield, total variable costs[a] (TVC), gross returns (GR), and net returns (NR) of farmers' traditional and experimental component crops in pattern trials at Solana outreach site, Cagayan, Philippines, 1981-82.[b]

Component crop	Stratum 1				Strata 2 and 3			
	Yield (kg/ha)	TVC ($/ha)	GR ($/ha)	NR ($/ha)	Yield (kg/ha)	TVC ($/ha)	GR ($/ha)	NR ($/ha)
Mungbean before rice								
Traditional	67	39	39	0	33	32	2.69	-1.41
Experimental	472	126	283	20.13	228	78	16.79	6.79
Mungbean after rice								
Experimental	54	88	30	-7.43	124	100	8.97	-3.20
TPR first crop								
Traditional (local)	1553	126	291	21.15	1657	136	38.97	21.54
Traditional (MV)	–	–	–	–	2158	141	51.41	33.33
Experimental (2 and 3)	–	–	–	–	2941/3661	249/286	66.54/81.54	34.61/44.87
TPR after mungbean								
Traditional (local)	1757	131	319	24.10	1665	118	37.31	22.18
Traditional (MV)	1027	103	177	9.49	–	–	–	–
Experimental	3202	250	531	36.02	2502	204	52.31	26.15
TPR after rice								
Traditional (local)	–	–	–	–	1665	139	40.38	22.56
Experimental (2 and 3)	–	–	–	–	1905/1620	199/162	41.15/38.85	15.64/18.07
DSR first crop								
Experimental	–	–	–	–	3296	239	75.77	45.13

[a]Sum of all labor, power, and material input costs in production. [b]$1 = ₱7.80.

December plots failed.

Transplanted rice. Farmers' cultivation costs averaged 20-100% lower than experimental cultivation costs. Farmers' average gross returns from lower yields were also lower, despite the better prices local consumers pay for local rice varieties than for modern varieties.

With the exception of TPR after rice, which gave higher average net returns in farmers' plots than in experimental plots, all patterns with TPR as a component crop gave lower average net returns in farmers' plots than in experimental plots. It appears that farmers were able to control planting dates better. No crops failed in the farmers' two-rice patterns studied; one of three plots failed in the experimental patterns on stratum 2.

Dry-seeded rice. One of the more notable outcomes of the 1981-82 trials was the good returns of experimental plots. Although DSR was among the crops with the highest cultivation costs, its good yield performance enabled it to achieve the highest net returns among all crops in the pattern trials.

Cropping pattern costs and returns. Farmers' and experimental pattern costs, gross returns, and net returns and benefit-cost ratios are summarized in Table 3.

Wide differences in both total costs and net returns are apparent among the patterns. Farmers' patterns had uniformly lower costs and lower gross and net returns on both strata than corresponding experimental patterns. Benefit-cost ratios of some farmers' patterns compared favorably with those of the experimental patterns.

While most experimental patterns produced good returns above costs, often exceeding 100%, some patterns did less well. Mungbean - TPR - mungbean returned only about 40% above costs in stratum 2. Mungbean - TPR returned only 42%.

The experimental patterns that showed good returns above costs were mungbean - TPR in stratum 1; TPR - TPR and DSR - TPR in stratum 2, and TPR - TPR in stratum 3. They were high-cost patterns, however. The only patterns that combined relatively low costs with relatively high returns were experimental mungbean - TPR in stratum 1 and farmers' TPR - TPR in stratum 2.

While power costs remained low and stable, differences in labor and material costs were dramatic. Some experimental patterns required labor investments of about 100% and material investment of 600-800% more than farmers' traditional cultivation expenditures. Particularly notable is

Table 3. Variable costs, gross and net returns, and benefit-cost ratios of traditional and experimental cropping patterns at Solana outreach site, Cagayan, Philippines, 1981-82.

Cropping pattern[a]	Variable (cultivation) costs ($/ha)				Returns ($/ha)		B-C ratio
	Labor	Power	Material	Total	Gross	Net	
Stratum 1							
Fallow - TPR (local)[b]	91	24	10	125	291	166	2.3
Mungbean - TPR (local)[b]	125	25	22	172	362	190	2.1
Mungbean - TPR (MV)[b]	97	18	21	136	207	71	1.5
Mungbean - TPR	196	25	132	353	845	492	2.4
Mungbean - TPR - mungbean	224	33	215	472	832	360	1.8
Strata 2 and 3							
Fallow - TPR (local)[b]	104	24	8	136	304	168	2.2
Mungbean - TPR (local)[b]	104	26	20	150	311	161	2.1
TPR - MV - TPR (local)[b]	220	41	20	281	716	435	2.5
Mungbean - TPR	113	16	125	254	440	186	1.7
Mungbean - TPR - mungbean	198	36	176	410	708	298	1.7
DSR - TPR	230	25	198	453	903	450	1.7
TPR - TPR (stratum 2)	230	32	172	434	850	416	1.9
TPR - TPR (stratum 3)	252	39	157	448	939	491	2.0

[a]TPR = transplanted rice, MV = modern variety, DSR = dry-seeded rice. [b]Farmers' traditional pattern.

Table 4. Total and cash costs of alternative cropping patterns in rainfed wetland rice areas of Solana outreach site, Cagayan, Philippines, 1981-82.

Cropping pattern[a]	Total variable cost ($/ha)	Total cash cost ($/ha)	Cash cost (% of TVC)	Increase in			
				Total variable cost[b]		Cash cost[b]	
				$/ha	%	$/ha	%
Stratum 1							
Fallow - TPR (local)[c]	126	10	8	–	–	–	–
Mungbean - TPR (local)[c]	172	22	13	46	(37)	12	(120)
Mungbean - TPR (MV)[c]	137	21	21	11	(9)	11	(110)
Mungbean - TPR	353	132	37	227	(180)	122	(1220)
Mungbean - TPR - mungbean	473	215	45	347	(275)	205	(2050)
Strata 2 and 3							
Fallow - TPR (local)[c]	136	8	6	–	–	–	–
Mungbean - TPR (local)[c]	150	20	14	14	(10)	12	(150)
TPR (MV) - TPR (local)[c]	281	20	7	145	(110)	12	(150)
Mungbean - TPR	254	125	49	118	(90)	117	(1460)
Mungbean - TPR - mungbean	410	176	43	274	(200)	166	(2075)
DSR - TPR	453	198	44	317	(232)	190	(2375)
TPR - TPR (stratum 2)	434	172	40	298	(218)	164	(2050)
TPR - TPR (stratum 3)	448	157	35	312	(228)	156	(1951)

[a]TPR = transplanted rice, MV = modern variety, DSR = dry-seeded rice. [b]Compared with farmers' traditional fallow - TPR (local) pattern. [c]Farmers' traditional pattern; all other patterns used modern varieties (MV) of rice and mungbean.

the magnitude of the difference in cash costs between experimental and farmers' patterns (Table 4). This difference is attributable to the low cash inputs used by farmers compared with those applied to experimental patterns.

Potential gains from experimental pattern adoption. Although experimental data from the Solana outreach site are still limited, it is possible to make some preliminary projections of the potential gains if farmers' traditional patterns are replaced with experimental patterns. The marginal benefit-cost ratio (MBCR) test can be applied to the 1981-82 costs-and-returns data. The test relies on the assumption that when faced with several profitable alternatives, farmers will replace their traditional technology or cropping patterns by that alternative

Table 5. Incremental gains from replacing traditional patterns with more intensive cropping patterns, Solana outreach site, Cagayan, Philippines, 1981-82.

Farmers' traditional cropping pattern[a]	Area planted (%)	Replacement cropping pattern	TVC increase[b] (%)	Marginal benefit-cost ratio[b]
Stratum 1				
Fallow - TPR (local)	44	Mungbean - TPR (local)[c]	37	1.5
		Mungbean - TPR (MV)[c]	9	[e]
		Mungbean - TPR[c]	180	2.4
		Mungbean - TPR - mungbean[d]	275	1.6
Strata 2 and 3				
Fallow - TPR (local)	55	Mungbean - TPR (local)[c]	10	0.5
		TPR (MV) - TPR (local)[c]	110	2.8
		Mungbean - TPR[d]	90	1.2
		Mungbean - TPR - mungbean[d]	200	1.5
		DSR - TPR[c]	232	1.9
		TPR - TPR (stratum 2)[d]	218	1.8
		TPR - TPR (stratum 3)[d]	228	2.0

[a]TPR = transplanted rice. [b]TVC = total variable cost. Increase calculated as TVC of replacement pattern minus TVC of traditional pattern, divided by TVC of traditional pattern. Marginal benefit-cost ratio calculated as gross returns of replacement pattern minus gross returns of traditional pattern, divided by TVC of replacement pattern minus TVC of traditional pattern. [c]Farmers' pattern. [d]Experimental pattern. [e]Added costs exceeded added returns.

which offers the highest incremental returns per unit of incremental costs incurred by switching to alternative patterns. Table 5 compares experimental patterns with the most common traditional patterns.

Alternative patterns. *Stratum 1.* The single TPR, fallow - TPR (local) pattern, one of the most popular cropping patterns, occupies 44% of the land in stratum 1. Mungbean - TPR (local) occupied 30% of the land and minor patterns, the remainder.

The best alternative to a fallow - TPR pattern with present farmer technology is farmers' mungbean - TPR (local) (it offers the highest net returns). A shift to a more intensive mungbean - TPR (local) pattern would require only a 37% increase over the present level of investment in fallow - TPR (local) while offering $1.50 on every additional $1 investment.

Experimental mungbean - TPR pattern appears to be the likely replacement for farmers' single- or double-crop patterns. Experimental mungbean - TPR pattern requires a 180% greater outlay than farmers' fallow - TPR (local) but returns $2.40, and 100% more than farmers' mungbean - TPR (local), but returns $2.70 for every $1 invested. Establishing an additional mungbean crop (as in mungbean - TPR - mungbean), lowers the rate of return per additional $1 of inputs.

Strata 2 and 3. Farmers' single transplanted rice (fallow - TPR [local]) occupied about 55% of the land area in 1981-82. An additional 32% was planted to mungbean - TPR (local) and 13% to TPR (MV) - TPR (local).

Farmers' TPR (MV) - TPR (local) pattern offered the best alternative among both farmers' and experimental technologies. Its returns above costs were about 151% higher than those of a single rice crop. Although it required 110% more outlay than the current farmers' pattern, it returned $2.80 in added income for each $1 of added costs. The less expensive mungbean - TPR (local) pattern returns only $0.50 per $1 additional cost. Experimental mungbean - TPR returns $1.20; mungbean - TPR - mungbean, $1.50; DSR - TPR, $1.90; and TPR - TPR, $1.80.

Recommendations. Table 6 ranks farmers' and experimental cropping patterns according to measures of economic performance: gross and net economic returns, total and cash costs, and returns on investment. No pattern is superior to others in all cases. Farmers' patterns rank poorly in relation to gross and net returns but rank higher than experimental patterns in cost savings and returns on costs.

Pattern selection based on long-term yield and income stability may prove more important than pattern selection based on the 1-year trials.

Table 6. Ranking[a] of traditional and experimental cropping patterns according to selected economic criteria, Solana outreach site, Cagayan, Philippines, 1981-82.

Cropping pattern[a]	Ranking[b]							
	Economic returns		Variable costs		Cash costs		Benefit-cost	
	Gross	Net	Total	%	Total	%	BCR	MBCR
Stratum 1 (parang)								
Fallow - TPR (local)[c]	4	4	1	–	1	–	2	–
Mungbean - TPR (local)[c]	3	3	3	2	3	2	3	4
Mungbean - TPR (MV)[c]	5	3	2	1	2	1	5	3
Mungbean - TPR	1	1	4	3	4	3	1	1
Mungbean - TPR - mungbean	2	2	5	4	5	4	4	2
Strata 2 and 3 (kalayakan)								
Fallow - TPR (local)[c]	8	7	1	–	1	–	2	–
Mungbean - TPR (local)[c]	7	8	2	1	3	2	3	6
TPR (MV) - TPR (local)[c]	4	3	4	3	2	1	1	1
Mungbean - TPR	6	5	3	2	4	3	6	6
Mungbean - TPR - mungbean	5	6	5	4	7	6	6	5
DSR - TPR	2	2	8	7	8	7	5	3
TPR - TPR (stratum 2)	3	4	6	5	6	5	5	4
TPR - TPR (stratum 3)	1	1	7	6	5	4	4	2

[a]TPR = transplanted rice, MV = modern variety, DSR = dry-seeded rice. [b]1 = highest, 7 = lowest. Highest ranking given to highest gross and net returns and benefit-cost ratio (BCR) and marginal benefit-cost ratio (MBCR) and to lowest level and smallest increase in variable and cash costs. [c]Farmers' traditional pattern.

Table 7. Yield gap between researcher-recommended and farmers' management of mungbean, 1980-81.

Location	Trials (no.)	Yield (t/ha)		
		Recommended	Farmer	Gap
Basista	8	0.77	0.37	0.39
Santa Maria	8	0.70	0.41	0.29
Malasiqui	8	0.89	0.59	0.30
All	24	0.79	0.46	0.33

PILOT PRODUCTION PROGRAM ON MUNGBEAN TECHNOLOGY

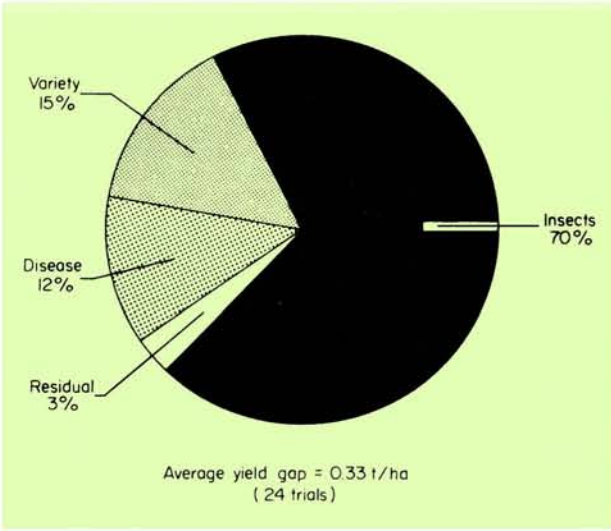
Rice Production Training and Research and Agricultural Economics Departments

Increased emphasis was placed on the development of methodology for preproduction testing of cropping systems in response to requests from the Asian Cropping Systems Working Group. A procedure for the monitoring and evaluation of pilot production programs was tested in Pangasinan. The pilot program, code-named Manbilayka, was based on the results of cropping systems research at Manaoag (reported in earlier annual reports). This study, conducted jointly with the Philippine Ministry of Agriculture, focused on the mungbean component of the recommended rice-mungbean pattern for rainfed areas.

The evaluation procedure had three components: multilocation production plots, superimposed trials, and farm surveys. Production plots (1,000 m^2) normally were designed to test the agronomic performance of recommended practices in the same season as the production program. That made it possible to compare agronomic performances with and without the economic constraints farmers face. The plots also were used by the Ministry of Agriculture to conduct 2 field days during the 1980-81 season.

With recommended technology, the yield was 0.79 t/ha, compared with 0.46 t/ha obtained by farmers participating in the Manbilayka program (Table 7). Superimposed trials showed that insects contributed the most to the yield gap (Fig. 1). Partial budget analysis showed an average benefit-cost ratio of 1.9 (Table 8). Regression analysis of the superimposed trials showed the importance of insect control and highlighted the effect of planting date and soil phosphate level on mungbean yields (Table 9).

Two methods were used for the farm survey component: 1) several visits to a small number of farmers, and 2) a single interview after harvest of a large sample of farmers (n = 169). Both methods had drawbacks. Multiple interviews required more



1. Average contribution of test factors to yield gap in mungbean. Pangasinan, 1980-81.

Table 8. Partial budget analysis of researcher's and farmers' insect control strategies, 1980-81.

Location	Incremental yield (t/ha)	Added value[a] ($/ha)	Insect control cost ($/ha)		Added cost[a] ($/ha)	Net benefit	Benefit-cost ratio
			Researcher	Farmer			
Basista	0.29	167.30	96.15	49.74	46.41	943	3.6
Santa Maria	0.15	86.54	96.15	17.82	78.33	64	1.1
Malasiqui	0.24	138.46	96.15	40.00	56.15	624	2.5
All	0.23	132.69	96.15	36.28	61.02	559	1.9

[a]$1 = ₱7.80.

Table 9. Factors contributing to differences in mungbean yields, Pangasinan experimental sites, Philippines, 1980-81.

Parameter	Regression coefficient	Contribution to R^2 (%)
Intercept	0.59	
Insect control	0.24	25
Disease control	0.03	0
Variety	0.05	1
STPhosphate	0.03	26
Planting date	-0.20	48
F-ratio	45.12	
R^2	0.54	
CV (%)	36.03	

manpower than most national programs could allocate. A single interview tended to result in erratic and seemingly unreliable results because it depended on farmer recall. However, the survey component highlighted deficiencies in extension workers' knowledge of recommended technology, particularly that related to chemical insect control. Seventy percent of the farmers participating in the Manbilayka program continued to spray when insects were seen, instead of following the recommendation for four prophylactic sprays.

When mungbean yields and soil analysis were evaluated, it appeared that yield was related to both phosphorus and potassium levels in the soils. Phosphorus and potassium treatments have been included in the design of trials planted in late 1981.

Interactions of tillage level, planting date, and weed population also were apparent.

PILOT EXTENSION PROGRAM ON TWO RICE CROPS

Rice Production Training and Research Department

A socioeconomic survey of Kabsaka and Kasatinlu, two of five pilot extension programs based on two-rice crops, examined, in the production phase, the adoption of the technology, improvement in the social and economic status of farmer-cooperators, and the impact of the introduction of the new technology on agricultural progress in general.

From 1974 to 1981, in the Kabsaka program, the area expanded from 0.24 to 6,302 ha and the number of farmers increased from 2 to 4,562; in Kasa-tinlu, the area expanded from 0.24 to 958 ha and the number of farmers increased from 2 to 729 farmers from 1977 to 1981 (Fig. 2,3).

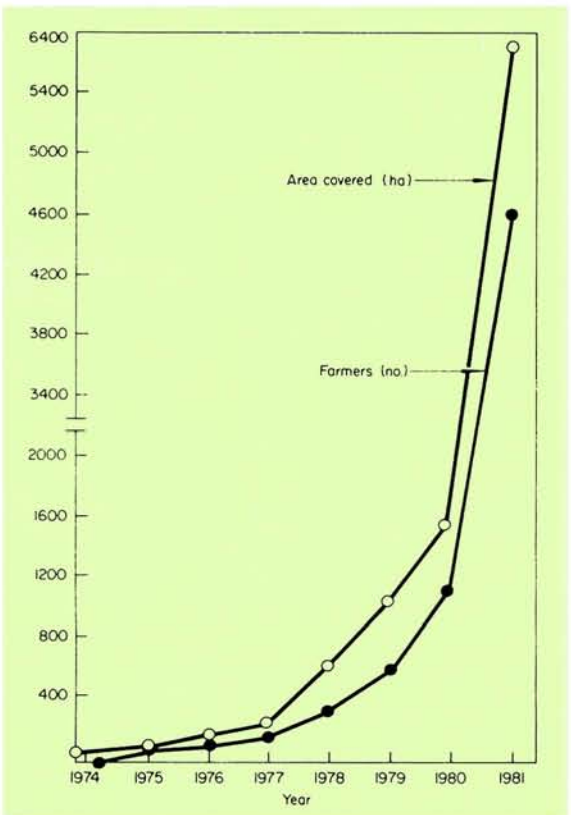
Financially, a seemingly endless state of indebtedness was overcome by some farmers. Living conditions were improved through the acquisition of appliances for home use. Continued and better support for education of the children also was noted.

The active participation of government agricultural extension technicians included in the program resulted in more frequent contacts with farmers.

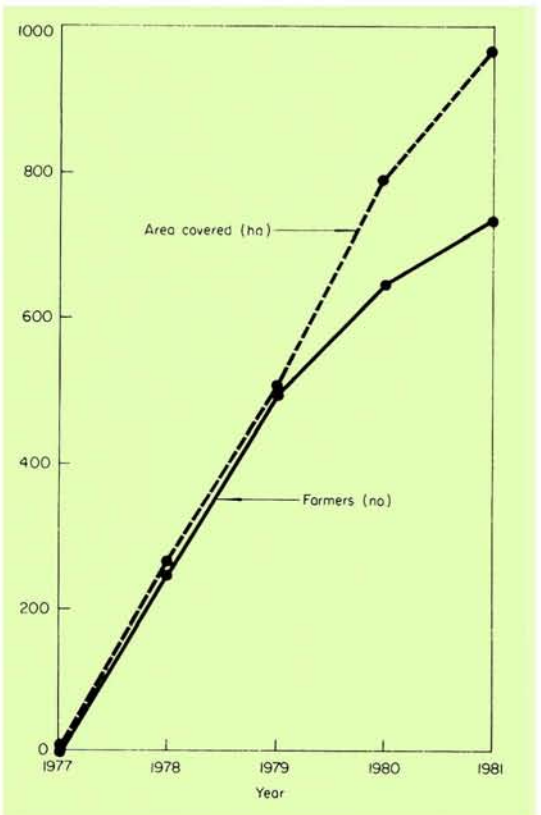
RAINFED RICE PRODUCTION TESTING

Rice Production Training and Research Department

Testing the package of technology developed for rainfed rice production in multiple locations continued in 1981. Yields of 5 t/ha or more were produced in 34 of 49 sites where dry-seeded rice was established. In Zamboanga del Sur, 9 of 14 plots produced 5 t/ha or more. In Antique, yields from 11 plots averaged 5.6 t/ha and ranged from 4.0 to 8.1 t/ha. Casamata in Iloilo produced 5.8



2. Annual increase in number of farmers and area covered by Kabsaka, Iloilo, project, 1974-1981.



3. Annual increase in number of farmers and area covered by Kasa-tinlu, South Cotabato, project, 1977-1981.

t/ha. Yields in North and South Cotabato were 3.9-7.7 t/ha (Table 10).

Table 10. Yield in dry seeded rice production plots, 1981 wet season.

Province, town, barangay	First-crop yield[a] (t/ha)
Antique	
Tabios Fornier	
Masayo	7.6
Igdaulog	7.5
Poblacion Sur	5.6
Abaca	4.7
Villaflor	4.0
Patnongon	
Poblacion #1	8.1
Badiangan	7.0
Padang	6.9
Mabasa	5.6
Casit-an	5.1
Poblacion #2	4.8
North Cotabato	
Kidapawan	
Macebolig #1	6.3
" #2	5.7
" #3	5.6
" #4	5.6
" #5	5.5
Gayola #1	4.9
San Roque #1	4.7
Gayola #2	4.6
San Roque #2	4.5
South Cotabato	
Banga	
Barrio 1 #1	6.6
Barrio 5 #1	6.5
Barrio 5 #2	5.4
Barrio 1 #2	5.3
Surallah	
Naci #1	7.7
Naci #2	6.5
Dajay	3.9
Koronadal	
Mabini	5.1
Zamboanga del Sur	
Pagadian	
Tiguma #1	4.7
Tiguma #2	4.1
Labangan	
Bulanit	5.6
Balimbingan	2.9
Titay	
Achasol #1	4.2
Achasol #2	4.0
Dalangin	3.2
Zamboanga del Sur (cont'd.)	
Ipil	
Upper Pangi #1	5.6
Upper Pangi #2	4.9
Dimataling	
Sugbay Uno #1	7.9
Sugbay Uno #2	6.0
Dumalinao	
Sumadat	5.4
Town #1?	
Tinigwangan	6.9
Tinigwangan	5.5
Town #2?	
Kagawasan	6.6
Iloilo	
Ajuy	
Casamata	5.8
San Antonio	3.4
Malayu-an	3.6
Balasan	
Aranjues	4.1
Poblacion Sur	3.8

[a] Av of 3- X 10-m^2 harvest samples.

Cropping systems program

Asian Cropping Systems Network (ACSN)

Multiple Cropping Department

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NETWORK ACTIVITIES

Network research sites concentrate on the design and testing of cropping patterns. Research on such component technology as varietal testing, fertilizer rates, and pest control is under way. The main focus is on increasing cropping intensity from 1 crop a year to 2 or more and from 2 crops to 3 or more while increasing production in each crop and increasing overall net income.

NETWORK RESEARCH SITES

In 1981, the cropping systems network included 30 operational research sites in 9 countries — Indonesia, Thailand, Bangladesh, Philippines, Sri Lanka, India, Burma, Nepal, and South Korea (Table 1). The sites represent a broad range of climatic zones, soil type, soil texture, and socioeconomic conditions. More sites are doing research on rainfed wetland cropping systems. Cropping patterns are also being tested in partially irrigated, irrigated, rainfed dryland, deepwater, and tidal swamp rice lands.

China joined the network this year. Three research sites — one in the north in collaboration with the Chinese Academy of Agricultural Sciences, Peking, and two in Central China with Zheijiang Academy of Agriculture Sciences Hongshuo are being planned.

NATIONAL PROGRAMS

National programs have established more cropping systems research sites, basically using ACSN methodology. In 1981, the establishment of 76 more rice-based cropping systems sites increased to 106 the total number of operational sites (Table 2). Cropping patterns are tested in rainfed wetland,

Table 1. Research sites in the Asian Cropping Systems Network (ACSN), 1981.

Country	Sites (no.)					
	In ACSN	Rainfed wetland	Partially irrigated	Irrigated	Rainfed dryland	Deep water
Philippines	4	3	1	–	3	–
Burma	4	2	2	1	–	–
Indonesia	4	2	–	–	2	1
Korea	3	–	–	3	–	–
Nepal	3	3	3	3	–	–
India	1	–	–	–	1	–
Bangladesh	4	1	–	1	1	2
Sri Lanka	3	2	1	–	–	–
Thailand	4	3	–	1	–	–
Total	30	16	7	9	7	3

Table 2. Research sites in national cropping systems programs in Asia, 1981.

Country	Sites (no.)					
	In national programs	Rainfed wetland	Partially irrigated	Irrigated	Rainfed dryland	Deep water
Philippines	19	18	1	–	5	–
Burma	7	2	4	2	2	–
Indonesia	21	6	–	–	16	1
Korea	9	–	–	9	–	–
Nepal	6	5	6	6	–	–
India	1	1	–	–	1	–
Bangladesh	28	11	4	10	3	4
Sri Lanka	7	4	2	1	–	–
Thailand	8	7	–	1	–	–
Total	106	54	17	29	27	5

partially irrigated, irrigated, rainfed dryland, and deepwater areas.

Indonesia, the Philippines, and Bangladesh established national networks of cropping systems research sites. Indonesia is concentrating more on rainfed dryland rice-based cropping systems in the islands of Sumatra, South Kalimantan, and Sulawesi. Bangladesh is emphasizing rainfed wetland, irrigated, and deepwater rice. The Philippines is focusing on rainfed wetland and dryland rice.

The Philippines, Thailand, and Bangladesh also established upland crops-based cropping systems as part of their national networks.

Bangladesh. The Bangladesh Rice Research Institute (BRRI) cropping systems program intensified work at deepwater rice and dryland farming research sites, in addition to that at rainfed and irrigated sites. BRRI also continued collaborative research with 24 sites run by other agencies. The second annual review meeting was held in September 1981. Four Bangladesh sites are in ACSN.

Salna site (irrigated). A triple rice-cropping pattern involving high yielding varieties gave the highest agronomic productivity (11.1 t/ha) and net return. Rice - rice - wheat was also promising. Applying sulfur and zinc improved rice yields considerably.

Daudkandi site (deepwater). Of the 15 cropping patterns at Daudkandi, deepwater rice - wheat is the most predominant. Deepwater rice - potato - sesame and deepwater rice - potato - chili were the most profitable. Although deepwater rice - wheat gave a lower net return than all but deepwater rice - Italian millet, about 25% farms grew this pattern to meet family grain consumption needs. Deepwater rice was 100% more profitable than jute. Improved crop management is being used to improve production per unit area.

Dacca-Narayanganj-Demra (DND) Project (deepwater). The Bangladesh Water Development Board and BRRI scientists jointly developed boro (winter) rice - deepwater rice - mustard and boro rice - deepwater rice patterns to replace the traditional single boro rice crop. Boro rice - deepwater rice - mustard had a more than 100% higher net return than a single crop of modern boro rice. The newly developed patterns are being widely adopted.

Rajshahi site (dryland and rainfed wetland). The major cropping patterns are local aus rice - local t. aman rice - barley + chickpea and local aus rice - local t. aman rice. Barley + chickpea and wheat + chickpea are common mixed cropping practices during winter. Higher soil moisture in lowland areas produces yields considerably higher than those in upland areas. Work is underway to replace local rice varieties with improved high yielding varieties.

Burma. Collaboration is with the Agriculture Development Corporation, particularly the Agriculture Research Institute, which organized a national cropping systems working group that provides policy and general guidelines for the implementation of cropping systems research. Of seven cropping systems research sites, four are in ACSN. Testing started in 1980-81.

Patheingyi site (partially irrigated). In the dry zone of central Burma, the traditional pattern has been one rice crop. But with the Sedawgyi irrigation project, other crops can be planted. Of the patterns tested, the most promising was long staple cotton - rice and peanut - rice. Income from long staple cotton and peanut crops was about six times that from a single rice crop.

Pyinmana site (partially irrigated). In the moderate monsoon climate with 4 wet months and 6 dry months, 7 experimental patterns were tested: rice - sunflower, rice - sesame, rice - peanut, rice - mungbean, rice - corn, and rice - sorghum. Rice yields ranged from 4.13 to 5.52 t/ha, compared with farmers' yields of 2.81 t/ha. Yield data for the second crop were not available.

Wakema site (rainfed wetland). More than 50% of lower Burma rice is grown in the Irrawaddy Delta, which has heavy rainfall, with 5 wet months and 6 dry. The traditional cropping pattern has been rice - fallow and jute - rice. The 4 cropping patterns tested — rice - pulses, jute - rice, rice - sesame, and rice - sunflower — yielded higher net incomes than the farmers' traditional pattern. Net income for rice - pulses was $587; for rice - sunflower, $489, for rice alone, $67; and for jute - rice, $210.

North Nawin site (partially irrigated wetland). On the bank of Irrawaddy River, near Prome, rainfall is moderate with 4 wet months and 6 dry months. The predominant cropping pattern has been rice - fallow, with some farmers planting cotton after rice. Four cropping patterns were tested in

1981 — rice - cotton, rice - mungbean, rice - sesame, and rice - sunflower. Rice yields ranged from 3.96 to 4.35 t/ha, higher than farmers' yield of 2.29 t/ha. The second crops had not been harvested.

India. The collaborating institution is the Indian Council of Agricultural Research (ICAR). The network site, at Ranchi, with Birsa Agriculture University, is part of the All India Coordinated Research Project for Rainfed Agriculture. The subcatchment of River Junar, it covers about 650 ha, consisting of rainfed dryland and rainfed wetland areas. Major efforts focus on dryland cropping systems. Farmers grow monocrop dryland rice, finger millet, blackgram, pigeon pea, maize niger, and horse gram.

The project has identified better varieties of dryland rice (Kian, Improved gooa, and Bala), finger millet (A404), peanut (AK 12-24), pigeon pea (Laxmi), and soybean (Punjab 1). Because rain is uncertain and planting a second crop difficult, intercropping pigeon pea with dryland rice and peanut is the most promising alternative to monocropping.

Indonesia. The network collaborates with the Central Research Institute for Food Crops. The 22 operational research sites in 1981 studied mostly dryland rice-based systems and some rainfed wetland and tidal swamp rice lands. In some sites in the islands of Sumatra, Java, Kalimantan, Sulawesi, and Timor, particularly in the fragile dryland soils of Sumatra, research is carried out within the framework of the farming system and includes an animal component.

Madura (rainfed wetland and dryland rice). The hilly drylands are predominantly upland crops and rainfed wetland rice. The main constraint has been low soil fertility. Higher rates of fertilizer application and band placement of phosphate with seed give considerable yield increases and show a potential for increased cropping intensity and food production. In the low-lying coastal wetlands, dry-seeded rice gave higher net returns and yield than transplanted rice. Dry-seeded rice - corn + peanut is the best cropping pattern.

Tajau Pecah (dryland rice). Maize intercropped with dryland rice, with cassava relay planted into maize rows and later cowpea intercropped with cassava after rice harvest was the most promising pattern. Introduction of animals and perennial crops further increase production and income.

Barambai (tidal swamp rice). The fragile nature of the potentially acid-sulfate soils in the tidal swamp within the Barambai Transmigration project requires long-term management strategies. Using the furrow-bed system to circumvent flooding of upland and perennial crops and sufficient water for wetland rice has been important. The most promising cropping pattern was intercropping maize and upland rice relayed with cassava on raised beds and double cropping rice in furrow beds.

Korea. The network collaborates with the Korean Office of Rural Development. Three network sites in Suweon, Iri, and Milyang represent temperate rice environments with good irrigation and drainage. The Provincial Office of Rural Development also is testing cropping patterns in other parts of the country.

Suweon (irrigated). A single crop of rice is predominant in central Korea. Five cropping patterns were tested — rice - barley, rice - wheat, potato - rice, pea - rice, rice - rye (for green manure or fodder), and rice - fallow — with optimum cultural practices. Net income with rice - fallow was $2,065; with potato - rice and rice - rye, $2,194. At high management, potato - rice gave a higher income ($3,485) than one rice crop ($2,088).

Iri site (irrigated). Double cropping is traditional in the wetlands of southern Korea. The predominant cropping patterns are rice - barley and rice - rape. Recently, more farmers have been growing only one rice crop. Eight cropping patterns were tested — rice - pea, potato - rice, rice - strawberry, rice - onion, rice - rape, rice - naked barley, rice - wheat, rice - rye, and rice - fallow. Rice yields in the patterns were lower (7-7.48 t/ha) than single-crop rice yields (7.63 t/ha). Rice - wheat gave the highest net income ($3,744). Potato - rice and rice - strawberry also gave higher net returns than rice - barley or rice - rape.

Milyang site (irrigated). The predominant cropping patterns in southeastern Korea are rice - barley and rice - wheat. Cropping intensity is higher than in the central and southwestern zones. Five cropping patterns were tested — rice - barley, rice - wheat, potato - rice, sweet maize - rice, and rice - soybean. Rice yields were higher in single-crop rice than in rice plus other crops. Sweet maize - rice gave the highest income ($7,172), 276% more than

the predominant 2-crop patterns and 400% more than a single rice crop. Two other promising cropping patterns were rice - wheat and potato - rice.

Nepal. Of six Department of Agriculture and International Agricultural Development Services sites that carry out cropping systems activities, three are in the ACSN. Primary goals are: to introduce to existing farmers' patterns such modifications as new varieties and management, to alter and intensify existing cropping patterns by adding another crop, and to introduce completely new crop combinations.

Parsa site (irrigated and rainfed wetland). Parsa has 4 wet months and 8 dry. The predominant cropping pattern at the rainfed site at Suckchaina village is rice alone. Most farmers use local varieties. Yields of modern varieties Janaki, Sabitri, and Laxmi were more than 3.5 t/ha; yields of local varieties were only 1.4 t/ha. In areas with low production potential, IET 1444 yielded 3.13 t/ha, local varieties 1.30 t/ha. Wheat was a good second crop, although yields were low in 1980 because of an outbreak of leaf rust. Net income from rice - wheat was about 500% more than that from one rice crop.

At the irrigated site started in August 1980, six cropping patterns were tested: rice - rice - wheat, rice - corn - mungbean, rice - potato - maize, rice - wheat - green manure, rice - wheat - mungbean, and rice - maize - maize. The most promising, rice - maize - maize, was better than rice - wheat, the predominant cropping pattern.

The Ratna Nagar site (rainfed wetland and irrigated). Rainfall in the inner terai is similar to that in Parsa. The predominant cropping patterns are rainfed rice - fallow and irrigated rice - wheat. Rainfed rice - maize and rainfed rice - wheat gave higher net incomes than rice alone. Irrigated rice - wheat - maize and irrigated rice - wheat - mungbean are promising. Net income from rice - wheat - mungbean was 85% more than that from farmers' rice - wheat.

Pumdi Bhumdi site (wetland). Rice - wheat - maize in wetland with high production potential and rice - wheat in wetland with low production potential are the most promising cropping patterns. New varieties of rice and wheat and improved management have been introduced. Rice yields in the high-production-potential area increased 109% with the introduction of T176, and wheat yields increased 61% with RR21. There was less increase in low-production potential areas. Net income was 91% higher with the improved cropping pattern than with farmers' pattern.

Philippines. In 1981, 19 research sites were operational, four in the network in collaboration with the Ministry of Agriculture and the National Food and Agriculture Council. The site in Solana, Cagayan, is managed directly by IRRI in collaboration with the Cagayan Integrated Agriculture Development Project. This reports on the other three sites.

Bukidnon (dryland and partially irrigated). The site in Pangantucan has even rainfall distribution with 6 wet months and 3 dry. In partially irrigated area, the traditional pattern is two crops of transplanted rice. Three crops of transplanted rice gave higher yields and incomes than the rice - rice pattern, although the third rice crop yielded only 1.19 t/ha because of rat damage. In the dryland area, traditional patterns are maize - maize and dryland rice - maize. Experimental patterns were dryland rice - peanut, dryland rice - maize - mungbean, and maize - peanut. All three experimental patterns were better than farmer's cropping patterns. Maize - peanut gave the highest income, 190% better than farmer's dryland rice - maize and 450% better than farmer's maize - maize.

Capiz (rainfed wetland and dryland rice). High rainfall Capiz has 8 wet months and 3 dry. The predominant cropping patterns are rice - rice in rainfed wetlands and one maize crop in drylands. The most promising cropping patterns in drylands are maize - peanut - cowpea and dryland rice - maize + dryland rice - mungbean. However, third crops were not planted in 1981 because of early drought. Net incomes of the two promising cropping patterns were 20 times better than those of farmers' maize crops. In rainfed wetland, the predominant pattern is rice - rice using improved varieties. The most promising cropping pattern was rice - rice - mungbean, but the mungbean crop was not planted in 1981 because of drought. The net income of the experimental rice - rice was 120% more than the farmers' rice - rice pattern.

Agusan (rainfed wetland and dryland). Rainfall in Talacogon, Agusan del Sur, is distributed throughout the year, with 10 wet months and no

dry month. The predominant cropping pattern in rainfed wetlands is transplanted rice - rice. The most promising cropping pattern was wet-seeded rice followed by transplanted rice. With improved varieties and better management, income from the promising pattern was 285% better than that from farmer's patterns. The traditional cropping pattern in drylands is maize - maize. Net incomes of the experimental and farmers' cropping patterns were the same.

Sri Lanka. The Department of Agriculture has seven research sites, five in the dry zone, one in the intermediate zone, and one in the wet zone with high elevation. Two sites in the dry zone and one in the intermediate zone are in the ACSN.

Walagambahuwa site (minor tank irrigation). About 10,000 tanks throughout the country irrigate 120,000 ha. The traditional cropping pattern has been one rice crop, with a probability of a successful crop once in 5 or 6 years. After 5 years of cropping pattern testing, 2 crops of rice are now grown, and in some years a portion of the area is planted to a third upland crop such as soybean, mungbean, or chili. Technology includes timely, (direct-seeded dry) cultivation and early-maturing rice varieties. Average rice yields have increased from 1.2 t/ha in 1976-77 to 2.9 t/ha in 1980-81. The current focus is on component technology to further increase rice yields. A pilot production program with the many small tanks in Anuradhapura and Kurenegala was started in the 1979-80 crop year.

Katupotha site (rainfed wetland). The traditional pattern is rice - rice in the valley bottom and rice - fallow on the side slopes and upper part of the catena. Rice often fails on the upper part of the catena because of lack of moisture. Better rice varieties have been identified for the rice - rice pattern in the valley bottom and sideslopes. Rice - mungbean and rice - peanut are the most promising cropping patterns for the upper part of the catena, with better net incomes than with the rice - rice pattern. Rice - peanut gave 101% more income than rice - rice.

Paranthan site (rainfed wetland). In the dry zone of northern Sri Lanka, farmers grow only one rice crop with an average yield of 1.5 t/ha. Upland crops tried after rice for 3 years have had unstable, poor yields. The use of better varieties, weed management, and more fertilizer has increased one-rice-crop yields two to three times. Upland crops have been ruled out and work will focus on the partially irrigated area of the Iranamadu irrigation system.

Thailand. Collaborative cropping systems research is with the Rice Division, Department of Agriculture, and the Division of Agriculture Economics in PiMai and Phrae; with the Technical Division, Department of Agriculture, and Division of Agricultural Economics at the Kampangpet site; and with Kasetsart University at the Bangpae site. Four more sites are located in Khon Kaen with Khon Kaen University and in Surin, Phayao, and Sithamarat with the Rice Division.

PiMai (rainfed wetland). Rainfall has been highly variable during the last 4 years and performance of upland crops before rice very unstable. Performances of 4 cropping patterns tested in 1981 (peanut - rice, sesame - rice, glutinous maize - rice, and glutinous maize + mungbean - rice) were better than those of the traditional single-rice crop.

Kampangpet site (rainfed wetland). Kampangpet has 2 wet months and 4 dry. Poor soil and erratic rainfall make the introduction of mungbean and peanut before rice difficult. Rice yields are being stabilized and a rice - rice pattern is being tested. Early-maturing RD7 was found suitable for dry-seeded rice, with yields of 4.3 t/ha, and for transplanted rice, with yields of 4.8 t/ha.

Phrae site (partially irrigated). Phrae, in northern Thailand, has 3 wet months and 6 dry, with supplemental irrigation for the third crop. Farmers traditionally grow two crops a year. Four cropping patterns were tested — mungbean - rice - sweet maize, mungbean - rice - soybean, sweet maize - rice - peanut, and rice - rice. Mungbean - rice - soybean and sweet maize - rice - peanut are the most promising. Peanut, mungbean, and sweet maize were successfully grown before rice. Some farmers are planting mungbean before the main rice crop.

Bangpae site (rainfed wetland). The Bangpae site has 2 wet months and 7 dry. The water table is shallow. Farmers traditionally grow 2 crops a year. The best cropping patterns are mungbean - rice -mungbean, sweet maize - rice - mungbean, and glutinous maize - rice - mungbean.

CROPPING SYSTEMS WORKING GROUP MEETINGS

The 11th meeting in Indonesia, 18-22 May 1981, was cosponsored by IRRI and the Central Research Institute for Food Crops of Indonesia. It was attended by 11 members of the working group from 9 countries and IRRI and 26 resource persons, 14 from Indonesia. The group reviewed progress at research sites and discussed collaborative research in agricultural economics, entomological research methodology in the cropping systems program, multilocation test and pilot production program procedures, challenges and experiences in transferring technology through extension to farmers, long-term cropping systems experiment needs, the annual summary of ACSN testing, and cropping systems training.

Cropping systems entomologists met for 3 days before the working group meeting, with 21 participants from Indonesia (11), Thailand (3), Bangladesh (1), Sri Lanka (1), India (1), and IRRI (3). They discussed contemporary issues, with emphasis on methodology for entomological research at cropping systems research sites and areas of collaboration. A collaborative project to evaluate using economic thresholds as a basis for insecticide application is planned.

The 12th meeting in Burma, 8-13 Dec. 1981, was cosponsored by IRRI and the Ministry of Agriculture and Forests of Burma. It was attended by 13 members of the working group from 10 countries and IRRI. China sent a participant for the first time. There were 12 resource persons, and several ranking officials of the Ministry, and cropping systems site coordinators attended as observers. Discussions concentrated on proposed collaborative research on varietal improvement of upland crops, monitoring and evaluating pilot production programs, long-term cropping pattern experiments, fertilizer efficiency in cropping systems, simple farm implements for cropping systems, assessment of changes in productivity and farmers' welfare at cropping systems research sites and other areas, and cropping pattern monitoring. Multilocation testing and alternative methods for moving cropping systems technology to farmers also were discussed.

CROPPING SYSTEMS STUDY TOUR

Three cropping systems study tours were conducted in 1981. The 15-28 February tour was concentrated on formulating, structuring, and implementing pilot production programs in Sri Lanka and Nepal. The 20 participants from 7 countries were senior research staff and extension officers. Objectives were to familiarize participants with the on-going production programs to develop methodology for pilot production program activities within the network.

The second and third study tours focused on methodology for cropping systems research and development, with 35 new site coordinators, component technology scientists, program supervisors, and extension officers participating in each. They visited IRRI; cropping systems research sites in Iloilo, Capiz, and Cagayan; multilocation testing in Capiz; and the production program in Iloilo.

TRAINING

There were 42 trainees in the 1980-81 cropping systems 6-month training course; 40 are attending the 1981-82 course. All are from collaborating countries: Bangladesh (15), Burma (5), Indonesia (55), Malaysia (8), Philippines (14), Sri Lanka (5), Nepal (12), Thailand (15), India (1), and Vietnam (2).

In the first on-the-job training on varietal screening, 4-13 January 1981, 10 participants from six countries collaborated on varietal testing. Training focused on field layouts for yield trials, trial management, data collection, and analysis and interpretation of results.

Twenty-two students are pursuing MS degrees and nine, PhD degrees under the supervision of IRRI senior scientists from five departments.

Machinery development and testing

Agricultural Engineering Department

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THREE-HORSEPOWER TILLER

Development of the 3-hp tiller continued. Field tests showed that both the engine support and the implement hitch should be strengthened.

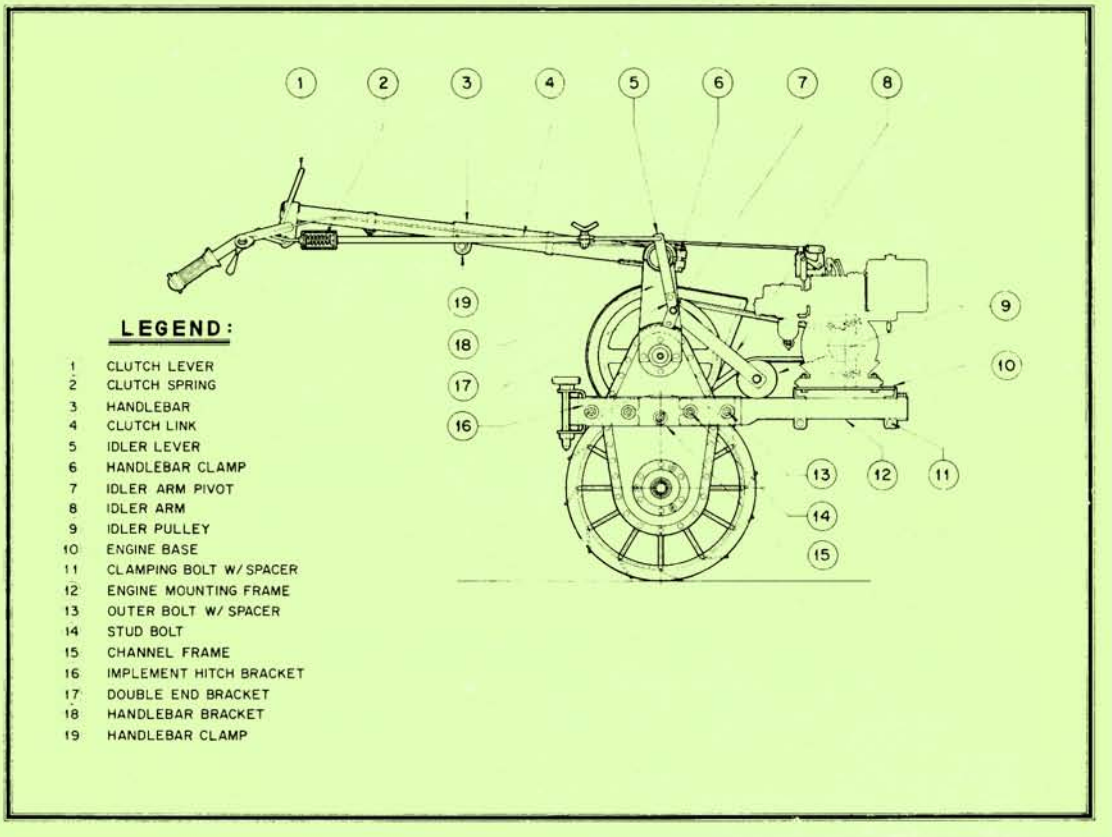
A pair of 4-mm deck channels was welded to the transmission case to distribute the additional load (Fig. 1). The engine mounting frame and the implement hitch are bolted to these channels with symmetrically positioned bolts. That allows the engine to be mounted either forward or to the rear of the transmission case for use with the front- or rear-mounted implements.

The handle bar mounting bracket also was modified to make it more rigid and to provide the necessary space for the engine to be mounted at the rear. Friction joints allow the handle bar to be varied in length and height to suit the operator and the implement being used.

Field operation evaluation showed short belt life and belt slippage due to the small arc of contact on the engine pulley. The single B section belt was changed to two A section belts and the arc of contact on the engine pulley was increased with a large spring-loaded clutching idler. The spring-loaded idler automatically provides the correct belt tension, increasing its life. The engine was bolted to the tiller, making a more rigid unit.

A new type of cage wheel, with 1-inch expanded metal covering the entire periphery, appears to give greater flotation in soft soil. Its design should be particularly valuable for use with the 1-m reaper attachment.

Applied research testing of this machine is almost completed. It should be ready for release early in 1982.



1. Modified 3-hp power tiller. IRRI, 1981.

Rice transplanter. Although the transplanter has performed satisfactorily, in many areas farmers have been slow to adopt it. The main constraint has been the large quantity and cost of the wooden frames required for growing seedlings.

A method of growing seedlings to overcome these constraints has been used on a corporate farm in Bukidnon, Philippines. The seedlings are grown on plastic sheets with narrow irrigation canals at each side of the bed. Soil is spread about 14 mm deep on the plastic sheet, pregerminated seeds are sown, and an additional 2 mm soil is added to cover the seeds. The seedlings are irrigated daily and are about 15 cm tall by 14 days after seeding. Older seedlings soon show leaf yellowing.

Seedlings grown in this way have an entangled root system. Sections can be easily cut into the proper-size rectangles, rolled up like a rug, and transported to the field.

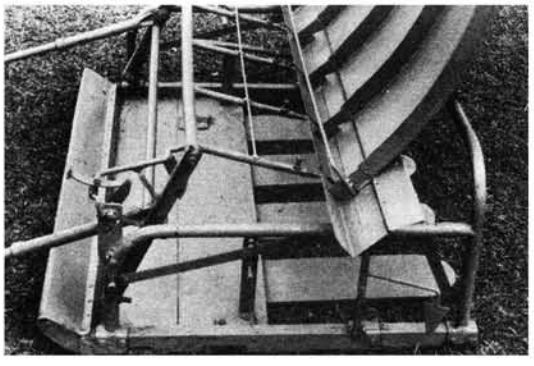
When tested in the IRRI transplanter, the seedlings often were not released into the soil by the pickers. To overcome this problem, a V-type, two-prong picker was designed. The picker wedges the seedlings as it passes through the mat but releases them easily on the return stroke.

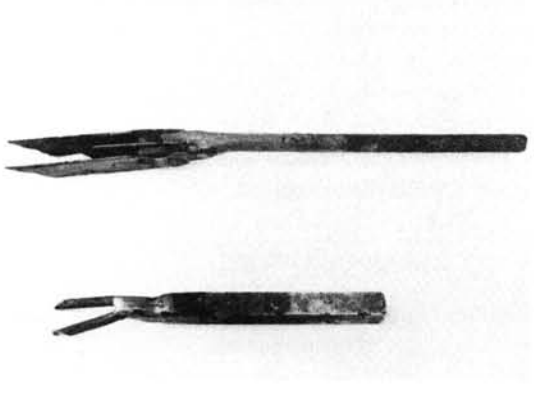
The feeding frame also was modified, to give the seedling tray a steeper angle (Fig. 2). One leg of this frame, originally vertical, was inclined forward so that the seedling stems would be parallel to the incoming pickers. A support bar was attached at the lower portion of the tray to hold seedling leaves away from the path of the pickers.

The modified machine with the new pickers is now being field tested using seedlings grown in the modified system. Initial results show the machine performs better than the original, which used seedlings prepared in double frames.

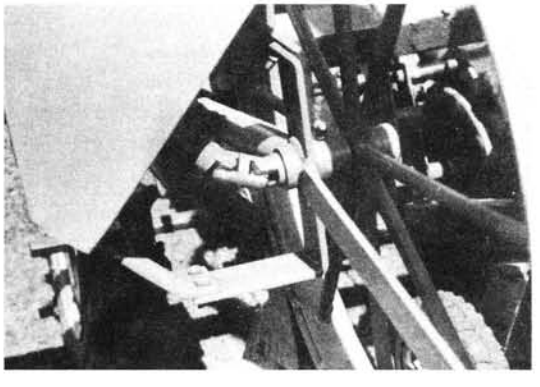
Inclined plate planter. Development of the inclined plate planter is continuing. The inclined presswheel, which also drives the metering system, under some conditions, slipped, causing nonuniform metering. A vertical presswheel now drives the inclined plate metering mechanisms through a double-hook universal joint (Fig. 3).

When attached to a hand tractor, the planter was difficult to turn at the end of the row. The operator had to lift the handle bar sufficiently to raise the planter out of the ground while turning the machine into the return row. To solve this problem, the toolbar is now supported by a caster wheel assembly. A foot-powered cam-and-roller assem-

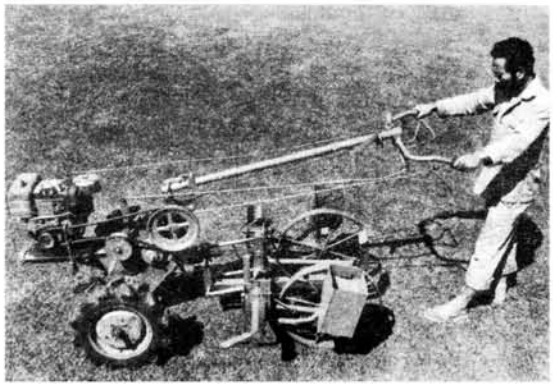




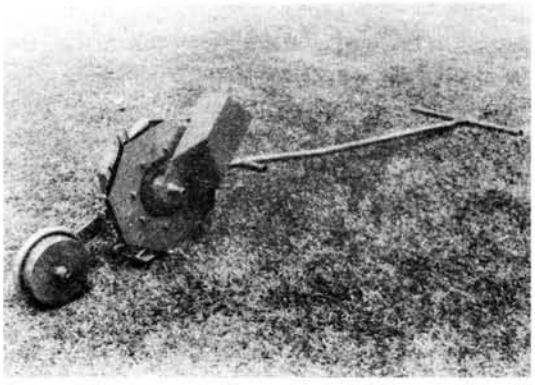
2. Mechanical transplanter with modified picking fingers and seedling trays. IRRI, 1981.



3. Double hooks universal joint for driving inclined plate-metering mechanism. IRRI, 1981.



4. Inclined plate planter in the raised position attached to a power tiller. IRRI, 1981.



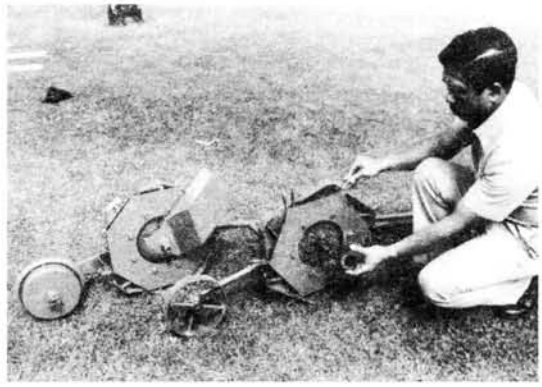
5. Single-handle rolling injection planter. IRRI, 1981.

bly raises the two-row planting unit in relation to the toolbar, which relieves the operator of any lifting as he turns the tractor for the return pass (Fig. 4).

Development of a fertilizer applicator attachment, further design simplification and improvement, and extensive testing are planned for 1982.

Rolling injection planter. Drawings of the International Institute for Tropical Agriculture (IITA) rolling injection planter were made available to IRRI in 1978. A prototype was fabricated and subsequently modified according to IITA specifications and several field trials and some replicated controlled experiments were made. IRRI engineers modified the cells of the metering roller to improve metering of seeds.

In June 1981, modified drawings of the planter were brought to IRRI where applied research



6. The wheel and metering roller on the modified rolling injection planter are easy to change. IRRI, 1981.

experiments were conducted. A single-handle unit constructed at IRRI (Fig. 5) was preferred by users because the single handle facilitated changing of the metering roller. However, the model was more difficult to balance during transport. The handle was offset 10 cm from the center of the hexagonal wheel. Excessive fabrication tolerance between the presswheel arm hub and the axle caused the presswheel to be misaligned from the row.

To eliminate these problems, the handle was bent to align with the presswheel for a more balanced assembly. The presswheel arm, originally of pipe, was changed to a flat bar with the same torque resistance. The arm was fixed on the axle by two washers to eliminate wheel misalignment.

An octagonal wheel to inject seeds 20 cm apart was adapted to the same axle and hopper assembly.

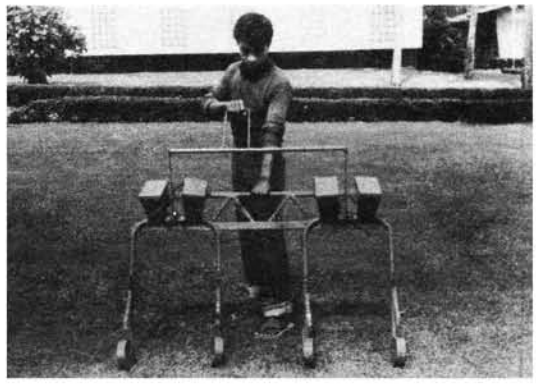
The final prototype (Fig. 6) has a changeable wheel for 25- and 20-cm plant spacing and a changeable metering roller to suit different upland crops, such as rice, corn, cowpea, soybean, mungbean, sorghum, and indigo. The final specifications for the metering rollers are being determined through calibration tests. Plans will be available to cooperating manufacturers in early 1982.

FERTILIZER APPLICATORS

Granular applicators. *Two-wheel tractor attached.* Development of the power tiller-attached four-row fertilizer applicator (Annual report for 1980) continued (Fig. 7). Testing showed it effectively delivered fertilizer up to 15 cm below the soil surface.



7. Operating the 4-row granular fertilizer applicator (power tiller attached). IRRI, 1981.



8. Manually operated spot injection applicator. IRRI, 1981.

The machine applies 47 kg urea or 22 kg N/ha in a single operation.

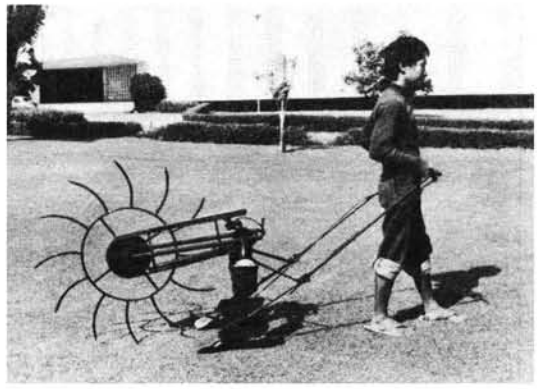
Field experiments in cooperation with the Agronomy Department evaluated the new practice of applying fertilizer during the last land preparation harrowing. Urea (58 kg N/ha) was applied over the injected area, from the periphery to the center of the plot. The machine will be modified to give higher rates in a single-pass operation.

Manually operated. The manually operated spot injection applicator (Annual report for 1980) has undergone considerable field testing (Fig. 8). Operators complained of physical strain after operating the machine 15-20 minutes. Fifteen priming strokes are required before the machine is applied to the mud. Also, discharge rates between orifices were not uniform.

A wheel-driven, pull-type applicator was designed (Fig. 9) to reduce physical effort. The operator walks forward, between the harness, pulling the machine. To eliminate the priming operation, the hopper was transferred from the horizontal to the vertical section of the delivery pipe.

The outside diameter of the spring auger was increased from 18 to 23 mm and the inside diameter of the delivery tube from 22 to 29 mm. The pitch and wire diameter were also increased from 12 and 3 mm to 16 and 3.5 mm to give higher discharge rates.

Tests showed that this wheel-driven spring auger gives a continuous, uniform band placement of fertilizer. Its application rate was about 70% higher than that of the first prototype. The furrow created

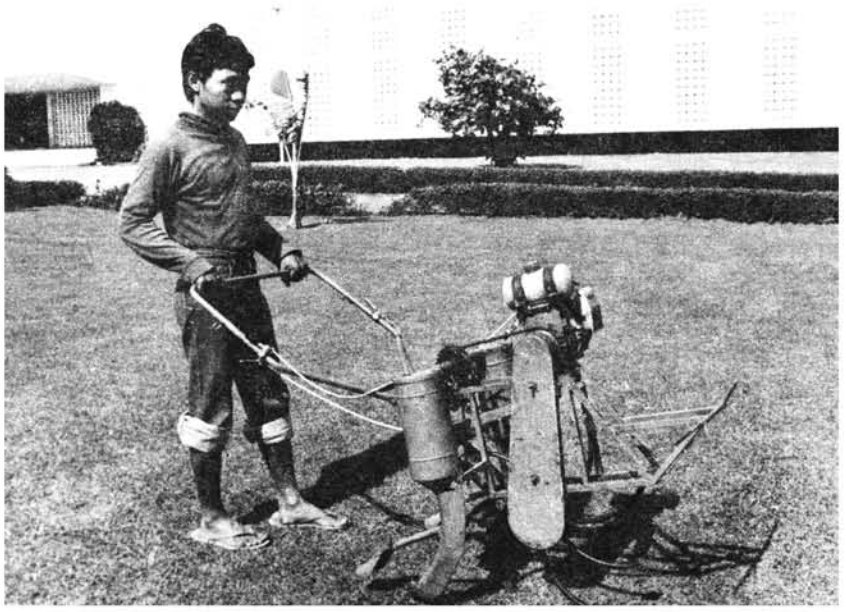


9. Manually operated pull-type applicator. IRRI, 1981.

by the fertilizer orifice is covered by a spring-loaded furrow closer. The operator can override the furrow closer to increase the pressure when working in relatively hard mud. The machine can apply from 38 to 75 kg N/ha through a 10-speed bicycle-sprocket-chain transmission system. It requires about 10 kg of force to operate the applicator in soft mud and about 15 kg to operate it in relatively hard mud.

The machine is ready to be tested for application efficiency and durability testing.

Engine-driven. A four-row, engine-driven applicator was developed to reduce the time required to apply fertilizer manually (3-4 days) to about 0.5 day. The machine is powered by a 1.7-hp engine with built-in gear box driving a single lug wheel via a water-sealed chain-and-sprocket power transmission system (Fig. 10).

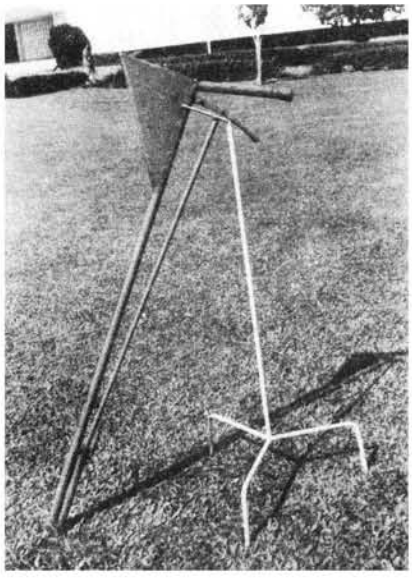


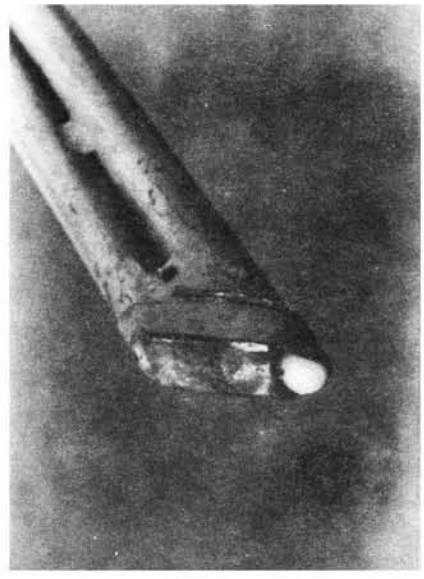
10. Granular fertilizer applicator with a spring auger metering system powered by a 1.7-hp engine. IRRI, 1981.



11. Urea supergranule applicator constructed from bamboo. IRRI, 1981.

Metering is achieved using a pair of spring augers driven separately from the engine. The applicator is fitted with a jaw clutch to disengage the augers during transport. It is also equipped with a 5-speed bicycle sprocket-chain transmission to vary application rates from 40 to 200 kg urea/ha. The hopper has a capacity of 3 kg and is located in a vertical section of the delivery tube to eliminate priming. The spring auger, which passes through the center of the hopper, also acts as an agitator. Placement depth (5-12 cm) is controlled through adjustment of the furrow closer. The operator has only to keep the furrow closer in constant contact with the mud to ensure furrow closure.





12. Grip-actuated plunger-type urea supergranule injector. Right: supergranule being ejected from tip of plunger. IRRI, 1981.

In initial testing, fertilizer was easily placed at selected depths. The machine can readily travel and be maneuvered along levees.

Applied tests are under way to determine operation, uniformity of application rates, crop development, and yield.

Supergranule injectors. *Low-cost bamboo.* A low-cost fertilizer applicator was constructed from bamboo (Fig. 11). The hopper (9 cm in diameter, 36 cm long), feed tube, and delivery tube are glued, forming a single structure. The metering device consists of a hand-operated spring plunger and rubber flap. Granules are gravity fed from the metering device to the soil.

To operate the applicator, the hopper is half-filled with granules and the operator shakes it to fill the feed tube. The tip of the delivery tube is thrust into the mud to the depth of the furrow closer. The plunger at the bottom of the feed tube is pushed and one granule falls through the delivery tube into the mud. The 60° angle cut at the bottom of the delivery tube prevents mud from entering the tube if the applicator is moved in the direction of the cut. Sliding the applicator forward closes the furrow and covers the granule with soil.

Initial test results are promising. Efficiency and durability tests are being conducted.

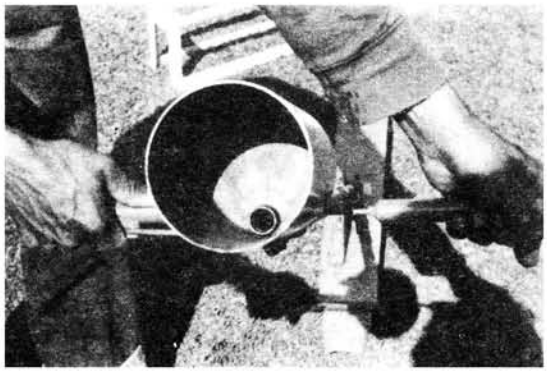
Plunger type. The initial development of a Rockwood plunger applicator for deep placement of 1 g supergranules involved the design of a metering unit to discharge a granule at every stroke of the hand grip actuator (Fig. 12). The metering unit uses a round shaft, 1.59 cm (5/8 inch) in diameter machined to 1.43 cm (13/32 inches) and housed in a steel tubing welded to the feed tube. The feed tube functions both as the delivery tube connecting the triangular hopper and a metering unit. It is also the structural frame of the machine. A rubber strip was provided at the discharge of the feed tube to control the flow and allow metering of individual granules.

Initial field tests showed the metering unit performed well, but mud accumulated at the discharge of the feed tube, preventing flow of granules into the metering unit. Bridging of the supergranules in the hopper also restricted their flow into the feed tube. Disengaging the bridge necessitates a mechanical agitator, but agitation is difficult when the hopper is full.

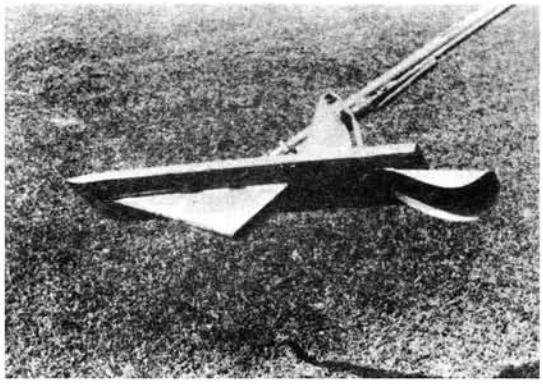
To eliminate bridging of the supergranules, an agitator-type and a dispenser-type hopper (Fig. 13) were developed and mounted on two plunger-type applicators.

To prevent mud accumulation, the metering unit was mounted on a wooden skid equipped with a furrow opener and furrow closer (Fig. 14).

Results of preliminary tests in IRRI fields are encouraging. Although this applicator arrange-



13. Mechanical agitator inside hopper to prevent bridging of supergranules. IRRI, 1981.



14. Plunger-type applicator mounted on skid with furrow closer. IRRI, 1981.

ment (push-type with furrow opener) works well, it should be tested in farmers' fields to determine its adaptability over a range of conditions.

Liquid chemical injectors. Development of the 10-row liquid injector continued. To eliminate dripping at the end of the nozzle, the design of the metering device was further improved.

Because basic design parameters for the peristaltic pump were needed, a laboratory model was developed. A load cell was used to determine the radial force required to press the tubing against a stationary circular backing at different clearances, the optimum force for good pump action, and the torque needed to drive the pump.

These experiments helped determine appropriate sizes for pump rollers, pump shaft, and stationary cylindrical backing to give negligible deflections. The intermediate bearing support was eliminated to simplify assembly and disassembly. The revised design was more compact and lighter. Four roller configurations with a 90° angular displacement per stroke were incorporated to minimize cyclic variation.

Three types of chemical applicators using the revised metering device were developed (Fig. 15): a 15-row fertilizer and systemic insecticide marker-injector, a 10-row posttransplant fertilizer injector, and a transplanter-mounted fertilizer and systemic insecticide injector.

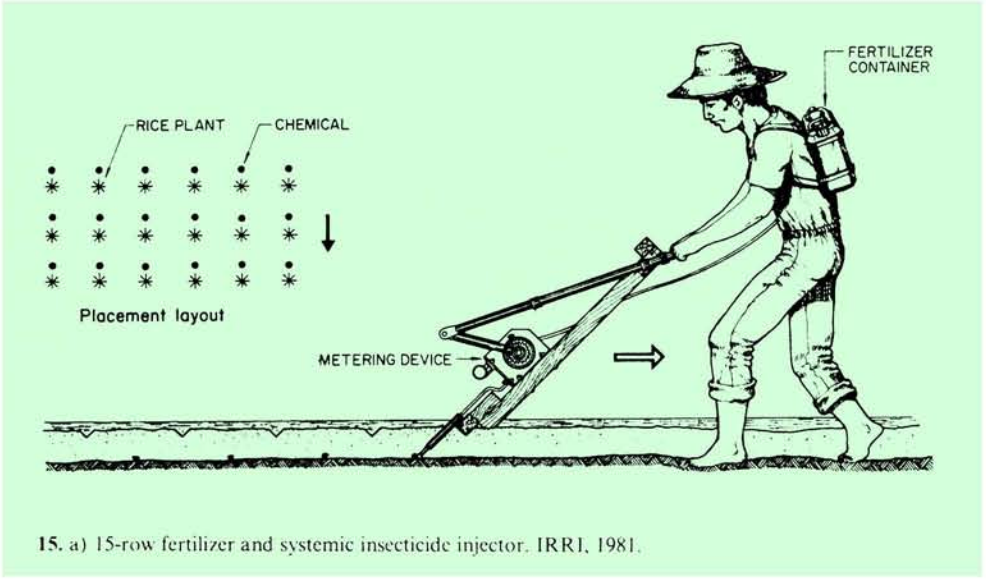
These applicators will be tested to determine field capacity, durability, and acceptability to small farmers.

CAAMS-IRRI REAPER PROJECT

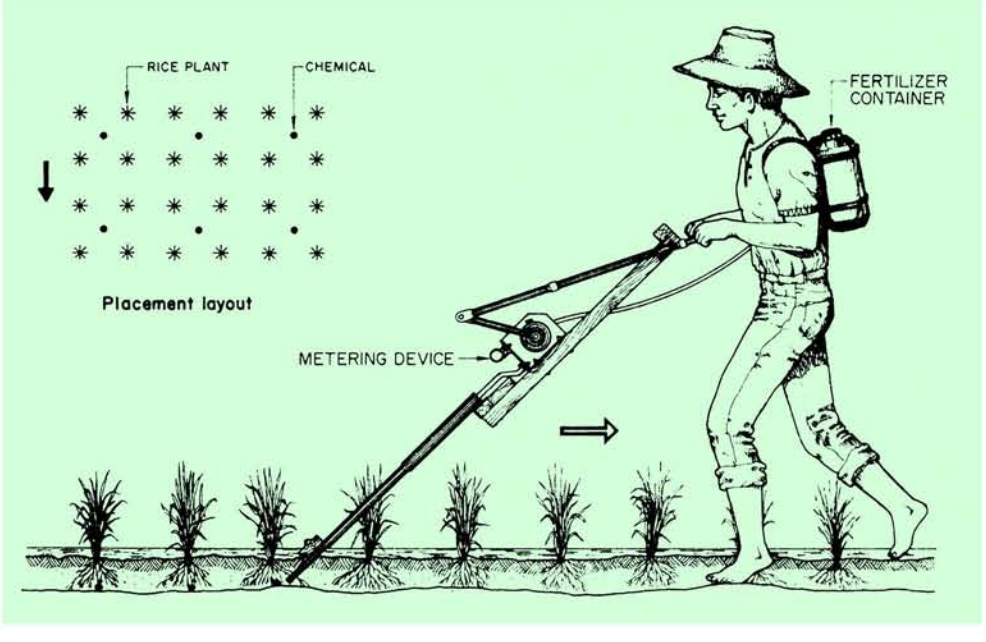
1.6- and 1.0-m prototypes. A series of 1.6- and 1.0-m reaper prototypes were adapted from the original design of the Chinese Academy of Agricultural Machinery Sciences (CAAMS) (Fig. 16). Adaptations were directed toward improving machine function, simplifying construction, increasing durability, and lowering fabrication costs.

The optimum average knife velocity on both machines was 1.3 times the forward velocity of the reaper. The lugged V-belts on the gathering headers were found unnecessary in both lodged and standing crops and were eliminated. Using the recommended operator technique, these machines were able to satisfactorily handle most lodged crops. The gathering headers were further simplified by eliminating curved pipe and by using the same design for both machines. The left gathering header was modified so it would not damage an adjacent crop. The connecting hitches were redesigned so that the reapers could be easily detached from the power tiller without tools. An adjustable skid to vary cutting height was also built into the hitch.

The major problem encountered on both the Chinese and the early IRRI prototypes was the short life of the flat belt conveyor. Belt life was greatly extended by improving the belt splicing method and adding spring-loaded idlers. To simplify manufacture, knife parts and flat belt pulleys were made interchangeable for the 1-m and 1.6-m machines. The starwheels that help gather and hold the crop were originally made from injection-molded plastic, generally not available in develop-



15. a) 15-row fertilizer and systemic insecticide injector. IRRI, 1981.

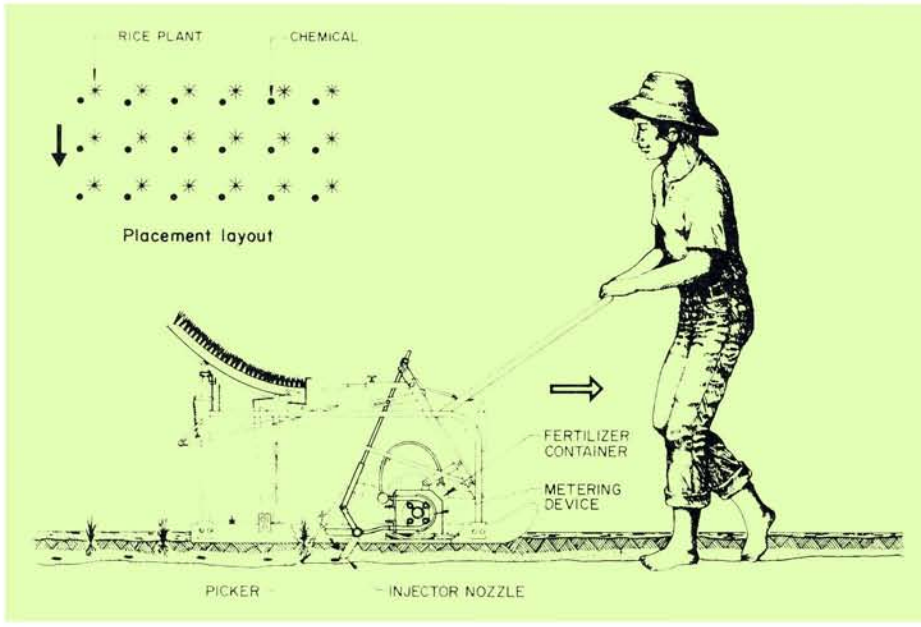


15. b) 10-row posttransplant fertilizer injector. IRRI, 1981.

ing countries. Hard rubber or polyvinyl chloride plastic sheet proved to be the best alternative material.

The 1.6-m reaper is driven through a unit-drive assembly, which contains one set of bevel gears and one roller chain drive enclosed in an oil bath. The drive assembly is made from jeep gears, sprockets, bearings, and seals normally kept in stock, plus simple parts fabricated with a saw, drill press, and lathe. These parts are held in accurate relationship with a jig and are welded together. This drive is economical and durable and allows the machine to be easily attached to a variety of tillers.

Life of the quarter-turn V-belt drive on the 1-m



15. c) Transplanter-mounted fertilizer and systemic insecticide injector. IRRI, 1981.



16. A 1.6-m reaper cutting and windrowing rice stalks. IRRI, 1981.



17. A 1-m reaper recently released for commercial production. IRRI, 1981.

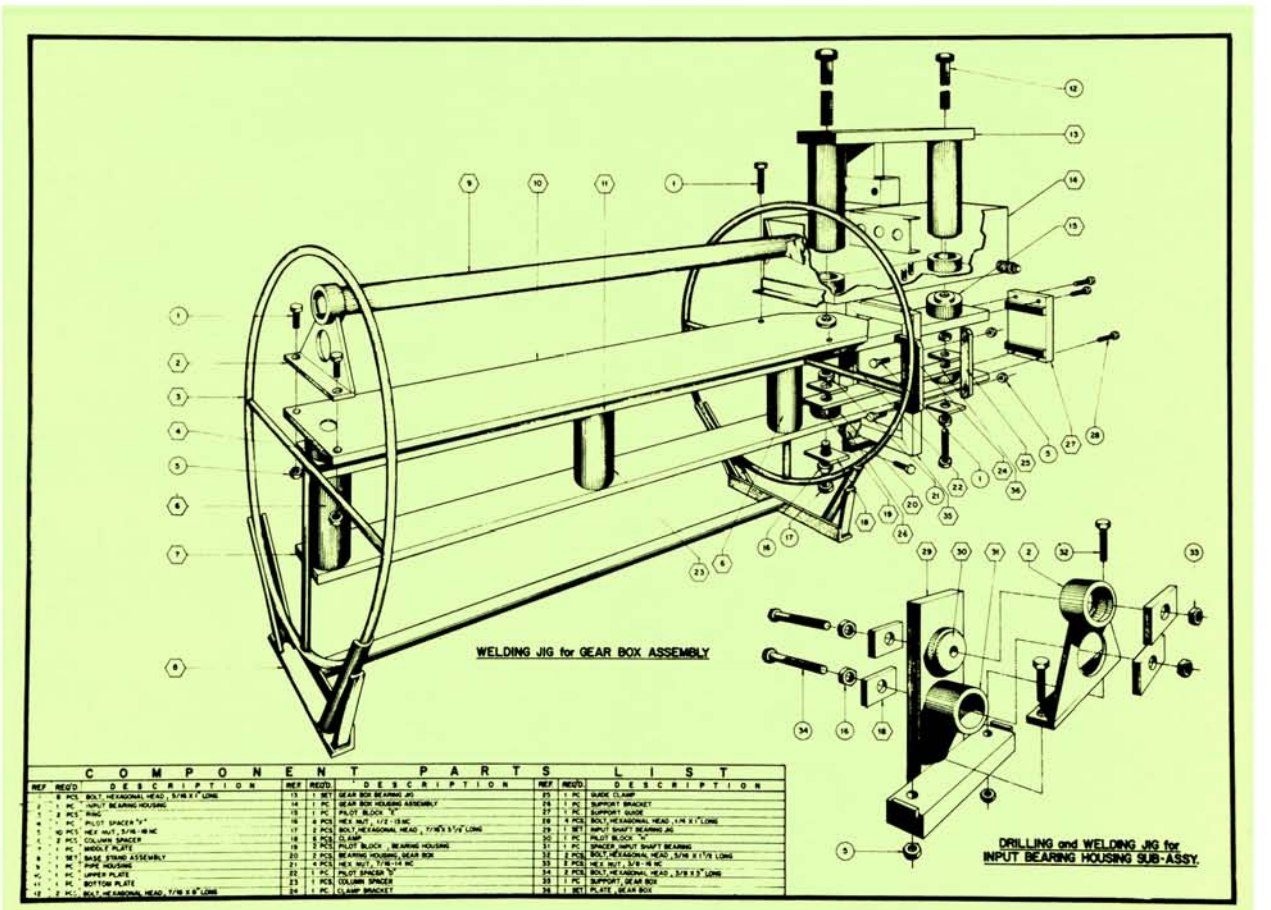
reaper was initially very short. The design of an inclined, spring-loaded idler, which allows the belt to track equally well in forward and reverse, increased belt operating life considerably.

Because of its compact size and light weight, the 1-m reaper mounted on a small power tiller, such as the new IRRI 3-hp model, performs well in the small fields and soft soil conditions found in much of Southeast Asia's rice lands. When the unit is detached, two men can carry the tiller and the reaper into remote fields accessible only by narrow foot paths (Fig. 17).

These machines have been extensively tested in Luzon and Mindanao. Drawings and specifications have been prepared for the reapers, and their associated jigs and plans will be disseminated to cooperating manufacturers early in 1982.

Reaper gearbox jig. The original CAAMS 1.6-m reaper with 3 sets of gearboxes was modified to have 1 gearbox. But the numerous bolted integral parts make it laborious to align and assemble. Loosening of most bolted parts led to frequent machine breakdowns.

A one-piece gearbox was constructed with the



18. Drilling and welding jig for input bearing housing subassembly. IRRI, 1981.

aid of a newly designed welding jig (Fig. 18). The bearing housing and mounting holes, which demand three-dimensional accuracy, are piloted and securely clamped. All worn or damaged pilot guide blocks are replaceable. The length of the working pilot guide is only 5 mm, preventing capturing the gearbox in the jig. Heavy transverse members, brackets, and spacers were used to resist thermal stress during repeated full welding operations and handling.

The assembly jig is provided with two circular welding rails that allow the welder to position and weld the parts conveniently.

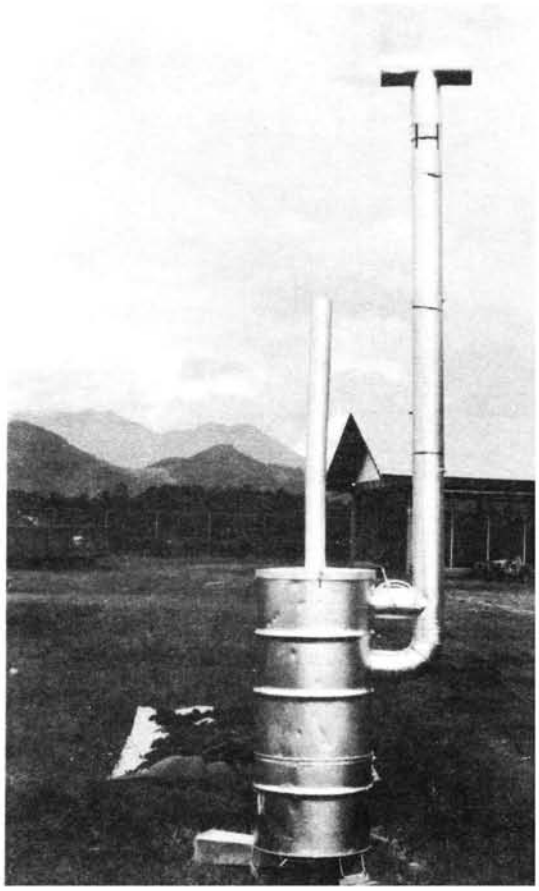
A gearbox was fabricated to test the reliability and accuracy of the jig. After full welding and removal of retaining clamps, the gear box could be easily separated from the jig by a single light hammer blow near its center of gravity. Ten units were made with tolerances of 0.8 mm in all critical parts. Jig plans have been released to manufacturers.

FURNACES AND WIND MACHINES

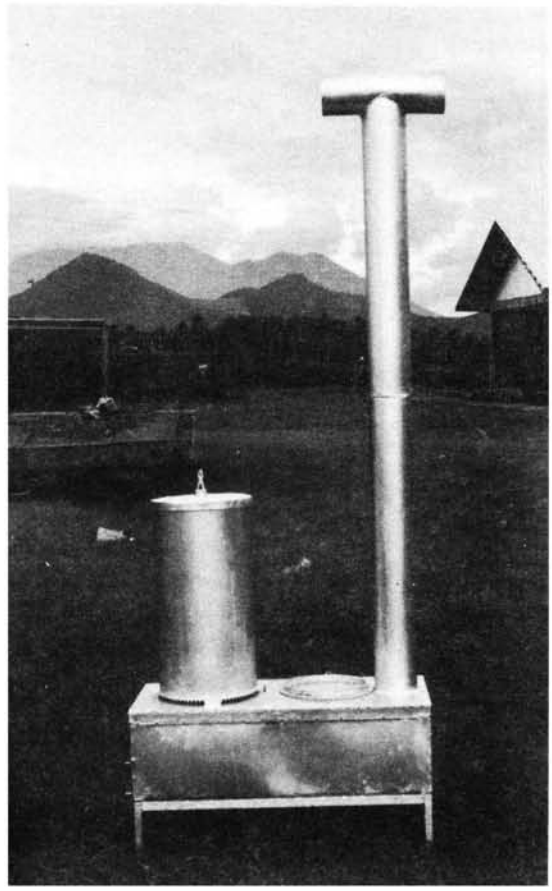
Two types of furnaces fueled with different agricultural waste products were designed for crop drying and circulatory water heating.

The first type (Fig. 19), made from an oil drum, consists of a burning chamber, hopper, chimney, ash damper, and air inlet. Burning involves a carbonization process, followed by gasification to complete the combustion. A secondary air supply hastens the process.

The second type (Fig. 20), made from G. I. sheets, consists of a cylindrical hopper, secondary combustion chamber with a secondary grate, and a chimney. Burning takes place directly around the hopper bottom on an adjustable grate that controls



19. Type 1 furnace. IRRI, 1981.



20. Type 2 furnace. IRRI, 1981.

the rate at which partially burned material drops to the secondary grate. Air is admitted between the hopper bottom and the ash box.

The two furnaces were used in a circulatory water-heating system (Fig. 21). A test furnace temperature greater than 600° C can increase the temperature of 200 liters of water by 10° C an hour. Material feed rate varied from 5 to 60 kg/hour.

The versatility and durability of the first furnace are being tested by coupling it with a natural convection tray dryer (Fig. 22). The dryer also uses a wind machine (Fig. 23) to expel drying air at a rate of 5-20 m^3/min. In contrast to conventional wind machines used for generating power, the wind machine vanes are stationary. The rate of airflow is controlled by adjusting the length of the blade skirt and the venturi blade clearance.

TESTING AND EVALUATION

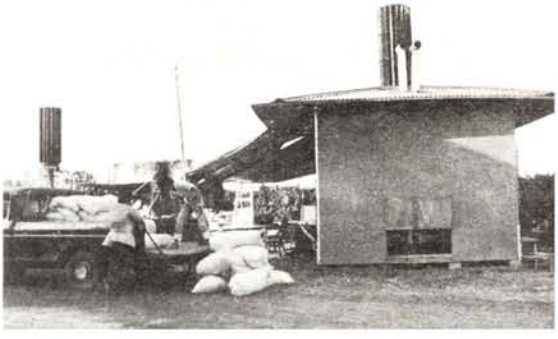
Transplanter-injector. An injection system to place liquid fertilizer and systemic insecticide below the soil surface was installed on the transplanter. Preliminary laboratory and field tests are encouraging.

Supergranule fertilizer applicator. Laboratory testing of a deep-placement, single-row, push-type supergranule fertilizer applicator (Fig. 24) gave good injection efficiency. Missed granules can be attributed to some irregular shapes. Preliminary field testing showed that the applicator is difficult to push through hard soil.

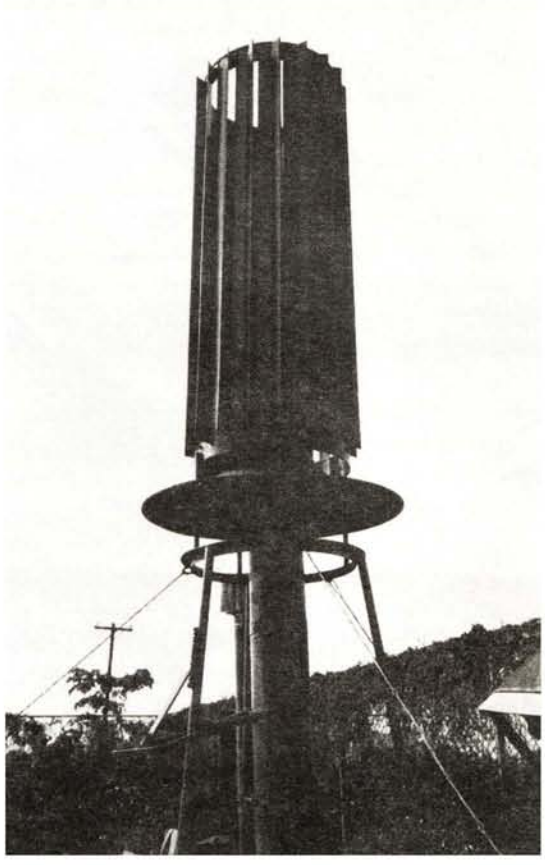
Flatbed dryer. Cooperating farmers have indicated problems with uneven drying and a kerosene smell imparted to the grain. The kerosene smell was remedied by changing a wornout burner plate.



21. Furnaces coupled with the circulatory water-heating system. IRRI, 1981.



22. The natural convection tray dryer-warehouse. IRRI, 1981.



23. The windmill. IRRI, 1981.

Marker-injector. Relative efficiency tests of fertilizer deep-placement using the marker-injector showed a yield increase of 60.5% for IR36 and 56.3% for IR42 during the dry season (Table 1). Wet-season yields increased 54.7% for IR36 fertilized with the marker-injector 20 days after transplanting (Table 2).

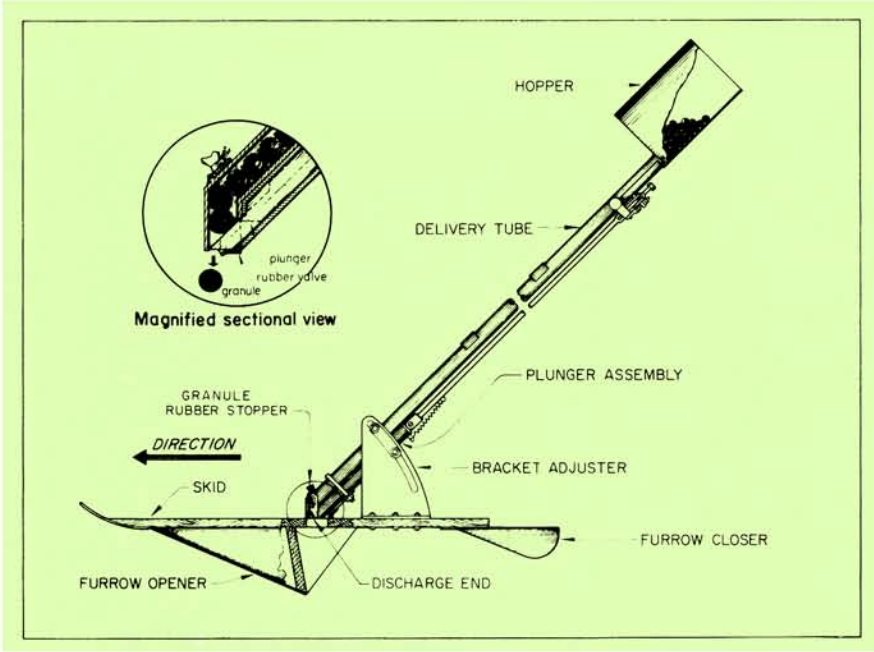
The marker-injector had a recorded field efficiency of 81.5% at a capacity of 0.23 ha/8-hour day. Field capacity when fertilizing during marking was 0.53 ha/8-hour day.

The marker-injector was also evaluated on a paddy with a rice-fish culture. Preliminary results indicated that fish may be stocked in the paddy 6 days after injection of chemicals with no significant increase in mortality.

IRRI 1.6-m reaper. A laboratory test of the IRRI 1.6-m reaper was made to determine the most suitable flat belt conveyor and belt connections to the flat belt pulley. Vibration, temperature rise of moving parts, and wear were analyzed.

A 1-hp variable-speed electric motor was used as the prime mover of a reaper mounted on a test stand. A 19 mm-ϕ rubber air hose was used to artificially load the flat belt conveyor and starwheels. The machine was operated with an input shaft speed of 830 rev/minute, the equivalent of a 3.92 kg/hour machine speed for 145 hours.

Of the flat belt and pulley combinations tested, the flat belt using controlled rivet and bolt-type connectors with the tapered pulley with a wide shoulder was most efficient. Wear on the pulley surface and flat belt edge was relatively small after 50 hours of operation compared with the flat belt



24. Reciprocating feeding rod system. IRRI, 1981.

Table 1. Dry-season yield of IR36 and IR42 as affected by methods of fertilizer application. IRRI, 1981.

Treatment	Yield (t/ha)	
	IR36	IR42
No fertilizer (control)	3.1	3.8
Best split	4.3	5.4
Deep placement of liquid during marking	4.9	5.9
Split application using marker-injector during marking and at panicle initiation	4.4	4.9
Split application; broadcast during marking and deep placement at panicle initiation	4.6	5.2

Table 2. Wet-season yield of IR36 fertilized by marker-injector. IRRI, 1981.

Fertilizing schedule[a]	Yield (t/ha)
Broadcast during transplanting and at panicle initiation	2.4
During marking	3.1
10 DT	3.3
20 DT	3.8
10 DBPI	3.1

[a]DT = days after transplanting, DBPI = days before panicle initiation.

with alligator-type connectors and an ordinary shaped flat-belt pulley. Temperature rise in all moving parts was normal and the permanent elongation of the flat belt relatively negligible.

PT-5 power tiller. The first prototype of the 3-hp tiller underwent 127.5 hours of field testing in IRRI and farmers' fields. The tests showed the PT-5 to be ideal for tillage of sandy loam and clay loam wetland fields. It is lightweight and maneuverable, and has low fuel consumption.

Plowing was done best with a standard-size moldboard plow with a disc coulter. The coulter makes the initial soil cut, minimizing clogging of weeds in front of the share. In plowing wet but firm fields, attaching an 18-cm-wide cage wheel to run in the furrow improved directional stability and ensured a uniform width of cut. An average 14.4 hours was required to plow 1 ha. Gasoline consumption averaged 1.2 liters/hour.

A standard comb harrow combined with a pair of puddling wheels 0.4 m wide was most appropriate for harrowing in very soft fields. An average of 9.1 hours was needed to harrow 1 ha, and gasoline consumption was 1.2 liters/hour.

After testing, changing the sliding engine belt

tensioning system to an idler pulley belt tensioning system was recommended. The large tension force needed in the sliding engine system adversely affected the clutch-engaging linkage and the engine-support bracket. The small angle of wrap at the engine pulley caused excessive belt slippage and shortened belt life considerably. Reinforcing the joint between the engine-mounting bracket and the tiller-transmission case and the joint between the hitch bracket and the transmission case also was recommended.

PT-5 power tiller with 1-m reaper. The first unit of the 3-hp tiller and 1-m reaper was evaluated for plowing and reaping. The power tiller unit logged a total of 114 hours.

Prony brake testing. A 10-hp prony brake from the Institute of Agricultural Machinery in Japan was added to the testing facilities. A power tiller mounting frame, a prony brake mounting frame, and a prony brake to power tiller coupling system was designed so that all types of power tillers can be easily coupled to the prony brake.

The setup, currently installed at the Agricultural Machinery Testing and Evaluation Center, is being used to test the durability of the 3-hp power tiller transmission.

Comparison of axial-flow and centrifugal pumps. A 15-cm (6-inch) axial-flow pump and a 10-cm (4-inch) centrifugal pump were tested for capacity performance by running both pumps alternately, using a 5-hp engine at heads of 107 cm, 151 cm, and 283 cm. Capacity was measured with a 20-cm cut-throat flume.

The 15-cm axial flow pump had 310% higher capacity than the 10-cm centrifugal pump at 107 cm head (2,762.7 liters/minute versus 900.0 liters/minute; 280% higher at 151 cm head (2,400.7 liters/minute versus 857.7 liters/minute, and 200% higher at 283 cm head (1,616.0 liters/minute over 802.7 liters/minute. Fuel consumption did not vary significantly, averaging 1.38 liters/hour.

INDUSTRIAL EXTENSION

Industrial extension projects are active in Burma, Egypt, Indonesia, Pakistan, Philippines, and Thailand. A project is planned for India, where several manufacturers are now fabricating IRRI-designed machinery.

Burma. Interest in the manual transplanter increased considerably during 1981. Over 60 transplanters were constructed and a total of 3,243 ha of rice were transplanted with IRRI-designed units. Over 500 people were trained to operate the transplanter.

The reaper windrower was introduced and is being adapted to the locally built power tiller.

The rotary injection planter also is considered appropriate for conditions in Burma. All cropping systems research sites are being equipped with a set of appropriate small machines to be introduced to farmers.

Indonesia. Industrial extension personnel have translated drawings from IRRI into the Indonesian language. Prototypes of hand tractors, axial-flow pumps, transplanters, and weeders have been built. A 2-stage (8-inch) axial-flow pump has been constructed and is undergoing testing. The rotary injection planter is being tested for use in the transmigration area.

A training program was conducted in the local language for 20 participants of the staff of DIPERTA, Perindustrian, cooperative manufacturers from West Sumatra, South Kalimantan, and South Sulawesi.

A 2-year pilot project was initiated in the Luwu district of South Sulawesi, where over 10,000 ha have been brought into production under a transmigration scheme. Ten locally built hand tractors have been introduced for comparison with four-wheel tractors.

A pedal-powered (bicycle) paddy thresher has been built for use in densely populated areas.

Five local manufacturers are now producing IRRI designs, mainly of paddy threshers and hand weeders. The potential demand for paddy threshers is estimated at 2,300/year.

Pakistan. The IRRI-PAK Agricultural Machinery Program established close contacts with manufacturers of agricultural machines and implements. Project staff paid more than 150 visits to assist cooperating manufacturers in improving and testing machines and implements in Pakistan. In general, manufacturers are hesitant to risk producing new IRRI-PAK machines because of market uncertainties. Production of IRRI-PAK machines also requires a somewhat higher level of precision than is generally followed in Pakistan.

To overcome these problems, the IRRI-PAK program made numerous personal contacts with manufacturers and organized a number of machinery demonstrations and displays at farm locations and agricultural fairs. Farmers' and manufacturers' interest was encouraged through field demonstrations of IRRI machines, especially threshers, in many rural areas. These efforts have resulted in the production of IRRI-PAK machines by 17 manufacturers in Pakistan.

The inability of small manufacturers to produce machines according to specifications, a chronic problem, has resulted in a general lack of quality production and in poor field performance of commercially produced IRRI-PAK machines. The IRRI-PAK program has had to rectify many defects in machines produced by cooperating manufacturers.

During the early stages, drawings were provided all manufacturers indicating interest in producing the machines. Experience indicates that initial commercialization efforts should be directed to a few key manufacturers capable of maintaining quality, able to work from drawings, and with adequate financial resources to take initial risk of introducing a new machine. The IRRI-PAK Program is now working with a limited number of selected manufacturers.

The industrial extension staff has developed closer working relationships between research organizations and agricultural machinery manufacturers and distributors in Pakistan. Close contacts with financing organizations, such as the Agricultural Development Bank of Pakistan, and with other international organizations interested in agricultural mechanization also have been developed.

A twice-a-year IRRI-PAK newsletter is mailed to more than 300 agencies in Pakistan and other countries. A regularly published semiannual progress report is sent to more than 200 organizations in the developing countries. The industrial extension section also prepared leaflets and instruction manuals and related reports on machines being developed by the IRRI-PAK program, which were provided free to manufacturers fabricating IRRI-PAK machines.

During the first 3 years of the program, when the IRRI Industrial Extension Project was a centrally

Table 3. Production of commercially produced agricultural machinery, by firm size and type, in the Philippines in 1980.

Machine	Units produced (no.) by									
	IRRI-cooperating firms[a] with					Non-IRRI cooperating firms[b] with				
	1-9 employees	10-19 employees	20-49 employees	50 & more employees	Total	1-9 employees	10-19 employees	20-49 employees	50 or more employees	Total
Axial-flow thresher	30	137	22	656	844[c]	4	12	30	200	246[d]
Portable thresher	54	120	110	718	1002[e]	–	–	15	50	65[f]
Pedal thresher	–	–	–	–	0[g]	100	108	–	–	208[h]
Power tiller	22	352	115	905	1394[i]	53	–	20	945	1018[j]
Rice blower	–	–	80	100	180[k]	4	10	–	10	24
Total	106	609	327	2379	3420	161	130	65	1205	1561

[a] Based on 28 firms surveyed. [b] Based on 191 firms surveyed. [c] Figures based on 10 firms with reported production; 3 firms gave no figures and 1 firm stopped production in 1980. [d] Threshers are the big, Cotabato-type (Presto-patented) machines. [e] From 12 firms with reported production. Two firms gave no figures and 1 stopped production in 1980. [f] A modified IRRI portable thresher or smaller version of threshers mentioned in b. [g] One IRRI cooperator produced the machine in 1981. [h] One non-IRRI cooperator gave no figures. [i] Figures based on 11 firms only. [j] Includes 948 units of the turtle-type power tiller. [k] Based on 2 firms only.

funded USAID regional project, the IRRI-PAK machines were also extended to neighboring countries, especially Afghanistan and India. The project director visited Afghanistan in early 1978 to introduce the IRRI-PAK machines to the government officials and manufacturers. A prototype IRRI axial-flow thresher was fabricated by M/s Jangalak Industries, a nationalized manufacturer of various metal products in Kabul. Two engineers from the company were trained by the IRRI-PAK program at Rawalpindi in the use and manufacture of IRRI-PAK machines.

In India, manufacturers have shown considerable interest in the IRRI-PAK machines. M/s Suri Research Foundation, New Delhi, and the Agricultural University, Pantnagar, have assisted IRRI in introducing IRRI-developed machines into India. The IRRI-PAK program worked closely with the Punjab Agricultural University (PAU), Ludhiana, and the project director visited cooperating organizations and manufacturers to encourage local production.

Two manufacturers in Ludhiana produced the IRRI-PAK standard threshers, which were tested by the PAU. The Agricultural University (AU), Pantnagar, also built the IRRI-PAK thresher and conducted many design optimization studies. Results of tests by PAU Ludhiana and AU Pantnagar were published in a number of international journals. Engineering drawings of the IRRI-PAK threshers have also been provided to two IRRI subcontracting organizations and to various manufacturers and agricultural engineering organizations in India.

The original IRRI axial-flow paddy thresher developed in the Philippines has been adapted for tractor PTO operations. Manufacturers in the Ludhiana, Amritsar, and Moga area have produced over 150 tractor-powered paddy threshers.

Production of the IRRI diesel power tiller with steering clutches has made considerable headway. One company at Hyderabad has built a prototype unit of the IRRI motorized cart and has shown interest in its production. Drawings of the IRRI-PAK four-wheel tractor also have been provided to manufacturers, and one company is trying to fabricate a prototype unit.

Philippines. On 16 June 1981, Dr. Robert Stickney was appointed coproject leader of the Ministry of Agriculture-International Rice Research Institute (MA-IRRI) Industrial Extension project located in the Agricultural Engineering Division of the Bureau of Plant Industry (BPI) in Manila.

A special 2-week training course in July 1981 for members of the Agricultural Engineering Division of BPI included visits to manufacturers to examine the potential for agricultural machinery fabrication.

Asean Fabricators, Inc., was assisted in a production study of machine and manpower requirements, based on an annual production of 300 units each of the portable thresher, axial flow thresher, and other IRRI designs.

Newly designed reapers were extensively tested in Mindanao. The manual transplanter was introduced in Mindanao, and several new manufacturers became IRRI cooperators.

A study, *Technical change in the Philippine agricultural machinery industry*, documents 1980 agricultural machinery production by firm size and type (Table 3). It attempts to identify innovative qualities of firms and ways by which technology changes occurred.

Thailand. Manufacture of IRRI-designed axial-flow threshers continues to expand. In 1980, 933 axial flow threshers were produced by 4 new firms.

Forty-five transplanters were built by five new manufacturers and introduced to farmers. The transplanter requires new methods of growing seedlings, because it uses mat-type seedlings instead of root-washed seedlings.

The IRRI memorandum of agreement was signed by 23 new manufacturers.

Tests on a redesigned buffalo plow were completed. The draft was reduced 34.3% by changing the shape and angle of the moldboard. Another improved plow with 50% more cross-sectional area than the traditional plow had about the same draft.

Associated formal training

IRRI resident training and educational programs help research and extension organizations of developing countries strengthen their capabilities in rice and rice-based cropping systems research methodology. The programs are research and production oriented and fully integrated with the Institute's research activities. They include postdoctoral research fellowships, MS and Ph D degree programs, special nondegree research programs, and training courses supportive of various research and international network activities. During 1981, 491 participants (equivalent to 213 person-years) from 34 countries took part in IRRI training.

RESEARCH-ORIENTED PROGRAMS

Individuals with Ph D degrees are designated *postdoctoral fellows,* those with master's degrees or the equivalent are called *research* or *postmasteral fellows,* and those with a bachelor's degree are called *research scholars.* In 1981, 235 scientists participated in research training at IRRI for 3 months to 1 year — 38 postdoctoral fellows, 93 postmasteral fellows, and 104 research scholars (Table 1, 2).

Among the postmasteral fellows and research scholars, 50 were Ph D students and 105 were master's degree students. Eleven were pursuing grad-

Table 1. Distribution by country of IRRI research fellows and scholars, 1981.

Country	Post-doctoral fellows	Research fellows			Research scholars		Total
		PhD	MS	N.D.[a]	MS	N.D.[a]	
Bangladesh	3	5	21	3	2	–	34
Philippines	2	5	–	2	13	1	23
India	17	4	–	1	1	–	23
China – Mainland	–	–	–	6	13	2	21
– Taiwan	–	–	–	–	2	–	2
Sri Lanka	2	2	–	–	15	–	19
Thailand	1	5	–	2	6	3	17
Indonesia	–	2	–	–	8	2	12
U.S.A.	2	4	–	–	3	–	9
Japan	4	1	–	2	–	2	9
Nepal	–	1	–	1	7	–	9
Korea	1	4	–	–	2	1	8
West Germany	2	4	–	1	–	–	7
Vietnam	–	2	–	–	–	5	7
Burma	–	–	–	–	3	3	6
England	1	2	–	3	–	–	6
Pakistan	–	4	–	–	2	–	6
Mexico	–	1	–	–	1	–	2
Netherlands	–	2	–	–	–	–	2
Colombia	–	1	–	–	1	–	2
Ghana	–	–	–	–	1	–	1
Kenya	–	–	–	–	1	–	1
Malaysia	1	–	–	–	–	–	1
Peru	1	–	–	–	–	–	1
Italy	1	–	–	–	–	–	1
Panama	–	1	–	–	–	–	1
Senegal	–	–	–	–	1	–	1
Sudan	–	–	–	–	1	–	1
Venezuela	–	–	–	–	1	–	1
Samoa	–	–	–	–	–	1	1
Egypt	–	–	–	1	–	–	1
Total	38	50	21	22	84	20	235

[a] Nondegree.

uate studies in selected universities in the United States, the Netherlands, and Australia. Forty-two scientists received nondegree training.

During the year, 16 postdoctoral fellows, 16 Ph D, 30 MS, and 19 nondegree scholars completed their training at IRRI.

TRAINING COURSES

Seven regular and two special formal training courses were offered in 1981.

Course	*Date offered*
Genetic Evaluation and Utilization Course (GEU)	9 February-29 May 17 August-4 December
International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)	9 February-29 May
Rice Production Training Program (RPTP)	9 March-28 August
Cropping Systems Training Program (CSTP)	7 September 1981- 5 March 1982
Irrigation Water Management Training (IWMT)	20 July-28 August
Agricultural Engineering Course (AEC)	1-12 June 6-17 July 7-18 December
Integrated Pest Management Course (IPM)	1 September- 16 December
Farm Management Training (FM)	6-24 July
Agricultural Economics (Ag. Econ.)	4 May-3 June

Table 3 shows the distribution, by course and country, of the 256 trainees who participated in these courses. The number excludes 53 trainees who participated in the special 2-week Rice Production Training courses on 16-27 February, 11-22 May, 20-31 July, and 16-22 November.

Most of the trainees came from Bangladesh, Burma, India, Indonesia, Philippines, China, Sri Lanka, and Thailand.

The names of research fellows, scholars, and trainees, including their country and research project areas, follow. An asterisk (*) indicates completion of the MS degree; two asterisks (**), completion of the Ph D degree.

RESEARCH SCHOLARS

Agricultural Economics

Afzal Hossain.* Bangladesh. Optimal cropping systems for some selected farms in Dacca district, Bangladesh.

Table 2. Distribution by department of IRRI research fellows and scholars, 1981.

Department	Post-doctoral fellows	Research fellows			Research scholars		Total
		PhD	MS	N.D.[a]	MS	N.D.[a]	
Plant Breeding	3	7	3	1	10	7	31
Agricultural Economics	2	10	3	1	13	1	30
Agronomy	7	5	2	1	8	–	23
Entomology	4	5	2	1	7	2	21
Agricultural Engineering	1	2	2	5	8	1	19
Plant Pathology	4	1	1	3	7	2	18
Multiple Cropping	3	3	3	–	7	1	17
Plant Physiology	5	5	–	3	1	3	17
Water Management	1	5	–	–	5	1	12
Soil Chemistry	2	2	1	2	3	1	11
Soil Microbiology	4	1	1	1	2	–	9
Statistics	–	–	–	1	3	1	5
IRTP	2	–	–	–	1	–	3
OIS	–	1	–	1	1	–	3
Training Office	–	–	–	2	–	–	2
RPTR	–	–	2	–	–	–	2
Chemistry	–	–	1	–	–	–	1
(Abroad)	–	3	–	–	8	–	11
Total	38	50	21	22	84	20	235

[a]Nondegree.

Table 3. Distribution by country of participants in IRRI training courses,[a] 1981.

Country	GEU	INSFFER	RPTP	CSTP	IPM	IWMT	AEC	FM	Ag Econ	Total
Bangladesh	1	–	2	8	2	8	1	3	–	25
Burma	6	2	3	2	1	2	4	2	–	22
Egypt	–	–	1	–	–	–	–	–	–	1
Ghana	–	–	–	–	–	–	1	–	–	1
Guyana	1	–	–	–	–	–	–	–	–	1
India	6	4	6	1	1	–	5	–	–	23
Indonesia	6	3	2	9	7	5	5	4	4	45
Kenya	–	–	1	–	–	1	–	–	–	2
Laos	–	–	3	–	–	–	–	–	–	3
Malaysia	–	–	1	3	1	2	1	–	–	8
Nepal	1	1	1	–	–	–	–	–	–	3
Nigeria	–	–	–	–	–	–	1	–	–	1
Pakistan	–	–	1	–	–	–	3	–	–	4
Philippines	3	4	3	6	2	6	25	–	–	49
China	14	6	–	–	–	–	–	–	–	20
Sri Lanka	3	–	2	3	–	2	1	2	–	13
Thailand	6	2	2	8	4	2	3	2	–	29
Upper Volta	–	–	1	–	–	–	–	–	–	1
Vietnam	3	–	–	–	–	–	2	–	–	5
Total	50	22	29	40	18	28	52	13	4	256

[a]GEU = Genetic Evaluation and Utilization, INSFFER = International Network on Soil Fertility and Fertilizer Evaluation for Rice, RPTP = Rice Production Training Program, CSTP = Cropping System Training Program, IPM = Integrated Pest Management, IWMT = Irrigation Water Management Training, AEC = Agricultural Engineering Course, FM = Farm Management (special course), Ag Econ = Agricultural Economics.

Carolyn Melgar.* Philippines. Technical innovations and farm resource constraints.

Satoshi Mori. Japan. Productivity and economics of the *sorjan* cropping system in Solana, Cagayan.

B. A. A. Mustafi.* Bangladesh. An economic analysis of the factors affecting the adoption of modern varieties of rice in some selected sites of Bangladesh.

Laurence Pauling.* USA. Role of credit in multiple cropping on Solana farmers, Cagayan, Philippines.

Rosalinda Servano.* Philippines. Economic value of children in agrarian household economics.

Yolanda Tan.* Philippines. The impact of farm mechanization on small-scale rice production.

Agricultural Engineering

Md. Abdul Baqui.* Bangladesh. Testing, evaluation, and modification of the IRRI manual rice transplanter in Bangladesh.

Kent Mikkelsen.* USA. Technology change in the Philippine agricultural machinery industry.

Agronomy

Sinnadurai Kandasamy.* Sri Lanka. Response of rice roots to simulated soil compaction with emphasis on water uptake.

Entomology

Md. Sayed Ahmed.* Bangladesh. Evaluation of rat control techniques in experimental fields of the International Rice Research Institute.

Bishnu K. Gyawali.* Nepal. Feeding behavior and damage assessment of rice seed bug *L. oratorius* F. on rice leading to the development of economic thresholds.

Suleman Okech.* Kenya. Mechanisms and possible causes of resistance in selected rice varieties to Biotype 1 brown planthopper, *Nilaparvata lugens* (Stal.).

Rochman. Indonesia. Chemical insect control and yield loss on soybean.

Irrigation and Water Management

Arturo Acoba.* Philippines. Determinants of efficient management of tubewell irrigation system.

Nelson Devanadera.* Philippines. Rainfed toposequence moisture evaluation of a communal irrigation system in Bicol.

Hermenigildo Gutierrez.* Philippines. Technical and economic evaluation of a communal irrigation system in Bicol.

Somchai Juntharasri. Thailand. Agro-meteorological analysis of rainfall effectiveness and net irrigation demand for Northeastern Thailand.

Wimson Fredie Purba.* Indonesia. The effectiveness of tertiary improvement on increasing irrigation efficiency.

Gloria Soltes.* Philippines. Farmers' attitude and behavior toward a sub-system management technology in a communal irrigation system in Bicol.

Multiple Cropping

Abdul Quddus.* Bangladesh. Effect of some growth regulators and cultural management practices on rice ratooning.

Didi Suardi.* Indonesia. Estimation of crop coefficient and other parameters for an evapotranspiration model to evaluate the potential for rice in cropping patterns.

Plant Breeding

Jose Hernandez.* Philippines. Genetics of resistance to whitebacked planthopper *Sogatella furcifera* (Horvath) in some rice varieties.

Li Qin-xiu. China. Breeding of male-sterile lines possessing long, well-exserted stigma for use in hybrid rice.

Lu Yuan-xing. China. Identification of restorer lines possessing multiple disease and insect resistance.

Pitoyo. Indonesia. Breeding for disease and insect resistance.

Plant Pathology

Ernesto Andrade.* Colombia. Physiology and pathogenicity of *Rhynchosporium oryzae* (Hashioka-Yokogy), causal agent of leaf scald disease of rice.

Rogelio Cabunagan.* Philippines. Adaptabilities of *Nephotettix virescens* on IR34 and its transmission of rice tungro virus.

Jesus Abel Flores Gaxiola.* Mexico. Inheritance of resistance to leaf blast *Pyricularia oryzae* (Cavara) in some rice lines and varieties.

Ming Teh-chiu.* Republic of China. Effects of temperature on the latent period of rice ragged stunt virus in brown planthopper *Nilaparvata lugens* (Stal.) and rice plant.

Jae Dang Yoo. Korea. (1) Screening of Korean pedigree lines in blast nursery and BLB in IRRI farm; (2) Preliminary study on the function of blast forecast at blast nursery.

Rice Production Training and Research

Khairul Alam Billah.* Bangladesh. Agricultural extension.

Soil Chemistry

Mujibol Islam.* Bangladesh. Soil and plant tests for available sulfur in wetland rice soils.

Soil Microbiology

Taufiqul Aziz.* Bangladesh. Effect of neem cake and straw on phototrophic nitrogen fixation.

Laddawan Loudhapasitiporn.* Thailand. The growth of azolla in acid phototrophic nitrogen fixation.

RESEARCH FELLOWS

Agricultural Economics

Emelyn Navera.** Philippines. Role of credit in multiple cropping on Solana farmers, Cagayan, Philippines.

Joyotee Smith.** India. The effect of the new rice technology on labor utilization in Laguna.

Agricultural Engineering

Duncan Boughton.** United Kingdom. Energy use in alternative rice production system in Nueva Ecija, Central Luzon, Philippines.

Agronomy

Amnart Chinchest.** Thailand. The effects of water regimes and nitrogen rates on nitrogen uptake and growth of rice varieties.

Hans G. Schoen.** West Germany. Ammonium dynamics in flooded rice soils.

Entomology

Nazira Kamal.** Bangladesh. Suppression of whitebacked planthopper *Sogatella furcifera* (Hor-

vath), and rice leaffolder *Cnaphalocrocis medinalis* (Guenee) populations by natural enemies.

Dang Thang Ho.** Vietnam. Mechanism of moderate resistance in rice varieties to brown planthopper *Nilaparvata lugens* (Stal.).

Volkmar Hasse.** West Germany. The influence of vegetational diversity on host-finding and larval survival of the Asian corn borer *Ostrinia furnacalis* Guenee (*Lepidoptera*; *Pyralidae*)

International Rice Testing Program

M. N. Shrivastava.** India. Studies on genetic diversity and combining ability in rice.

Irrigation and Water Management

Ma. Concepcion Cruz.** Philippines. Social and institutional factors affecting differential access to water: Findings on a corporate farm communal irrigation system linkage project.

Robert Siy, Jr.** Philippines. Indigenous water management organizations in Ilocos Norte.

Plant Breeding

Kevitt Brown.** USA. Increasing rice production under a cold temperature constraint.

David Mackill.** USA. Studies on the mechanisms and genetics of high temperature tolerance in rice.

Jorge Armenta Soto.** Mexico. Inheritance of root characteristics under aeroponic culture.

Yuan Long Pin. China. Techniques of seed production in hybrid rice.

Plant Physiology

Tawee Kupkanchanakul.** Thailand. Factors affecting tillering ability and yield performance of rice cultivars and different water levels.

Training Office

Carmencita Necesito. Philippines. IRRI training programs.

POSTDOCTORAL FELLOWS

Agricultural Economics

K. P. Kalirajan. India. (1) Yield constraints in rainfed Camarines Sur; (2) Error components of technical efficiency; and (3) Supply response (profit function) of rice production.

Agricultural Engineering

Shiva Kumar Tripathi. India. Testing and evaluation of IRRI vertical bin dryer.

Agronomy

A. William Ruscoe. USA. Rice cultivar tolerance to herbicides.

C. M. Singh. India. The use of interrow cultivation for weed control in dry-seeded rice.

Entomology

Chua Tock Hing. Malaysia. Biological control of brown planthopper.

G. S. Dhaliwal. India. Allelochemics and striped stem borer resistance in rice.

M. S. Venugopal. India. Phytotoxic effects of insecticides with special emphasis on carbofuran.

Irrigation and Water Management

Brij M. Sahni. India. Seepage and percolation analysis prediction in irrigation management refinement.

Multiple Cropping

J. Prabhakara. India. Soil desorption studies in relation to: (1) upland crop establishment following puddled rainfed lowland rice in rice-based cropping systems; (2) different land preparation methods for rice; and (3) soil texture and hydrological landscape positions of a toposequence.

Plant Breeding

Devendra Chaudhury. India. Mechanisms of drought resistance in rice cultivars.

Plant Pathology

G. L. Raina. India. Pathogenic variability of *Xanthomonas campestris* pv. *oryzae*.

Plant Physiology

Bhardan S. K. Roy. India. (1) Selection for cold tolerance characteristics during rapid generation advance; (2) Breeding for rice with ratooning ability for deepwater areas; and (3) Submergence tolerance.

M. Yamanouchi. Japan. Physiological studies on iron toxicity.

Francisco Zapata. Peru. Anther culture of rice.

Soil Microbiology

Ian Grant. United Kingdom. Blue-green algae-predator relationship.

B. P. R. Subudhi. India. Effect of neem cake on phototrophic N_2 fixation.

OTHERS

Agricultural Economics

Hori Lee Ainuu. Samoa. Yield constraints in rainfed rice in the Bicol Region.

Pancar Simatupang. Indonesia. Economics for agricultural researchers' training.

Jahlim Sudaryanto. Indonesia. Economics for agricultural researchers' training.

Achmad Suryana. Indonesia. Economics for agricultural researchers' training.

Andin Taryoto. Indonesia. Economics for agricultural researchers' training.

Agricultural Engineering

Madhab Raj Khoju. Nepal. Optimum pumpset size for different farm sizes in Terai, Nepal.

Ketut Nehen. Indonesia. Choice of technique with reference to land preparation in Indonesia.

Lavan Niyomvit. Thailand. Effect of mechanization on intensity of land use: Thailand.

Supachat Sukharomana. Thailand. Effect of mechanization intensity of land use: Thailand. Anuwat Wongsangaroonsri, Thailand. Effect of mechanization on employment and intensity of labor use: Thailand.

Information Services

Md. H. R. Talukdar. Bangladesh. Consultation on establishment, equipping, and training of staff for BRRI's information services.

Plant Breeding

Ling Zu-ming.† Differential variability of rice cultivars in short-term storeroom.

U Saw Stanley.† Burma. Seed technology.

Daw Hla Hla Tin. Burma. Seed technology.

Xie Yu Feng. China. Evaluation of seed storage methods and containers.

Plant Pathology

Anas Barata. †Indonesia. 1981 wet-season screening of rice varieties and lines for resistance to rice blast disease.

Murdani Diredja.† Indonesia. 1981 dry-season screening rice varieties for blast resistance.

Hin Shang-zhi.† China. Screening bacteriocin producer strain of *Xanthomonas campestris* pv. *oryzae*.

Liu Run-yang.† China. Screening for resistance to rice ragged stunt.

Tasanee Sa-Nguangsaj.† Thailand. Thai rice varieties as tungro virus source.

Yin Shang-zhi.† China. Reaction of IRRI, Korean, and Chinese varieties to pathotypes of *Xanthomonas campestris* pv. *oryzae* in the Philippines.

Soil Chemistry

Jasimuddin Ahmed.† Bangladesh. Effect of 4 salt concentrations on the growth of 10 rice varieties of Bangladesh.

U. Chandrasiri.† Sri Lanka. Screening for tolerance to salinity and alkalinity.

S. Hadiatmi. †Indonesia. Tolerance to salinity of deepwater rice varieties.

Nguyen Kim Hai.† Vietnam. Screening for salt tolerance at the seedling stage of rice.

Mervyn Kumara.† Sri Lanka. Screening for iron toxicity.

Meng Xiang-shen.† China. Screening for tolerance to salinity.

Cyril Roberts.† Guyana. Screening for salt tolerance.

Statistics

Manotosh Howlader. Bangladesh. Computer programming statistical applications.

Wanna Kaewmongkol. Thailand. IRRI computer systems.

GENETIC EVALUATION AND UTILIZATION COURSE
(9 February-29 May 1981)

Burma

U Myo Myint, research assistant, Rice Division, Agricultural Research Institute, Agricultural Corporation, Ministry of Agriculture and Forests, Yezin, Pyinmana

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†GEU trainee

U Tin Maung Myint, agricultural field inspector, Central Agriculture Farm, Agriculture Corporation, Mandalay

U Chit Ko Ko, research assistant, Rice Division, Agricultural Research Institute, Agricultural Corporation, Ministry of Agriculture and Forests, Yezin, Pyinmana

China

Chen Min-cai, research assistant, Plant Physiology and Genetics Institute, Fujian Academy of Agricultural Science

Liu Run-yang, research assistant, Guangxi Academy of Agricultural Science, Nan-ing

Liu Zhan-wen, research assistant, Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Science, Beijing

Chen Jin-can, research assistant, Kuandong Academy of Agricultural Science, Canton

Wei Ya-shu, research assistant, Sichuan Academy of Agricultural Science, Chengdu, Sichuan

Yin Zhang-zhi, research assistant, Jiangsu Academy of Agricultural Science, Nanking

Zhao Yong-xin, research assistant, Shanghai Academy of Agricultural Science, Shanghai

Zheng Kang-le, research assistant, Zhejiang Academy of Agricultural Science, Hangzhou

Guyana

Cyril S. Roberts, plant breeder, Rice Research Station, Burma, Maharony, E.C.D., Guyana

India

Shivaji A. Chavan, rice breeder, Agricultural Research Station, Ratnagiri, Maharashtra State

Parsuram Nayak, scientist S-1, Central Rice Research Institute, Cuttack 6, Orissa

Indonesia

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Murdani Diredja, technician, Central Research Institute for Agriculture, Bogor

Tutu Tersyana, research assistant, Pests and Diseases Division, Central Research Institute for Agriculture, Bogor

Philippines

Silvestre Tañgonan, agronomist, Bureau of Plant Industry, Cagayan Valley Experiment Station, San Mateo, Isabela

Gregorio Vargas, agronomist, Bureau of Plant Industry, La Granja Experiment Station, La Carlota City, Negros Occidental

Sri Lanka

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Thailand

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Monton Poonyarit, assistant plant breeder, Pitsanulok Rice Experiment Station, Pitsanulok

Prateep Rodpan, assistant plant breeder, Pitsanulok Rice Experiment Station, Pitsanulok

GENETIC EVALUATION AND UTILIZATION COURSE
(17 August-4 December 1981)

Bangladesh

Muniruzzaman Meer, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

U Sein Lwin, junior research officer, Agricultural Research Institute, Yezin, Pyinmana

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Maung Kyaw Myint, deputy farm manager (breeder), Central Farm, Mudin

China

Fu Xi-quin, technician (Plant Breeding), Hunan Academy of Agricultural Sciences, Changsha, Hunan

Lu Jin-tu, technician (Pathology), Shanghai Academy of Agricultural Sciences, Shanghai

Meng Xiang-zhen, assistant researcher (Plant Breeding), Scientific Research Institute of Land Recreation, Hebei

Ni Pi-cheng, assistant researcher (Plant Breeding), Crop Breeding and Cultivation Institute, Chinese Academy of Agricultural Sciences, Beijing

Tan Zhong-he, assistant researcher (Agronomy), Sichuan Academy of Agricultural Science, Chengdu, Sichuan

Wang Cheng-jiu, assistant researcher (Plant Protection), Lutai State Farm, Hebei

India

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Keshab Chandra Sarmah, assistant rice breeder, Rice Research Station, Titabar 785630, Assam

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Philippines

Thelma S. Paranpan, senior plant entomologist, Visayas Rice Experiment Station, Iloilo City

Sri Lanka

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L. B. Nimalaratna, plant pathologist, Regional Research Station, Angunukulapelassa

Thailand

Tasanee Sa-Nguansaj, plant pathologist, Chainat Rice Experiment Station, Chainat

Wilailak Somnut, agricultural technician (plant breeder), Surin Rice Experiment Station, Surin Province

Vasna Varamisra, rice agronomist, Chainat Rice Experiment Station, Chainat

Vietnam

Nguyen Kim Hai, plant breeder, Agricultural Science Institute, Vandien, Hanoi

Luong Thanh Nhi, plant breeder, Agricultural University No. 3, Bac Thai Province

Nguyen Thi Gai, plant breeder, Food Crops Institute, Hai Hung Province

INTERNATIONAL NETWORK ON SOIL FERTILITY AND FERTILIZER EVALUATION FOR RICE
(9 February-29 May 1981)

Burma

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U Sein Win, assistant analyst, Agricultural Research Institute, Yezin, Pyinmana

China

Huang Shi-zhen, assistant researcher, Soil and Fertilizer Institute, Fujian Academy of Agricultural Sciences

Li Ren-lin, assistant researcher, Sichuang Academy of Agricultural Sciences

Lu Wan-fang, assistant researcher, Agricultural Scientific Academy of Guang-xi

Peng Jian-ying, assistant researcher, Hunan Academy of Agricultural Science, Changsha, Hunan

Zheng Sheng-xian, assistant researcher, Hunan Soil and Fertilizer Research Institute, Hunan

Zhu Zhong-lin, assistant researcher, Soil and Fertilizer Institute, Sichuan Academy of Agricultural Sciences, Cheng Du

India

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Randhir Singh Chahal, soil scientist, Department of Soils, Haryana Agricultural University, Hissar

S. Kannaiyan, associate professor, Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu

R. D. Sheth, associate research scientist, Microbiology, Gusarat Agricultural University, Anand-Gujarat

Indonesia

Siti Mariam, Staff of Soil Science, Faculty of Agriculture, Padjadjaran University, Bandung

Agustine Pasolang, soil researcher, Maros Research Institute for Agriculture, Ujung Pandang, South Sulawesi

Jusuf Prawirasumantri, assistant researcher, Soil Research Institute, Bogor

Nepal

Surya Laxmi Maskey, soil scientist, Division of Soil Science and Agricultural Chemistry, Khumaltar, Lalitpur

Philippines

Celia Grospe, soil technologist II, Bureau of Soils, Alabang, Muntinlupa, Metro Manila

Ronnie B. Jamola, soil technologist I, Soil Services Division, Ministry of Agriculture, Region VII, Cebu City

Conrado C. Santos, supervising soil technologist, Soil Conservation and Research Station, Alabang, Muntinlupa, Metro Manila

Euperio B. Vicoy, soil technologist I, Ministry of Agriculture, Arellano Boulevard, Cebu City

Thailand

Anon Sooksavut, agricultural researcher, Pan Rice Experiment Station, Chiengmai

Wiwat Ingkapradit, agricultural researcher, Rice Division, Department of Agriculture, Bangkhen, Bangkok 9

RICE PRODUCTION TRAINING PROGRAM
(9 March-28 August 1981)

Bangladesh

Gazi Jashim Uddin Ahmed, senior scientific officer, Bangladesh Rice Research Institute, G.P.O. Box 911, Dacca

Md. Serajul Islam, scientific officer, Bangladesh Rice Research Institute, G.P.O. Box 911, Dacca

Burma

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Sein Sein, deputy township manager, Agriculture Corporation, 72-74 Shwedagon Pagoda Road, Rangoon

Thein Lwin, township manager, Agriculture Corporation, 72-74 Shwedagon Pagoda Road, Rangoon

Egypt

Mohamed Elchiaty, research assistant, Rice Research Section, Sakha Agricultural Research Station, Ministry of Agriculture, Sakha, Kafr Elsheikh

Indonesia

Ardan Ahmadin, Pathology Staff, Central Research Institute for Agriculture West Sumatra representative, Bandar Buat, Padang

Irmansyah, Pathology Staff, Central Research Institute for Agriculture, West Sumatra representative, Bandar Buat, Pandang

India

Shrivastava Jugal Prashad, assistant director of agriculture, Directorate of Agriculture, Madya Pradesh, Bhopal

Gopalakhrishna Konaje, deputy director of Agriculture, Directorate of Agriculture, Seshadri Road, P. O. Bangalore-1, Karnataka State

Brundaban Panda, assistant director of agriculture, Directorate of Agriculture and Food Production, Drissa, Bhubaneswar

Mihir Kumar Pradhan, water management specialist, Directorate of Agriculture and Food Production, Bhubaneswar

Kaushik Surendra Kumar, assistant agronomist, Agriculture Department, 76 B. Block, Sri Ganganagar, Rajasthan

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Kenya

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Bouakham Phouaravanh, agriculture technician, Department of Agriculture, Salakham Rice Station, RDPL, Vientiane

Sipaseuth, agriculture technician, Department of Agriculture, Salakham Rice Station RDPL, Vientiane

Malaysia

Protasius Jomoly Mukiau, padi officer, Sabah Padi Board, Kota Kinabalu, Sabah

Nepal

Ganesh Bahadur Chand, agri-officer, Agriculture Inputs Corporation, P.B. No. 195, Kathmandu

Pakistan

Mohammad Sarfraz Iqbal, assistant research officer, Rice Research Institute, Kala Shah Kaku

Philippines

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Angel Gildore, Jr., plant pest control technologist, Visayas Experiment Station, Hamungaya, Jaro, Iloilo

Josephine P. Tolentino, agronomist I, Research Division, Bureau of Plant Industry, Manila

Sri Lanka

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Kankanan Pathiranage Alfred, agriculture instructor, Agricultural Research Center, Angunakolapalassa

Thailand

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Chutiwat Wannasai, agriculture technician, Rice Division, Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok

Upper Volta

Jules A. Sawadogo, agronomist, assistant expert, Rice and Irrigated Crops Research Station (C.E.R.C.I.), P.O. Box 540, Bobo-Dioulasso, Upper Volta

CROPPING SYSTEMS TRAINING PROGRAM
(7 September 1981-5 March 1982)

Bangladesh

Md. Hazrat Ali, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Abdul Motalib Bhuiyan, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Joynal Abedin, scientific officer, Agricultural Economics, Bangladesh Rice Research Institute, Joydebpur, Dacca

Abul Hashem, scientific officer, Regional Agricultural Research Station, Hathazari, Chittagong

Rashid Md. Harunur, extension officer, T/W Project, Bangladesh Water Development Board, Dinajpur

Md. Taufiqul Islam, scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca

Islam Md. Nasirul, extension officer, G.K. Project, Bangladesh Water Development Board, Alamdanga Kushtia

Mofarah Us Sattar, scientific officer, Graduate Training Institute, Bangladesh Agricultural University, Mymensingh

Burma

U Taw Baw, deputy township manager, Agricultural Corporation, Htantabin Division, Rangoon

U Par, deputy township manager, Agricultural Corporation, Paukkhaung

India

Bhupendra Nath Sarmah, agronomist (Rice), Rice Research Station, Titabar-785630, Assam Agricultural University, Assam

Indonesia

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Reginald le Cerff, Soil Fertility Staff, Maros Research Institute for Food Crops, Maros

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Sutapradja Holil, researcher, Lembang Research Institute for Food Crops, Lembang-Bandung, West Java

Irfan, subject matter specialist, Agriculture Service Province, Bengkulu, Jln. Basuki Rahmat

Ishar Madi, Agronomy Staff, Sukarami Research Institute for Food Crops, Bandar Buat, P.O. Box, Padang

Dedi Priatna Saleh, Research Staff, Central Research Institute for Agriculture, Sukamandi, Subang, West Java

Dadang Sugriwa, subject matter specialist, Agricultural Service Office of Indramayu, Jl, R. Achmad, No. 1 Indramayu, West Java

Djendjen Zainuddin, subject matter specialist, Agricultural Service Office of Kuningan, Jalan Jendral Sudirman, 86 Kuningan, West Java

Malaysia

Ahmad Bin Haji Doon, assistant research officer, Stesen Penyelidikan Malaysian Agricultural Research and Development Institute, Bertam, Kepala Batas, Seberang Prai, West Malaysia

Muhamad Setefarzi B. Mohd. Noor, assistant research officer, Malaysian Agricultural Research and Development Institute, Besut, Trengganu, West Malaysia

Mohd. Nor Bin Sepit, assistant research officer, Malaysian Agricultural Research and Development Institute, Batu Berendam, Melaka, West Malaysia

Philippines

Ruben T. Baltonado, researcher, Betinan Research Station, San Miquel, Zamboanga del Sur

Samuel A. Guimmayen, science research assistant II, Cagayan Integrated Agricultural Development Project - Agricultural Pilot Center, Iguig, Cagayan

Juan D. Lasam, agricultural project coordinator II, Cagayan Integrated Agricultural Development Project- Agricultural Pilot Center, Iguig, Cagayan

Raul T. Repulda, senior soil technologist, Ministry of Agriculture, Region 8, Tacloban City

Abraham S. Suetos, soil technologist I, Cagayan Integrated Agricultural Development Project-Agricultural Pilot Center, Iguig, Cagayan

Sabas B. Tomas, science technician I, Cagayan Integrated Agricultural Development Project - Agricultural Pilot Center, Iguig, Cagayan

Sri Lanka

Senarath Nihal Jayawardena, experimental officer, Agricultural Research Station, Maha Illuppallama

Sinnadurai Rajakulendran, agricultural instructor, Regional Research Station, Angunukulapelassa

Marimuthu Selvarajah, agricultural instructor, Regional Research Station, Paranthan

Thailand

Vises Chanyanuwat, Agronomic Management Branch, Technical Division, Department of Agriculture, Bangkok 9

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Prasit Tunsrisawat, subject matter specialist, Department of Agricultural Extension, Bangkok

Kamolsak Kasevayuth, subject matter specialist, Department of Agricultural Extension, Bangkok

Preecha Tongprasirt, subject matter specialist, Department of Agricultural Extension, Bangkok

Prathan Potacharoen, subject matter specialist, Department of Agricultural Extension, Bangkok

Kruamas La-Iad-On, first grade economist (level 6), Office of Agricultural Economics, Bangkok

Wena Sucharitpanich, agronomist, Rice Division, Department of Agriculture, Bangkhen, Bangkok

INTEGRATED PEST MANAGEMENT COURSE
(1 September-16 December 1981)

Bangladesh

Md. Mostak Ahmed Chowdhury, scientific officer, Entomology Division, Bangladesh Rice Research Institute, Dacca

Md. Anwar Hossain, scientific officer, Plant Pathology Division, Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

U Myint Swe, deputy assistant general manager, Plant Protection, 459 Prome Road, Rangoon

India

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Indonesia

Catur Putra Budiman, Technical Staff, Directorate of Food Crop Protection, Jl. Ragunan Pasarminggu, Jakarta

Daryanto, chief, Planning and Evaluation Section, Directorate of Food Crops Protection, Jl. Ragunan, Pasarminggu, Jakarta

Oni Setiani Gunawan, researcher, Pathology Department, Lembang Research Institute of Food Crops, Lembang, West Java

Nusyirwan Hasan, researcher, Entomology Department, Sukarami Research Institute for Food Crops, P.O. Box 34, Pandang, West Sumatra

Sunoto, head, Laboratory of Pest Monitoring Agricultural Service, Jl. Pemuda 48, Pekalongan, Central Java

Ramli Rustam, Plant Protection Staff, Food Crop Agricultural Service, Padang, West Sumatra

Au. Wachyudin Sacadiria, Plant Protection Staff, Food Crop Agricultural Service, Majalengka, West Java

Malaysia

Yaakub Bin Kasin, entomologist, Malaysian Agricultural Research and Development Institute, Karang Selangor

Philippines

Manuel I. de Luna, senior plant entomologist, Bureau of Plant Industry, Rice Crop Protection Center, Maligaya, Muñoz, Nueva Ecija

Alfredo Palalimpa, plant entomologist II, Bureau of Plant Industry, Rice Crop Protection Center, Malaybalay, Bukidnon

Thailand

Sombat Chinawong, researcher, Weed Science Branch, Department of Agriculture, Bangkok 9

Sawang Kadkao, entomologist, Phan Rice Experiment Station, Phan, Chiangrai

Kasidis Phanomsawarn, head, Rice Pathology Section, Khon Kaen Experiment Station, Khon Kaen

Vanich Yaklai, entomologist, Rice Insect Pest Branch, Entomology and Zoology Division, Department of Agriculture, Bangkok

IRRIGATION WATER MANAGEMENT COURSE
(20 July-28 August 1981)

Bangladesh

Lukmanur Rahman Bhuiyan, scientific officer, Bangladesh Rice Research Institute, G.P.O. Box 911, Dacca

Sunil Ch. Dutta, assistant professor, Department of Irrigation and Water Management, Bangladesh Agri-Varsity, Mymensingh

Md. Abdus Sattar Mandal, assistant professor, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh

Md. Oabidur Rahman, executive engineer, Thakwyoan W. D. Division (East), Thakurgoar, Dinajpur

Md. Abdur Rashid, scientific officer (Irrigation), Bangladesh Rice Research Institute, Joydebpur, Dacca

Md. Abdul Basnet Sarker, superintendent engineer, G.K. Project, Kushtia

Rahman Md. Tutiar, executive engineer, G.K. Project, Kushtia

S. M. Nazim Uddin, scientific officer (Irrigation), Bangladesh Rice Research Institute, Joydebpur, Dacca

Burma

Daw Mi Mi Cho, junior research officer, Central Agricultural Farm, Mandalay

Daw Mya Thi, head, Department of Land Use and

Water Management, Central Agricultural Farm, Mandalay

Indonesia

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Sutadi Kasirun, chief, Division for Soil and Water Conservation and Plant Regulation, South Kedu Multipurpose Project, Jl. Hanoman 4, Gombong

Sudarmanto, deputy assistant (Operation and Maintenance), Jratunseluna River Basin Development Project, Semarang

Darsun Kartoredjo, head, Planning Division, Provincial Public Works, District of Irrigation, Surabaya, Bondowoso

Soma Ahmad S. Wityanara, research assistant (Water Management), Central Research Institute for Agriculture, Sukamandi

Kenya

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Malaysia

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Philippines

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Clarencio Escober, head, Institutional and Agricultural Development Division, National Irrigation Administration-Libmanan/Cabusao Integrated Agricultural Development Project

Rufino S. Garzon, instructor/researcher, College of Engineering, University of Southern Mindanao, Kabacan, North Cotabato

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Eleaser S. Villanueva, engineer B, National Irrigation Administration, District II, Talavera, Nueva Ecija

Sri Lanka

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Chelliah Thirunadarajah, agricultural officer, Soil Conservation Division, Royal Botanical Gardens, Peradeniya

Thailand

Somchai Ongprasert, research scientist, Multiple Cropping Project, Faculty of Agriculture, Chiang Mai University, Chiang Mai

Maitree Juangpanich, lecturer, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen

International activities

International research networks, cooperative country projects, collaborative research, training, and international meetings were the main thrust of IRRI international activities in 1981.

COOPERATION AND COLLABORATION

Bangladesh. Four IRRI staff members formed the core of the cooperative project with the Bangladesh Rice Research Institute (BRRI), which focused on training, research, and some capital improvements on laboratories and research stations. These four scientists work with a strong cadre of Bangladeshi scientists, both at BRRI headquarters and in substations located in various agroclimatic regions of Bangladesh, in varietal development for deepwater rice, cropping systems, soil fertility, irrigation water management, applied research trials, and farm mechanization. BRRI-developed technology contributed significantly toward rice self-sufficiency, which was nearly accomplished during the 1980-81 cropping season.

Burma. More crosses between promising lines were made (95 during the 1981 wet season alone) and these and earlier crosses were tested for yield, satisfactory resistance to or tolerance for diseases and insects, and grain quality. The screenings, conducted in various regions of the country, consisted of preliminary tests, national uniform tests, and tests in farmers' fields for dry- and wet-season entries, cold-tolerant varieties, and deepwater varieties.

Screenings were also conducted in nurseries of the International Rice Testing Program, namely, the Yield Nursery for Very Early Entries (IRYN-VE), the Rainfed Lowland Rice Nursery, and the International Upland Rice Observation Nursery.

In 1981 all the seven cropping systems sites in Burma were equipped with a basic set of research equipment and implements, and site personnel were instructed on their proper use and care. In addition 37 participants from the 7 sites took a 2-week training course in cropping systems research methodology.

The production and testing of IRRI-designed farm machines continued. Some 200 units of the manual transplanter TR-1 were manufactured. The prototype model of the newly designed IRRI reaper with winnower was tested in the field. More than 3,000 ha of rice land all over Burma were planted during the year with the IRRI-designed TR-1. Some 290 machines were used in the planting and over 500 persons were trained in the use of the TR-1. By the end of 1981, over 600 units of the TR-1 had been built under the sponsorship of the Small-Scale Mechanization Program of the Cooperative IRRI-Burma Project.

Egypt. The two scientists detailed to the collaborative project in Egypt have established good contacts and have begun developing programs in mechanization and applied research.

India. The exchange of scientists between IRRI and India was intensified in 1981. Some 30 IRRI scientists spent 154 man-days in India on discussions and consultations related to collaborative projects. More than twice this number of scientists from India attended meetings and conferences at IRRI or joined IRRI-organized monitoring tours. The number of IRTP nurseries in India increased to 261 in 59 sites.

Indonesia. Indonesia hosted and cosponsored with IRRI two important international workshops: the 11th meeting of the Cropping Systems Working Group for Southeast Asia in Bogor in May and the First International Tidal Swamp Workshop at Banjarmasin in late June. Excellent recommendations regarding the future directions of tidal swamp rice and rice-based cropping systems research resulted from these two meetings.

Indonesia harvested during the year a banner crop of rice estimated at 22 tons — some 2 tons above the estimated national consumption.

Through the leadership of the agricultural economist in IRRI's cooperative project with the Central Research Institute for Food Crops (CRIFC), data kept by the Indonesian Central Bureau of Statistics were analyzed and interpreted to find out how new varieties are diffused into the agricultural system. The result was a very important historical document that can be an excellent reference for plant breeders and agricultural planners in projecting future needs. It indicates that an Indonesian

farmer can readily adopt new improved varieties once he is convinced that benefits can be derived from their use. It also indicates the relative speed with which Indonesian researchers and extension staff, working together, can distribute stock seeds of promising new varieties.

Cropping systems progress in Indonesia has also been very significant in developing technology for rainfed and partially irrigated rice.

Pakistan. The crop production specialist assigned to Pakistan had earlier initiated applied research trials to evaluate new varieties and packages of rice production technology. Initial results from this effort were tested in pilot extension projects. The local manufacture of IRRI-designed or modified small-farm machinery was intensified under the support of the small-scale farm machinery industrial extension project.

Philippines. As in previous years, the Philippine program focused on the strengthening of links between research and technology transfer through agricultural extension. Philippine self-sufficiency in rice through its Masagana 99 program owes much of its success to the way the program was organized, its applied research and training program, and its carefully tested packages of practices for farm adoption.

Sri Lanka. The organized multidisciplinary research on varietal improvement and cropping systems was strengthened through the training of Sri Lankan scientists at IRRI.

Thailand. The five-man staff of the Thai-IRRI agricultural machinery program continued field tests on IRRI-designed farm machinery and modified the machines to adapt them to local field conditions. The staff also participated actively in farm machinery training courses organized by the FAO and the Thai Ministry of Agriculture. One such training course was held exclusively for employees of a bank that now functions as a dealer for manufacturers of IRRI-designed small-farm machinery. The bank transfers machines directly from manufacturers to holders of approved loans.

REGIONAL PROGRAMS

A liaison scientist stationed at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, and another at the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia, link IRRI with Africa and Latin America. These liaison scientists visit national rice programs within their respective regions to assist in the identification of problems limiting rice research. They assist IRRI in organizing and coordinating conferences such as the Fourth Conference on IRTP for Latin America, held at CIAT in August; and monitoring tours such as the observational tour of upland rice culture in Brazil in March, participated in by scientists from Bolivia, Brazil, Costa Rice, India, Korea, Mexico, and the United States.

INTERNATIONAL NETWORKS

The five international research networks coordinated by IRRI actively coordinated trials in many countries.

Network	Participating countries	Region	Sites or organizations	Cooperating scientists
International Rice Testing Program (IRTP)	75	Worldwide	200	500
Cropping Systems Network	9	Asia	22	178
International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)	18	Asia, Africa	50	45
AgroEconomic Research Network (IRAEN)	6	Asia	10	50
Agricultural Machinery Network	9	Asia, Latin America	12	20

Five hundred forty-three participants attended eight major IRRI-sponsored meetings at its headquarters and elsewhere.

Event	Date	Venue	Participants
Korea-IRRI planning meeting on collaborative research projects	24-27 February	IRRI	22
Exploratory workshop on the role of anthropologists and other social scientists in the development of improved rural technology	23-26 March	IRRI	36
International rice research conference	25 April-2 May	IRRI	139
Symposium on principles and methods of crop improvement for drought resistance with emphasis on rice	4-8 May	IRRI	75
Workshop on tidal swamp rice	22-25 June	Indonesia	100
Conference on weed control in rice	31 August-4 September	IRRI	74
Conference on the consequences of rice farm agricultural mechanization in Asia	14-18 September	IRRI	74
Tissue culture workshop	19-23 October	China	23
			543

Information resources, experimental farm, and service laboratories

LIBRARY AND DOCUMENTATION CENTER

Bibliographies. The 1980 Supplement to the *International Bibliography of Rice Research,* published in 1981, is the first computerized supplement jointly produced by the Library and the Statistics Department. It contains 4,714 references to scientific rice literature, most of which appeared in journals in 1980, classified according to subject matter. The supplement includes literature written in 24 languages and a list of 143 rice literature translations, mostly from Chinese to English. It has an author index and a keyword index.

Supplement 1979 to the *International Bibliography on Cropping Systems*, published in 1981, embraces worldwide published and unpublished technical reports produced in 1979. It deals with all aspects of cropping systems for food crops. 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 1981 supplement to *Theses and Dissertations on Rice Available in the Library of the International Rice Research Institute* lists 127 titles, bringing the overall collection of theses and dissertations to a total of 1,152.

All new bibliographies were sent to agricultural libraries and documentation centers of the rice-producing regions. Essentially, all citations included are available at IRRI.

References and circulation. The number of books and journals and other library materials borrowed within IRRI increased markedly during 1981. Requests for literature on Japanese genetics and breeding exceeded those for literature on all other aspects of rice culture. Requests for photocopies of papers on water management and irrigation also were received. Assistance in library organization and management and in the selection and acquisition of agricultural materials also was sought. Requests for short, specific-subject bibliographies increased notably. Most of such requests came from Bangladesh, India, Thailand, and Malaysia.

Library holdings. Additional 4,023 monographs (books, pamphlets, and reprints) increased the overall monographic collection to 59,385. A total of 143 serial titles were added through subscriptions, exchanges, and some donations. Maps, translations, and microfilms also were added.

Other library activities. To keep scientists informed of the latest publications on rice, tables of contents of newly received journals continued to be routed within IRRI and to the Bangladesh Rice Research Institute; the Central Research Institute for Food Crops, Indonesia; and the West African Rice Development Association, Liberia.

The Library continued to purchase books for IRRI research scholars and other training participants.

INFORMATION SERVICES DEPARTMENT

The Information Services Department (ISD) distributed about 45,000 copies of major publications during 1981: 82% to addresses in developing nations. About 18,000 publications were distributed free: 8,321 to developing nations and about 9,000 to highly developed nations.

Major publications. Major publications released in 1980 were:

- *Research highlights 1980*
- *Principles and practices of rice production*
- *Fundamentals of rice crop science*
- *Annual report for 1980*
- *A methodology for on-farm cropping systems research*
- *Manual for testing insecticides on rice*
- *International bibliography on cropping systems*

Serial publications. Four issues of the *IRRI Reporter* were published and distributed to about 14,000 rice workers. Six issues of the *International Rice Research Newsletter and Subject Index 1980* were published. Fifteen issues of the *IRRI Research Paper Series* were published:

No. 56 Rice grain properties and resistance to storage insects: a review

No. 57 Improvement of native rices through induced mutation

No. 58 Impact of a special high-yielding-rice program in Burma
No. 59 Energy requirements for alternative rice production systems in the tropics
No. 60 An illustrated description of a traditional deepwater rice variety of Bangladesh
No. 61 Reactions of differential varieties to the rice gall midge *Orseolia oryzae* in Asia. Report of an international collaborative research project
No. 62 A soil moisture-based yield model of wetland rainfed rice
No. 63 Evaluation of double-cropped rainfed wetland rice
No. 64 Trends and strategies for rice insect problems in tropical Asia
No. 65 Landforms in the rice-growing areas of the Cagayan River Basin
No. 66 Soil fertility, fertilizer management, tillage, and mulching effects on rainfed maize grown after rice
No. 67 High-temperature stress in rice
No. 68 Weed-fertilizer interactions in rice
No. 69 The *azolla-anabaena* complex and its use in rice culture
No. 70 An index to evaluate the effect of water shortage on the yield of wetland rice

Training. The ISD accepted an educator from the University of Agricultural Sciences, Bangalore, India, for degree training in agricultural education and development communication in 1981. An information specialist from Indonesia, on non-degree training in 1980, was accepted for degree training in development communication. A cartographer and an editor from the Bangladesh Rice Research Institute were accepted for short-term training on graphics and design and publications work.

Research and training support. The Rice Production Training and Research Department and the Information Services Department continued to develop a series of self-instructional slide-tape units on all aspects of rice production. Of 62 units planned, 10 were completed, bringing the number of units completed since 1978 to 52. Sale of these units to national rice improvement training programs continued. A series of modular instructional packages in cropping systems was started.

EXPERIMENTAL FARM

Development of the new wetland farm near the end of block 200 started after removal of the last batch of squatters. These wetland rice fields will have underground irrigation facilities. Conversion of all of block UK on the dryland farm to wetland fields was completed and it is now planted to its first crop.

The farm machinery section transferred to the new shed and is now the main repair shop for tractors and agricultural implements.

Problems with burnouts in deepwell electric pumps have been corrected with the installation of power monitors.

Thirteen trainees from Indonesia, Burma, Sri Lanka, Thailand, and Bangladesh attended a 3-week course in experiment-station operation and management.

A total of 172.19 ha was prepared and planted on the wetland farm; 97.18 ha on the dryland farm.

A total of 15.17 ha was planted, for seed multiplication, to 16 varieties and selections in the dry season, and to 10 varieties and selections in the wet. Varieties multiplied during the dry season were IR36, IR42, IR50, IR52, C-1074-2, C1059-3, C-1114-9, C-894-7, C-991-5, C1064-5, C1006-4, C-1121-4, C1252-9, C171-36, and BPI Ri-36. Multiplied during the wet season were IR29, IR43, IR44, IR45, IR46, IR50, IR52, IR9752-71-3-2, P33-C-19, and Suweon 290. Totals of 57.25 tons for seed and 13.45 tons for milling were produced.

Fertilizer consumption was 155.95 tons, valued at $32,751.28. Ammonium sulfate was most used, followed by urea, 14-14-14, solophos, and muriate of potash. Expenditure for insecticides and sticker totaled $81,684.83; for herbicides, $147,889.50. Contract labor cost $253,965.85, 25% more than in 1980, because of an hourly wage increase.

Installation and maintenance of rat fences continued. Sustained baiting with anticoagulants was maintained. Semipermanent rat stations were installed along creek and fence lines; coconut husks were used inside experimental plots. A total of 6.17 tons of rat bait were used; 38,667 rats were killed.

The 1981 farm income of $21,312 was derived from sales of rice for seed, rice for milling, milled rice, corn, sorghum, and rice bran.

ANALYTICAL SERVICE LABORATORIES

The Analytical Service Laboratory, the Radioisotope Laboratory, and the Mass Spectrometer Laboratory were combined into the Analytical Service Laboratories (ASL) 1 February 1981. ASL is administered by the Soil Chemistry Department.

Chemical Analysis Laboratory. In 1981, analysis reached a new high of 145,128 run on 62,167 soil, plant, and water samples, twice the rated capacity of the laboratory (72,000).

In March, the visiting consultant standardized operating conditions for the new Perkin Elmer Atomic Absorption Spectrophotometer Model 2380.

Mass Spectrometer Laboratory. The Mass Spectrometer Laboratory started ^{15}N analysis using a VG Micromass 622 Mass Spectrometer in May 1981 after a series of successful reproducibility check and linearity tests using labeled and unlabeled ammonium sulfate standards. Analyses run totaled 2,648, 1,699 from International Fertilizer Development Center research projects.

Radioisotope Laboratory. The Radioisotope Laboratory was transferred to a new building, which also houses the Mass Spectrometer Laboratory. The new laboratory was equipped with a high-vacuum preparation system and a new Liquid Scintillation Counter, Packard 460D. A plant growth chamber installed in the Phytotron building allows rice to be grown in $^{14}CO_2$ atmosphere under controlled temperature, humidity, and light intensity. The facilities are being used in studies on the decomposition of organic matter in tropical rice soils, in collaboration with the Institute of Soil Science, University of Hamburg, West Germany.

PESTICIDE RESIDUE LABORATORY

The Pesticide Residue Laboratory (PRL) handled two pesticide-related analysis projects in 1981 — simazine analyses of soil samples for the Agronomy Department herbicide persistence and migration study (Table 1) and analyses of monocrotophos, carbaryl, and lindane in rice leaf and grain samples in connection with an Entomology Department project on rice bug control.

Fully 40% of the work load resulted from requests for use of the PRL chromatographs for quantitative organic analyses. Aldononitrile acetate derivatives of rice grain cell wall sugars (305 analyses) were analyzed for the Chemistry Department. Samples of rice leaf and sheath extracts (42) were screened for volatiles for the ICIPE/Entomology insect resistance project; 24 samples were quantitatively analyzed for alditol acetate derivatives of sugars for the Soil Microbiology Department, and 32 samples were run for analysis of volatile-free fatty acids for the Soil Chemistry Department. One GC unit was lent to the Isotope Laboratory for analysis of ^{14}C-labelled volatile acids.

Table 1. Checklist of gas chromatographic analyses by the Pesticide Residue Laboratory. IRRI, 1981.

Constituent analyzed	Complete	GLC[a] injections only
Simazine	318	
Monocrotophos	118	
Carbaryl	104	
Lindane	100	
Others		403
Total	640	403

[a] Gas liquid chromatography.

A Packard Becker integrating gas chromatograph with NP detectors purchased this year has given PRL added capability for more efficient analyses.

PHYTOTRON

Thirty-seven research projects used the Phytotron in 1981. Eight were allocated space in glasshouse rooms for growing plants free from insects and diseases for seed production. The glasshouse room had the highest occupancy (96%); occupancy in other environment rooms ranged from 54% to 78%. All rooms and associated facilities were operated without any technical trouble but frequent power interruptions were still a problem.

All facilities received its regular maintenance check-up from 2 November to 6 December 1981. The heat exchanger of one of the chillers was damaged and replaced with a new one.

To ensure standard performance, controllers and recorders were calibrated and running tests were performed in all environment rooms.

Publications and seminars

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SEMINARS

The seminars held at IRRI during 1981 are grouped as Thursday seminars, Saturday seminars, and special seminars. The Saturday seminars report ongoing IRRI researches. Unless otherwise stated, the speakers were staff members.

Thursday seminars

Ifugao agriculture: an ethnographic and cartographic interpretation. Prof. Harold Conklin, anthropologist, Yale University, USA.

Studies on mineral nutrition and temperature stresses in rice. Dr. Zahurul Haque, postdoctoral fellow, Plant Physiology Department.

The IRRI international scientist. Dr. J. Ritchie Cowan.

Promise and problems in a fledging discipline. Mr. John P. Brien, visiting scientist, Information Services Department.

Agronomic constraints of corn production in farmers' fields in the Philippines. Dr. Antonio C. Mercado, Jr., assistant professor, University of the Philippines at Los Baños, College, Laguna, Philippines.

A strategy for international varietal testing and development in the 1980s. Dr. H. E. Kauffman.

International Federation of Agricultural Research System for Development (IFARD) and the Agricultural Research System. Dr. J. D. Drilon, Jr., director, Southeast Asian Regional Center for Graduate Study in Agriculture, College, Laguna, Philippines.

Reliability of rice crop estimates in the Philippines. Mr. Bruce M. Graham, visiting professor, Kansas State University, and senior statistician consultant to the Bureau of Agricultural Economics, Ministry of Agriculture, Philippines.

Roots? Social and economic aspects of the reclamation of acid sulfate soil areas. Dr. Robert Brinkman, visiting scientist, Soil Chemistry Department.

An ecological study of the Bondoc rice paddy system. Dr. Percy E. Sajise, dean, Institute of Human Ecology and Director, Program on Environmental Science and Management, University of the Philippines at Los Baños, College, Laguna, Philippines.

Radical rice research. Dr. R. W. Herdt.

Energy — a look at alternatives for agriculture. Dr. C. W. Bockhop.

The role of tissue culture in varietal imrovement. Dr. Ramon C. Barba, project leader, Tissue Culture and Plant Propagation Section, Institute of Plant Breeding; and Affiliate Faculty, Departments of Horticulture and Agronomy, University of the Philippines at Los Baños, College, Laguna, Philippines.

Role, methods, and findings of cropping systems economics research. Dr. E. C. Price.

Chinese crop germplasm: evolution, history, and conservation. Dr. T. T. Chang.

Phosphorus availability in soils subjected to cycles of waterlogging and drying. Dr. I. R. Willett, Division of Soils, Commonwealth Scientific and International Research Organization, Canberra, Australia.

The research program of the National Institutes of Biotechnology and Applied Microbiology (BIOTECH). Dr. William G. Padolina, associate professor and executive director, BIOTECH, University of the Philippines, College, Laguna, Philippines.

BPI development program on integrated pest control. Mr. Jesus P. Sumangil, chief, Crop Protection Division, Bureau of Plant Industry, Manila.

Role of IRRI's outreach staff in Eastern Indonesia. Dr. C. P. Mamaril.

Rice in coconut environment: an interim report from a coconut village in Laguna. Dr. R. Schmid, visiting scientist, Agricultural Economics Department, IRRI.

Weed-fertilizer interactions in rice. Dr. K. Moody.

Problems and properties of rainfed lowland rice in India, Dr. R. C. Chaudhary, postdoctoral fellow, Plant Breeding Department, IRRI.

So what about the other three? Dr. D. J. Greenland.

Nitrogen fixation by the legume-rhizobia association: grain and forest legumes. Dr. Irineo Manguiat, assistant professor, Department of Soils, University of the Philippines at Los Baños, College, Laguna, Philippines.

Rice handling off-farm: problems and aspirations in Southeast Asia. Dr. Dante de Padua, technical team leader, Postharvest, Southeast Asian Regional Center for Graduate Study in Agriculture, College, Laguna, Philippines.

Role of farmers in rice production technology generation in Japan. Dr. I. Watanabe.
Phosphate requirements of flooded rice soils. Dr. A. C. Roy.
Mobility in BPH population dynamics. Mr. T. John Perfect, visiting scientist, Entomology Department, IRRI.
Watershed management and erosion control: the Pantabangan case. Dr. Jose Galvez, acting project manager, National Irrigation Administration, Quezon City, Philippines.
Pairwise multiple comparison procedures — which one(s) to use? Dr. W. M. Walker, visiting scientist, Statistics Department, IRRI.
The rice plant as seen through the scanning electron microscope. Dr. Peter B. Kaufman, plant physiologist, Division of Biological Sciences, University of Michigan, USA.
Mass rearing lepidopteran insects for plant resistance programs. Dr. F. M. Davis, visiting scientist, Entomology Department, IRRI.
Pesticide regulation in the Philippines. Dr. F. F. Sanchez, director, National Crop Protection Center, University of the Philippines at Los Baños, College, Laguna, Philippines.
Extension of agricultural equipment for small rice farmers in the Philippines: initial plans, questions, and needs for collaboration. Dr. Robert Stickney, program co-leader, MAC-IRRI, Industrial Extension Program for Small Agricultural Equipment, College, Laguna, Philippines.
Rice postharvest technology in the Philippines. Dr. S. K. Tripathy, head, Agricultural Engineering Department, Indian Grain Storage Research Institute, Ministry of Agriculture and Irrigation, The Punjab, India.
Biological control of rice insects in China. Dr. D. W. Roberts, visiting scientist, Entomology Department, IRRI.
Farmer participant cropping systems research and development programs in Bangladesh. Dr. Z. Hoque.
God's greatest little bean — soybean. Dr. J. W. Pendleton.
Important factors in finding and using disease resistance. Dr. R. J. Williams, International Crops Research Institute for the Semi-Arid Tropics, India.
Decomposition of organic matter in flooded soils under tropical condition — a prologue. Dr. H. U. Neue, postdoctoral fellow, Soil Chemistry Department, IRRI.
A framework for analyzing rice policies in Southeast Asia. Dr. L. Gonzales.
Excess water and rice plant type improvement. Dr. D. HilleRisLambers.
Brown planthopper migration in the tropics. T. J. Perfect, visiting scientist.

Saturday seminars

Effect of water-extracted polysaccharides and lipids on cooked milled rice viscosity and consistency. Dr. B. O. Juliano.
The Solana cropping systems research program: agronomic adaptation. Mr. Hermenegildo Gines.
The first year at Solana: What have we learned? Dr. Richard A. Morris.
Protein requirements of young adult Filipinos consuming local diets. Dr. Carmen Ll. Intengan, Food and Nutrition Research Institute, Manila.
Effect of weeding intensity on weed community composition in rice and upland crops grown on a rainfed bunded toposequence. Dr. Dirk Drost, research fellow, Agronomy Department, IRRI, and Dr. K. Moody.
Flowering stage water stress using line source irrigation gradient. Mr. Rolando Cruz, Ms. O. S. Namuco, and Dr. J. C. O'Toole.
Effect of rice straw and neem cake on nitrogen fixation and nitrification in flooded soil. Mr. T. Aziz, research fellow, Soil Microbiology Department, IRRI.
Response of Azolla species to different temperatures. Ms. Nilda Berja.
Nitrogen balance studies of flooded rice soils. Ms. Teresita Santiago.
The spider fauna of Philippine dryland and wetland rice agroecosystems. Mr. Alberto Barrion.
Control of the corn borer through intercropping. Mr. Volkmar Hasse, research fellow, Entomology Department, IRRI.
Biological control of planthoppers and leafhoppers. Dr. T. H. Chua, postdoctoral fellow, Entomology Department, IRRI.
Microbial control of rice insect pests. Ms. R. M. Aguda, Dr. V. A. Dyck, Mr. A. C. Dulay, Mr. F. V. Palis, Dr. D. W. Roberts, and Dr. R. S. Soper, Entomology Department.
Monitoring adult densities of rice stem borers and leaffolders with sex pheromone and light traps for improved pest control. Mr. G. S. Arida, Dr. V. A. Dyck, and Dr. P. S. Beevor, Entomology Department.

Decomposing the impact of mechanization on production and employment. Ms. Yolanda Tan, research scholar, Agricultural Engineering Department, IRRI.

Analyzing production effects of mechanization using decomposition techniques. Ms. Yolanda Tan, research scholar, Agricultural Engineering Department, IRRI.

Contract tractor operations. Ms. Celerina Maranan.

Factors affecting tiller production and yield performance of deepwater rice under different water conditions. Mr. T. Kupkanchanakul, research fellow, Plant Physiology Department, IRRI.

Soil moisture desorption studies with respect to different methods of land preparation, soil profile textures, and landscape in a toposequence under rice-based cropping systems. Dr. J. Prabhakara, postdoctoral fellow, Cropping Systems Department, IRRI.

Physiological mechanism of rice tolerance for iron toxicity, Dr. M. Yamanouchi, postdoctoral fellow, Plant Physiology Department, IRRI.

Effect of host nutrition on rice diseases. Dr. J. P. Jones, visiting scientist, Plant Pathology Department, IRRI.

Assessment of *Pseudogonatopus flavisfemus* E & H (Dryinidae) as a biocontrol agent of the brown planthopper, Dr. T. H. Chua, postdoctoral fellow, Entomology Department, IRRI; Ms. N. B. Peña, Mr. F. V. Palis, and Dr. V. A. Dyck.

Detailed plant-soil water relationship studies on upland crops after rainfed wetland rice. Mr. V. A. Loon, research associate, Multiple Cropping Department, IRRI.

Breeding for adverse soil tolerance in rice. Dr. I. Gunawardena, senior research fellow, Plant Breeding Department, IRRI.

Testing, evaluation, and modification of the IRRI manual rice transplanter in Bangladesh. Mr. Md. Abdul Baqui, research scholar, Agricultural Engineering Department, IRRI.

Genetics of resistance to whitebacked planthopper in rice. Mr. Jose Hernandez, research scholar, Plant Breeding Department, IRRI.

Heterosis in rice. Mr. R. Aquino.

Constraints to increasing productivity of rainfed rice in Bicol, Philippines. Mr. A. Mandac.

Yield trends in IRRI's N-fertilizer response experiments. Ms. E. Labadan.

Consequences of technological changes in rice production in Central Luzon, Philippines. Ms. V. Cordova.

Constraints to rainfed rice production in Bicol, Philippines. Mr. A. Mandac.

Benefit-cost analysis of different types of irrigation systems in Central Luzon. Ms. P. Moya.

Returns to irrigation investment in Central Luzon, Philippines. Ms. P. F. Moya, Dr. R. W. Herdt, and Dr. S. I. Bhuiyan.

Design parameters affecting water distribution to farms in a diversion irrigation system. Dr. S. I. Bhuiyan, Mr. D. F. Tabbal, Mr. G. E. Dozina, Mr. R. A. Bautista, project director, On-Farm Facilities Studies-National Irrigation Administration (OFFS-NIA), Mr. F. F. Cortez, agricultural engineer and team leader at CamRis, and Ms. R. C. Celester, sociologist, OFFS-NIA.

The implementation of the tail-first water allocation method in a communal irrigation system. Ms. G. Soltes, Mr. H. M. Gutierrez, and Dr. A. C. Early.

Prediction of seepage and percolation loss of water in a wetland rice irrigation system. Dr. B. Sahni, postdoctoral fellow, Irrigation and Water Management Department, IRRI.

Drought response of rice at different nitrogen levels using a line-source sprinkler system. Mr. E. Aragon.

Response of dryland rices to seeding dates and applied nitrogen levels. Mr. J. A. Malabuyoc.

Tillage and soil moisture effects on growth of rainfed sorghum and mungbeans planted after wetland rice. Dr. S. S. Hundal, postdoctoral fellow, Agronomy Department, IRRI.

Breeding crop plants to tolerate soil stresses. Dr. F. N. Ponnamperuma.

Methods of improving rice production on acid sulfate soils. Ms. J. L. Solivas.

Seedborne pathogens of rice and their control. Mr. S. D. Merca.

Screening for disease resistance. Mr. F. L. Nuque.

Rice bacterial stripe: a seedborne disease. Ms. M. R. Baraoidan.

Soil-landform relationship study in a rice production area of the Cagayan River Basin. Dr. R. Bruce, senior postdoctoral fellow, Multiple Cropping Department, IRRI.

Korea-IRRI collaborative project on cold tolerance. Mr. R. Visperas.

Use of calcium peroxide for direct seeding of wetland rice. Mr. F. Parao.

Special seminar
Field and laboratory problems associated with surveying potential acid sulfate soils. Dr. J. A. Varley.

Finances

The Institute received $20,634,733.83 during 1981.

The United States Agency for International Development (USAID) gave $6,541,730.75 — $4,275,000 for core operations, $49,141.23 for expanding, strengthening, and further institutionalizing the National Applied Research and Extension Program for Transplanted Rice; and $265,455.98 for industrial extension of small-scale agricultural equipment developed at IRRI.

USAID also released $1,952,133.54 for continuing contracts:

- $753,977.80 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.
- $200,575.68 for a contract between the Arab Republic of Egypt and the Regents of the University of California and IRRI for a technical assistance relationship to aid in increasing production and improving the quality of rice in Egypt through the development and adoption of improved agricultural practices and rice varieties.
- $488,203.31 for supporting a 3.5-year project for accelerated development and use of improved rice technology in Indonesia.
- $116,788.09 for collaborative rice research in Pakistan.
- $230,733.66 for a project on the consequences of mechanization on small farms.
- $70,805 for applied research and training in water management.
- $91,050 to support establishing of a Nutritional Evaluation Laboratory as a regional center for research on the nutritional value of high-protein cereals and legumes and weaning foods for children.

The Japanese Government gave $3,150,000 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 $1,251,500 for the core program.

The Canadian International Development Agency gave $1,181,040 for core operations, $207,900 for cooperation between the Bangladesh Rice Research Institute and IRRI, and $310,842.67 for cooperative research on rice, rice-based cropping systems, and development of machines for small-scale farming by the Government of Burma and IRRI.

The International Development Research Centre (IDRC), Canada, gave $398,195.50 — $314,403 as part of a 3-year grant for cropping systems outreach in South and Southeast Asia and $83,792.50 as part of a 4-year grant to support a multiple cropping research project at the Bangladesh Rice Research Institute.

The European Economic Community gave $651,598 for water management, scholarships for candidates from developing countries, and partial support of the GEU program.

The Australian Government gave $864,885.21 — $637,759 for core operations, including travel of Australian scientists, and $227,126.21 for expansion of technical assistance and collaborative relationships with the Bangladesh Rice Research Institute.

The Federal Republic of Germany gave $584,090 for core operations and $3,883.77 for support of a visiting scientist in soil microbiology.

The International Development Association gave $480,000 for core operations and capital expenditures.

The United Nations Development Programme released $1,088,757 — $1,053,375 for international rice testing and improvement and $35,382 toward a meeting of the Nitrogen Fixation Advisory Committee and a seminar on rice policy.

The International Fund for Agricultural Development gave $1,700,000 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 $201,068 to IRRI for development of research facilities at the Sukamandi Branch of the Central Research Institute for Agriculture and for scientific and technical assistance to

rice research at Sukamandi.

The Government of Denmark gave $144,115.89 for the core program.

The Government of the Philippines gave $250,000 for the core program.

The Government of Sweden gave $215,897.94 for the core program.

The Swiss Federal Council, represented by the Swiss Development Corporation, gave $30,000 for an exploratory workshop on the role of anthropologists and other social scientists in interdisciplinary teams for food production research, and $9,000 to support a rural migration project.

The Ford Foundation gave $477,960 — $200,000 for core operations and capital expenditures, and $277,960 in support of rice research and development in Thailand ($18,960), Bangladesh ($100,000), India ($134,000), and the Philippines ($25,000).

The Rockefeller Foundation gave $175,000 — $150,000 for core operations and capital needs and $25,000 for a workshop on the role of anthropologists and other social scientists in interdisciplinary teams for food production research.

The Government of Mexico gave $100,000 for core operations.

The Government of New Zealand gave $21,400 for the core program.

The Government of Belgium gave $31,010.15 for a joint project of IRRI and the Rijksuniversiteit Gent to conduct collaborative research on the control of bacterial blight on rice in developing countries by use of low-cost bactericidal or bacteriostatic compounds.

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 1981, $40,272.89 was released.

Since February 1978, a contract between IRRI and the International Fertilizer Development Center (IFDC) has supported a joint project on the fate and efficiency of nitrogen fertilizers in wetland rice. In 1981, $42,122.24 was reimbursed.

Other donors were:

- Philippine Council for Agriculture and Resources Research, cooperative applied research on rainfed rice $45,728.63
- National Food and Agriculture Council, training government extension technicians 38,467.75

International Board for Plant Genetic Resources:

Field collection of indigenous rice germplasm in South and Southeast Asia $37,442.94

Third meeting of the IBPGR/IRRI Rice Advisory Committee in India 18,000.00

- 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
- American Cyanamid Overseas Corporation, weed control and insect control 5,000.00
- UN University, research on protein requirements of young Filipino adults 12,764.50

Office of Rural Development, Korea, seed multiplication program and cooperative research program 87,410.00

- Hoechst, AG, research work at IRRI 5,750.00
- Minister for Development Cooperation, The Hague, project on reclamation of acid sulfate soils 16,400.00
- SKW Trosberg Aktiengesellschaft, soil fertility research 2,000.00

Staff changes

January

Dr. Howard H. Hagerman of the Lyman Briggs College, Michigan State University, joined the Rice Production Training and Research Department as visiting communications specialist.

Dr. Robert Schmid, professor of the University of Zurich, joined the Agricultural Economics Department as visiting associate agricultural economist.

Dr. Gerald E. Wilde, associate professor, Kansas State University, joined the Entomology Department as a visiting entomologist.

Dr. Cezar P. Mamaril, formerly with IRRI's joint program with the Central Research Institute for Agriculture in South Sulawesi, joined the headquarters staff as agronomist.

Dr. Osamu Horino of the Tropical Agricultural Research Center, Ministry of Agriculture, Forestry, and Fisheries, Japan, joined the Plant Pathology Department as visiting scientist.

Dr. J. P. G. Webster of Wye College completed a 6-month assignment as visiting agricultural economist, Agricultural Engineering Department.

February

Dr. James A. Litsinger, entomologist, began a 1-year sabbatical leave at the University of Hawaii.

Mr. John Brien of the University of Sydney completed a 3-month assignment as visiting scientist, Information Services Department.

Dr. C. Lorenzo Pope of Rice Researchers, Inc., California, joined the Plant Breeding Department as a short-term visiting scientist.

Mr. Vernon E. Ross rejoined the IRRI staff as rice production specialist with the cooperative project in Egypt.

March

Mr. Jack Barton Duff, IRRI associate agricultural economist, began a 1-year sabbatical leave at the University of California-Davis.

Dr. C. Lorenzo Pope of Rice Researchers, Inc., California, completed a short-term assignment as visiting scientist, Plant Breeding Department.

Dr. Jacques L. Auclair of the University of Montreal completed a 7-month assignment as visiting entomologist, Entomology Department.

Dr. H. David Catling rejoined IRRI in the Cooperative Project with the Rice Division, Ministry of Agriculture and Cooperatives in Thailand, as entomologist.

April

Mr. John Lingard of the University of Newcastle Upon Tyne joined the Agricultural Engineering Department as visiting agricultural economist.

Dr. Makoto Ariyoshi of the Agricultural Machinery Institute of Japan joined the Agricultural Engineering Department as agricultural engineer.

Dr. Walter L. Griffeth, formerly with the IRRI-Sri Lanka project, joined the Rice Production Training and Research Department as visiting crop production specialist.

Dr. Chon Suh Park of the Office of Rural Development, Korea, completed a 2-year assignment as a visiting scientist with the Agronomy Department.

Dr. Gun Sik Chung of the Office of Rural Development, Korea, joined the Plant Breeding Department as visiting scientist.

Prof. Dr. J. C. G. Ottow of the University of Hohenheim completed a 9-month assignment as visiting soil scientist, Soil Microbiology Department.

*Dr. Francisco Javier Zapata joined IRRI as associate plant physiologist, Plant Physiology Department.

May

Dr. Donald W. Puckridge of the University of Adelaide joined the IRRI staff in Thailand as agronomist.

Dr. Nyle C. Brady, resigned as director general to join the United States Agency for International Development as senior assistant administrator, Bureau of Science and Technology.

Dr. J. Pat Crill, resigned as plant pathologist and head, Plant Pathology Department.

Mr. Glenn Peterson, resigned as agricultural engineer with the BRRI-IRRI Collaborative Program.

June

Dr. Pierre A. Roger of The Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) began a 1-year assignment as visiting scientist with the Soil Microbiology Department.

Dr. Clarence J. Miller joined the IRRI staff in Bang-

ladesh as agricultural economist in the BRRI/IRRI Collaborative Program.

Dr. Robert E. Stickney, formerly of USAID, Peru, joined IRRI as agricultural engineer, Agricultural Engineering Department.

Dr. John C. O'Toole, agronomist, began a 1-year sabbatical leave at the University of California, Davis.

Dr. Virgilio R. Carangal, agronomist, completed a 1-year sabbatical leave at the North Carolina State University.

Dr. Grace E. Goodell of Harvard University completed a 3.5-year assignment as visiting scientist, Agricultural Economics Department.

Dr. Foster B. Cady joined the International Rice Testing Program Department as visiting scientist.

July

Dr. Billy Cochran of Louisiana State University began a 1-year assignment as visiting agricultural engineer, Agricultural Engineering Department.

Dr. Derk HilleRisLambers, plant breeder, IRRI cooperative projects with the Ministry of Agriculture and Cooperatives in Thailand, began a 1-year assignment as visiting scientist, Plant Breeding Department.

Dr. Robert Schmid of the University of Zurich completed a 6-month assignment as visiting associate agricultural economist, Agricultural Economics Department.

Dr. Edwin C. Price, agricultural economist, began a 1-year sabbatical leave at Yale University.

Dr. Tom W. Mew, plant pathologist, began a 1-year sabbatical leave at the North Carolina State University.

Ms. Debrah Jefferson of the University of Missouri completed a 1-year assignment as visiting associate editor, Information Services Department.

Dr. Phillip E. Church of USAID/Bangladesh began a 1-year assignment as visiting associate agricultural economist, Agricultural Economics Department.

Dr. Osamu Mochida rejoined IRRI as entomologist, Entomology Department.

Dr. Richard A. Morris, agronomist, began a 1-year sabbatical leave at the IBM de Mexico.

Dr. John P. Jones of the University of Florida completed a 1-year assignment as visiting scientist, Plant Pathology Department.

Dr. Foster Cady completed his assignment as visiting scientist, the International Rice Testing Program Department.

Dr. LaRue Pollard of the Iowa State University began a 1-year assignment as visiting science editor, Information Services Department.

Dr. Leo Dale Haws completed a 1-year sabbatical leave at the Texas A&M University.

Dr. Igmidio T. Corpuz of the University of the Philippines at Los Baños joined The Cooperative CRIFC-IRRI Program in Maros, South Sulawesi, Indonesia, as agronomist.

Dr. Reeshon Feuer, crop production specialist, retired from the Institute.

August

Dr. Kwanchai A. Gomez, statistician began a 1-year sabbatical leave at the Food Research Institute, Stanford University.

Dr. William M. Walker of the University of Illinois at Urbana-Champaign began a 1-year assignment as visiting scientist, Statistics Department.

Dr. Danny R. Minnick of the University of Florida began a 6-month assignment as visiting entomologist, Entomology Department.

Mr. Orlando G. Santos, associate farm superintendent, began a 1-year sabbatical leave at Bowling Green State University.

Dr. Benito S. Vergara, plant physiologist, began a 1-year sabbatical leave at the University of California, Davis.

Ms. Lina M. Vergara, librarian, began a 1-year sabbatical leave at the University of California, Davis.

Dr. Frank M. Davis of USDA, completed a 6-month assignment as visiting entomologist, Entomology Department.

September

Dr. Robert Brinkman of the Agricultural University of Wageningen completed a 2-year assignment as visiting soil scientist, Soil Chemistry Department.

October

Dr. Richard H. Bernsten, resigned as associate agricultural economist, Cooperative CRIFC-IRRI Program in Indonesia.

November

Dr. Jeff Simpson, Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, began a short-term assignment as visiting scientist, Soil Chemistry Department.

December

Dr. William M. Walker, University of Illinois at Urbana-Champaign, left after completing a 4-month of assignment as visiting scientist, Statistics Department.

Dr. Danny R. Minnick of the University of Florida left after completing a 5-month assignment as a visiting entomologist, Entomology Department.

Dr. Harold E. Kauffman, resigned as plant pathologist to accept the position of Director, International Soybean Program, College of Agriculture, University of Illinois at Urbana-Champaign.

Dr. Gerald E. Wilde of Kansas State University completed a 1-year assignment as visiting entomologist, Entomology Department.

Dr. Alva A. App of Boyce Thompson Institute for Plant Research, Inc. completed a 2-year assignment with the Soil Microbiology Department as visiting scientist.

Mr. John Lingard of the University of Newcastle Upon Tyne completed a 9-month assignment as visiting agricultural economist, Agricultural Engineering Department.

Dr. Robert E. Huke of Dartmouth College began a short-term assignment as a visiting scientist, Agricultural Economics Department.

Crop weather

Total 1981 rainfall was 1,786 mm — 517 mm less than that for 1980. The period from January to the first week of May was extremely dry. Also, May had lower-than-normal rainfall, while rainfall in June and July was much higher than normal. A long dry period was recorded from 8 August to 13 September. The second half of September, October, and November had more rain than normal. Rainfall was recorded on 200 days. The heaviest 24-hour rainfall, 103 mm, occurred on 25 September.

Maximum temperature was highest in April (36.2° C) and lowest in January (28.7° C). Minimum temperature was highest in May (23.9° C) and lowest in January (20.6° C).

Relative humidity was always above 95% at night and lowest around noon. It gradually dropped from about 65% in January to about 45% in March-April, leading to a vapor pressure deficit of 32 mbar, then rose to about 65% (or 16 mbar vapor pressure deficit) in June-September and to 75% (or 11 mbar vapor pressure deficit) in October-November.

Total radiation was highest in April (640 cal/cm^2 per day) and lowest in November (325 cal/cm^2 per day). Wind speed was reasonably constant throughout the year with velocities higher than 2 m/second during the dry season and lower than 2 m/second during the wet.

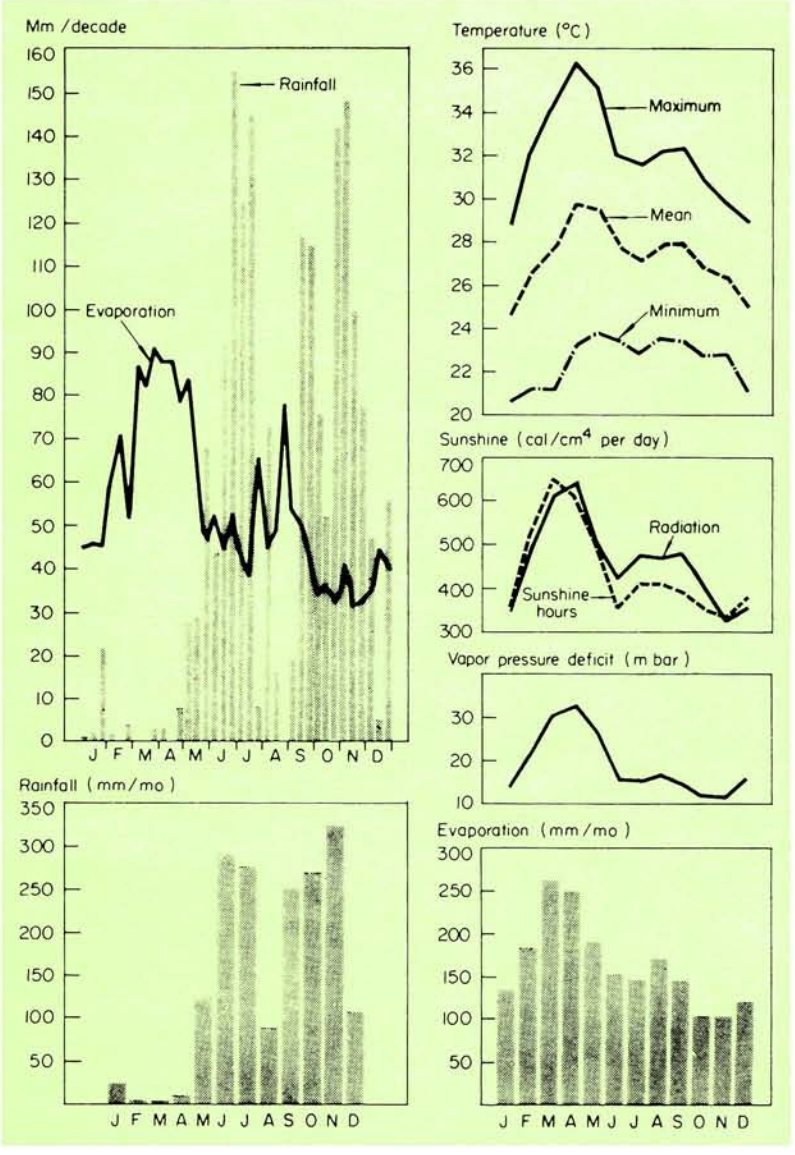
Evaporation rates rapidly increased from January (136 mm/month) to March (261 mm/month) and gradually dropped to about 150 mm/month from June to September. They were lowest (103 mm/month) in October-November.

Twenty-three tropical disturbances crossed the Philippines. Eight affected the weather at IRRI: tropical storm Daling, 28 June-2 July; tropical storm Elang, 3-5 July; typhoon Rubing, 15-21 September; tropical depression Saling, 24-26 September; tropical storm Unsing, 12-14 October; typhoon Yeyeng, 16-21 November; typhoon Anding, 21-27 November; and typhoon Dinang, 23-28 December.

Table 1 gives a monthly summary of major weather parameters in 1981; Figure 1 illustrates weather highlights.

Table 1. Monthly weather data at the IRRI upland farm, Los Baños (14°10'N, 121°15'E), Laguna, Philippines, 1981.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	25	6	3	11	125	292	278	90	251	270	327	108
Max temp (°C)	28.7	32.1	34.5	36.2	35.1	32.0	31.6	32.2	32.3	30.8	29.8	29.0
Min temp (°C)	20.6	21.2	21.2	23.3	23.9	23.5	22.9	23.6	23.5	22.8	22.9	21.2
Min relative humidity (%)	66	56	45	46	53	67	67	65	67	74	73	67
Max vapor pressure deficit (mbar)	13	21	30	32	27	16	15	17	16	11	11	13
Bright sunshine (h)	4.0	7.5	10.0	9.3	7.0	4.1	5.2	5.2	4.8	4.0	3.7	4.6
Total radiation (cal/cm^2 per day)	342	483	609	640	507	422	476	470	477	400	325	351
Wind speed (m/s)	2.2	2.0	2.3	1.6	1.1	1.9	1.6	2.3	1.6	1.2	2.0	2.1
Wind direction	NNE	NNW	NNE	NNE	NNE	SSE	SSE	SSE	NNE	NNW	NNW	NNW
Evaporation (mm)	136	184	261	248	190	151	147	171	144	103	104	121



1. Highlights of the 1981 weather at IRRI upland farm, Los Baños, Laguna, Philippines.

- RESEARCH HIGHLIGHTS
- GENETIC EVALUATION & UTILIZATION (GEU) PROGRAM
- CONTROL & MANAGEMENT OF RICE PESTS
- IRRIGATION WATER MANAGEMENT
- SOIL & CROP MANAGEMENT
- CLIMATIC ENVIRONMENT & RICE
- CONSTRAINTS ON RICE YIELDS
- CONSEQUENCES OF NEW RICE TECHNOLOGY
- CROPPING SYSTEMS PROGRAM
- MACHINERY DEVELOPMENT & TESTING