ADOPTION, SPREAD, AND PRODUCTION IMPACT OF MODERN RICE VARIETIES IN ASIA

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FOREWORD

Modern rice varieties (MVs) were introduced in tropical Asia in 1965 with the widespread testing of Taichung Native 1 and release of IR8. China had earlier developed fertilizer-responsive semidwarf varieties using a gene for dwarfing that later went into the parentage of IR8 and other semidwarf varieties. By 1980 nearly 40% of the rice area in South and Southeast Asia was planted to MVs and new hybrid rices were being grown in China. Despite their rapid spread, many questions are still asked about the spread of MVs and the technology associated with them. Where are MVs grown? What farmers grow them? What contribution have they made to production? This publication brings together the information that is available to answer these questions.

The first section documents the development and introduction of MVs in major South and Southeast Asian rice growing countries. The second section describes the methodology used to estimate the contribution of improved varieties to the increases in production that have occurred since 1965. It is estimated that by the early 1980s MVs contributed about $4.5 billion annually to the value of rice produced in Asia. In the third section of the monograph, the authors review many earlier studies that describe the MV adoption pattern and associated factors. Special attention is given to the question of farm size and adoption.

It is hoped that this compilation will answer many of the questions that are raised about MVs. IRRI recognizes that technological innovations alone cannot solve the pressing problems of development in the Third World, but at the same time we believe that new technology is one of the necessary components for a solution. We are proud to be partners with Asia's many national rice research and extension program that have made possible the development and spread of modem rice varieties.

The monograph was edited by Edwin A. Tout, assisted by Gloria S. Argosino.

M. S. Swaminathan
Director General

CONTENTS

The development and spread of modern rice varieties (MVs) have contributed substantially to increased rice production achieved by Asian countries since 1965. Rice production in Bangladesh, Indonesia, South Korea, Pakistan, Thailand, and the Philippines increased more than 3% annually between 1972 and 1979. Rice productlon in Burma, India, and China increased only slightly more slowly. Modern rices were introduced in most countries in the mid-1960s. By 1980 about 40% of the rice area in South and Southeast Asia was planted to them.

Fifteen years after MV introduction, many questions are still asked about the technology embodied in them. How fast and far have MVs spread? Under what condition are they grown? Are they continuing to spread? Have only big farmers adopted them? Are they grown only on irrigated land?

This paper examines evidence that helps answer these questions. The first part of the paper provides data on MV adoption in 11 market-directed developing Asian countries. We then estimate the contributions of new varieties to production, and review studies that seek to discover what factors are associated with the adoption of MVs and complementary inputs.

THE SPREAD OF MODERN RICE VARIETIES

During the 1970s Dalrymple (1978) collected and published data describing the worldwide spread of high bidding varieties (HYV) of rice and wheat, but his data stop at 1977. We have followed Dalrymple’s example by obtaining MV adoption information from national sources responsible for data collection and, where those do not exist, from informed individuals in each country.

Data are referenced in the text and the notes to the tables. Some data are official; in other cases, national governments have made unofficial estimates that can be obtained by knowledgeable individuals. Sometimes only informal, unofficial estimates are available. In nearly every case, Dalrymple's data to about 1977 have been used.

Definitions

There is disagreement about what constitutes a MV. HYV is often used, but we are reluctant to use it because new varieties may not be high yielding unless a high level of inputs is used. We prefer to use MV. Many MVs derive from IR8, a cross between Peta, an *indica* rice developed in Indonesia, and Dee-geo-woo-gen, a short *indica* rice said to have originated in Fukien (Dalrymple 1978) or Taiwan, China (IRRI 1966). A similar variety, TN1 was also released in the early 1960s by rice breeders in Taiwan, China. These were initially called HYVs because of their dramatic yield capabilities. Development of intermediate-height, fertilizer-responsive varieties and recognition that other inputs are also needed for high yields showed the need for a different name.

Many new rices are semidwarf, fertilizer-responsive and photoperiod-insensitive, but varietal characteristics are continually changed to meet new needs. Early IRRI varieties such as IR8 and IR20 were semidwarf, but varieties with intermediate height have also been developed. IR5, an early variety, was also intermediate. One of the plant breeders' original objectives was to develop fertilizer-responsive photoperiod-insensitive rices. More recent objectives include breeding photoperiod-sensitive fertilizer-responsive rices, and improved varieties that yield higher at low fertilizer levels.

Different national statistical services use their own definitions of HYV or improved rices. In Sri Lanka, the “H” series of rices were developed by the Department of Agriculture and released during the late 1950s, well before the semidwarf, photoperiod-insensitive varieties. They are called HYVs in Sri Lanka. Malaysia has released similar improved varieties that are also called HYVs. MV is used in this paper to include these and all other semidwarf and intermediate-stature, fertilizer-responsive, mainly photoperiod-insensitive rice varieties developed since 1960, regardless of the term used by individual nations.

Breakthroughs

Three distinct technological innovations can be identified in the varieties developed at IRRI since 1965. The first, typified by IR8, is the capacity to effectively utilize high rates of fertilizer and grow during any season of the year regardless of day length. These characteristics conferred the potential for high yields and wide adaptability throughout Asia. IR8 spread rapidly after release and was still grown by many farmers in Pakistan, Bangladesh, and other areas in 1980.

High fertilizer rates used with IR8 encourage lush growth and create an ideal ecology for pests. After IR8 and TN1 were grown for several years in many parts of Asia, insects and diseases began to cause heavy damage, especially during the monsoon. The second innovation, first incorporated in IR20 (about 6 years after IR8) and now in all newer varieties, is the genetic capacity to resist certain insects and diseases.

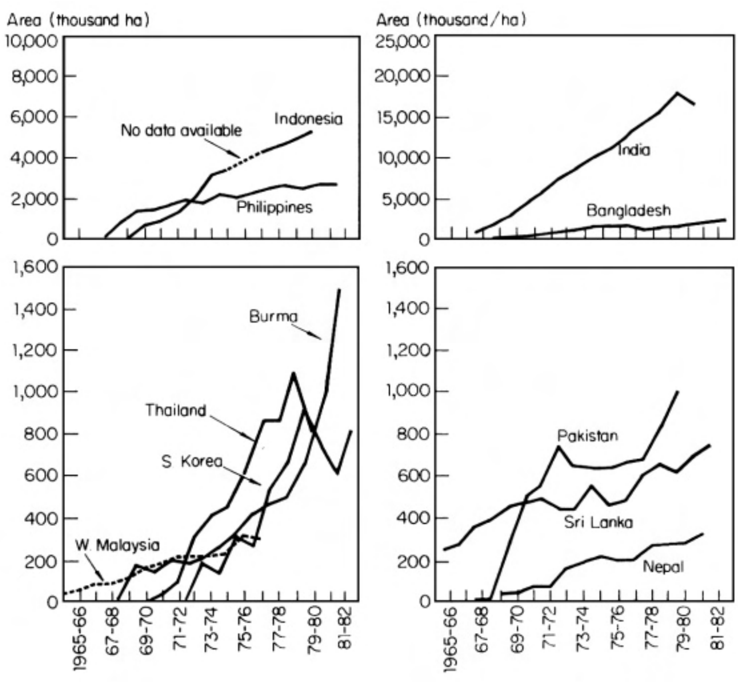
The third innovation was the development of a rice plant with a substantially shorter growth duration than traditional rices or the first MVs. Most traditional indicas are photoperiod sensitive so they flower in October and November and are harvested a month later, regardless of when they are planted. Usually farmers (especially in rainfed areas) plant with the early rains in June or July, so a 180-day growth period was not unusual. IR8 had a fixed 150-day maturity. The first really short-duration tropical rice, IR36, matures in 110 days. This means that it uses less water, is exposed to field hazards for less time, and, perhaps most important of all, can be planted and harvested early enough to allow farmers to plant and harvest another crop during the same monsoon season.

Rice researchers are working to make a fourth breakthrough: to develop a drought-tolerant rice; or perhaps the next innovation will be a variety that tolerates occasional high-salt conditons when sea water intrudes on coastal rice fields. Still other efforts are under way to develop varieties that will yield better where standing water depth regularly exceeds 30 cm and semidwarf rices have little or no advantage over tall rices.

Each technological innovation has broadened the appeal of MVs to farmers, and innovations still on the horizon seek to develop rices for areas where current varieties are unsuited. The record shows, however, that even with current characteristics. MVs have spread to large areas in many nations (Fig. 1), although the introduction process and the rate of spread differ between countries.

DEVELOPMENT AND INTRODUCTION OF MVS

Prior to the development and spread of tropical MVs, China and Japan had bred improved varieties from their indigenous rices (IRRI/CAAS 1980, Hayami 1975, Dalrymple 1978). China, in fact, was breeding improved varieties prior to the 1949 liberation (Kuo 1972). Rice hybridization began in 1926 and the first semidwarf variety (Guang-chang-ai) was developed in 1959 (Shen 1980). Semidwarf varieties spread rapidly in China in the 1960s. In Japan, selections by innovative veteran farmers (rono) after the Meiji Restoration (1868) and later efforts of the Japanese Ministry of Agriculture through its research experiment stations resulted in improved varieties from both pureline and crossbred (Norin) selections.



1. Area of rice planted to modern varieties, 1964-65 to 1981-82.

Although Japan and China made some of the early breakthroughs, we do not include in the tables data on MVs in those countries. No attempt was made to obtain a time series on MVs in China because aggregate data for China are difficult to obtain. Most observers agree that nearly all rice land in China was planted to MVs by 1980. In fact, by the late 1970s China had introduced hybrid rice and was growing it on over 6 million ha. Other Asian countries are just beginning to develop hybrid rice. No data are shown for Japan because it went through rapid changes in varietal types earlier in the 20th century (Hayami 1975).

The historical development and spread of MVs in Japan and its East Asian colonies were attributed to several factors by Hayami (1971):

1. the development of local MVs or adaptation of indigenous strains prompted by political and economic circumstances.
2. the presence of well-developed irrigation facilities and the support of government research experiment stations and farmer innovations that made the rapid spread of the MVs viable, and
3. good sources of chemical fertilizer that facilitated the spread of MVs (Manchuria and North Korea were fertilizer sources for Japan).

In South and Southeast Asia, these preconditions did not exist before World War II. The genetic capacity of the then available indica rices limited yields to about 3 t/ ha, regardless of fertilizer, irrigation, and cultural care (Herdt and Mellor 1964). Theestablishment of IRRI in 1960 and the start of its hybridiration program in 1962 catalyzed rice breeding efforts for the tropics (IRRI 1966).

IR8 resulted from tests of promising rice lines on experimental farms in India, Pakistan, Thailand, Malaysia. and the Philippines between 1962 and 1966 (IRRI 1967). IRRI grew 74 t of IR8 seed in 1966 and distributed it to over 60 locations worldwide. including the Philippines and many other Asian countries. MVs spread rapidly in some countries and gradually in others. It took 40 years, from 1880 to 1920, for 50% of Japa's rice area to be planted to the first MVs. It took 16 years, from 1920 to 1936, for the first MVs to be adopted on 50% of Taiwan's rice area, and it took only 5 years for 50% of Philippine ricelands to be covered with IRRI MVs (Kikuchi and Hayami 1978). Several countries still plant less than 50% of land to MVs.

As varieties modeled on IR8 were developed by national plant breeding programs, the proportion of rice area in MVs increased — from 1% in 1966 to 10% in 1969. Table I shows MV adoption from 1966. By 1979, they were planted on 40%, of the rice area in the 11 countries for which detailed data are given in this paper. Recognizing that China, Japan, and the United States, which grow semidwarf varieties almost exclusively, contain 25% of the world's rice area, it is fair to say that 50% of the world's total rice area was planted to modern rices in 1980. A background on rice production systems and MV introduction in each of the 11 countries follows.

Bangladesh

Rice is grown during three distinct seasons in Bangladesh. Aus rice is planted in March-May and harvested in August-September. It may be immediately followed by a second shortduration rice crop, called transplanted aman, or boro (winter) rice may be planted in December-January and harvested in March-April. Broadcast

Table 1. Rice area and rice area planted with MV in the 11 countries described in Figure 1.

Year	Rice area (thousand ha)	MV rice area (thousand ha)	% of area in MVs	World rice area (thousand ha)
1964–65	71,090	0	0	125,091
1965–66	70,527	42	0	123,751
1966–67	71,677	1,033	1.4	125,212
1967–68	72,293	2,648	3.7	126,934
1968–69	74.072	5,006	6.8	128,247
1969–70	75,860	7,563	10.0	131,599
1970–71	75,552	9,459	12.5	131,097
1971–72	75,556	12,386	16.4	132,011
1972–73	74,220	14,738	19.9	131,464
1973–74	78,148	18,799	24.1	135,770
1974–75	78,186	20,230	25.9	137,824
1975–76	80,876	23,083	28.5	142,677
1976–77	79,637	25,123	31.5	141,506
1977–78	81,686	28,023	34.3	143,661
1978–79	83,283[a]	31,695[a]	38.1	144,947
1979–80	81,904[a]	32,482[a]	39.7	143,066
1980–81	83,337[a]	32,945[a]	39.5	144,479

[a]Data for some countries are incomplete. This figure assumes total and MV area equal those from the last year for which estimates are available.

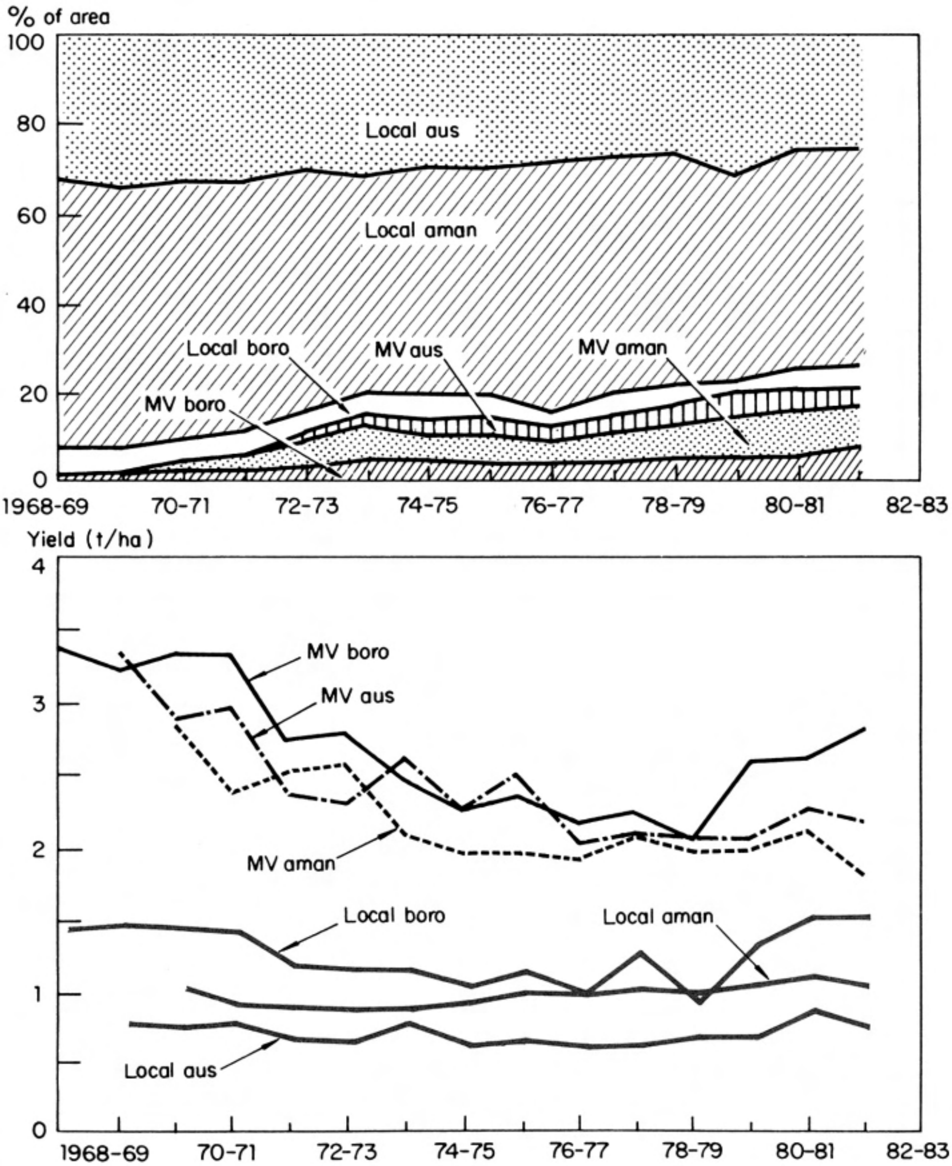
aman is also planted during early rains in March-May. It is a photoperiod-sensitive, long-duration crop generally planted where the water depth exceeds 1 m and is harvested when the water recedes in November-December. Some farmers may plant boro rice in low areas of receding water, but it usually is planted where there is pump irrigation.

In Bangladesh, MVs were experimentally introduced at the Bangladesh Academy for Rural Development in 1965 (Muqtada 1975). Since 1966, IR8 has been grown during boro in some areas where irrigation is available (Rochin 1973). In 1970, 1,800 t of IR20 was imported from IRRI (Chand1er 1973) and introduced in aman through the Accelerated Rice Production Program (ARPP) in selected areas (Rochin 1973).

Local and MV area and production data for rice grown in each season are published by the Bangladesh Government (Bangladesh Bureau of Statistics, various years). Although the reliability of the early MV data in Bangladesh has been questioned, improved data are now available (Pray 1980). They are recorded in Appendix Tables 1 and 2 and in Figure 2. MVs have been adopted in only a small area in Bangladesh.

Adoption varies by season. MVs were planted on more than 60% of the boro rice area in 1979-80 but on less than 15% of the aus and aman area. Boro MV area has increased each year except in 1966-67. However, the 15% level was reached in aus and aman in 1973-74, there was a sharp reduction in MV aman area through 1977-78, and then, MV area returned to the 15% level.

Bangladesh is a challenging environment for new variety development. It has the largest proportion of area with deepwater (> 1 m) and intermediate deepwater (30-100 cm) rices (Huke 1982) where present MVs are not suited. It also has a large shallow rainfed rice area for which present varieties are also not well suited. The



2. Percent of rice area and yields of milled rice in Bangladesh by season and variety groups, 1967-68 to 1981-82.

stagnation in MV adoption since 1975 shows it is unlikely that the currently available varieties will spread significantly beyond their present area. The challenge of developing intermediate and deepwater rices is great. However, as illustrated by the situation in Burma, present MVs can grow in shallow rainfed areas, and Bangladesh can move in that direction if there is the political will to do so.

Burma

During the 1960s Burma had few links with institutions and organizations outside the country. Rice prices were kept low as a deliberate political policy and Burma's rice sector stagnated. MV seeds were introduced, however, and by 1968-69. MVs were grown on about 3.5% of the rice area (Table 2). When government policy changed in 1972 Burma became open to direct interactions with international organizations. Seed exchanges and Burmese participation in international rice research meetings increased. Imported MVs and locally developed varieties spread gradually.

Data on varieties grown are published in some detail by the Burmese Ministry of Planning and Finance. In the 1976-77 report, area and production of three "high yield variety" rices were given and a fourth category of "other high yield" varieties was listed. The varieties were Yagyaw-1 (IR8). Yagyaw-2 (IR5), C4-63 (developed by the University of the Philippines at Los Baños. and Ngwetoe (a locally developed MV). In the 1981-82 report, Shwe War Htun and Manawhari were also listed. Manawhari was called (in parentheses) Ma Shu Yi, and sometimes referred to as the Malaysian variety, Mahsuri (Win et al 1981). These six are the most important MVs. Table 2 lists them as MVs and other rices as "improved varieties" (IVs). Support for these classifications is provided by yield differences between modern and improved varieties. Appendix 3 shows that from 1975 to 1980 MV yields averaged 2.7 t/ha, IV yields averaged 2.1 t/ha, and other rice yields averaged 1.6 t/ha.

Using the narrow definition of MV, data show that adoption began in 1967-68, reached 4% by 1972-73, took until 1978-79 to exceed 10%, then jumped to 19% by 1979-80 and to 29% by 1980-81. Using the broader definition, nearly 8% of the area

Table 2. The spread of modern and improved rices in Burma (Dalrymple 1978; Burma, Ministry of Planning and Finance).

Year	Rice area (thousand ha)					
	MVs [a]	Improve% varieties [b]	Other varieties	Total rice	% MVs	% modern and improved
1964-65	0	n.a.			0	0
1965-66	0	n.a.	4,848	4,848	0	0
1966-67	0	n.a.	4,513	4,513	0	0
1967-68	3.4	n.a.	4,703	4,706	0	0
1968-69	166.9	n.a.	4,597	4,764	3.5	3.5
1969-70	143.0	n.a.	4,811	4,954	2.8	2.8
1970-71	190.9	190.2	4,594	4,975	3.8	7.7
1971-72	185.1	216.4	4,577	4,978	3.7	8.2
1972-73	199.2	280.3	4,383	4,862	4.1	9.9
1973-74	245.6	319.1	4,525	5,089	4.8	11.1
1974-75	327.7	396.6	4,480	5,177	6.2	13.4
1975-76	407.3	487.7	4,309	5,204	7.8	17.2
1976-77	449.9	410.3	4,218	5,078	8.9	16.9
1977-78	495.8	511.1	4,129	5,136	9.6	19.6
1978-79	650.6	885.9	3,708	5,244	12.4	29.3
1979-80	948.4	777.4	3,300	5,026	18.9	34.3
1980-81	1,501.8	909.1	2,706	5,117	29.3	47.1

[a] Yagyaw 1, Yagyaw 2, C463, Ngwetoe, Shwe War Htun, and Manawhari. [b] All other high yielding varieties.

was planted to new varieties in 1970-71, but the spread was slow until 1978-79 when the area in new varieties increased by 50% in 1 year.

Rapid adoption after 1977-78 is surely due to the *Special High Yield Variety Paddy Program* launched in Burma that year. By 1979-80 new variety and technology adoption, including seed, fertilizer, planting, spraying, weeding, and other cultural practices was estimated to have reached over 1.3 million ha (Win et al 1981). Although Burmese officials and other observers credit the high yield program with the large gains, data in Appendix Table 3 show that all yields must have increased substantially in 1980-81 to produce the 11.9 million tons reported lor the year.

Burma had only about 850,000 ha of irrigated rice area in 1980. By, 1977, combined MV and IV area exceeded 1 million ha, and by 1979, MVs alone were planted on nearly 1 million ha, indicating that new varieties had expanded to nonirrigated areas under the encouragement of government programs. Yield data suggest that the expansion was accomplished without yield deterioration, but several additional years of data will be needed before high yields obtained in 1980-81 can be evaluated.

India

In India, MVs were introduced through long established programs to increase agricultural production. Early attempts to increase Indian rice productivity were made at Indian agricultura1 experiment stations. In the 1950s, the International Hybridization Scheme was set up by the International Rice Commission at the Cuttack Rice Research Institute to cross japonica varieties with indica varietics (Bhati 1976).

Agricultural policy to increase Indian rice production used several approaches to transfer technology to farmers. As early as 1960-61, improved practices, including better seeds and fertilizer were encouraged by the Intensive Agricultural District Program (IADP), which served 7 districts and had Ford Foundation financing (Rajagopalan and Singh 1971). It was moderately successful and in 1964-65 expanded to become Intensive Agricultural Area Program (IAAP), which served 115 districts and several crops (Kalirajan 1979).

In 1965-66, India imported 1 t of TN1 from IRRI for testing (Barker and Mangahas 1970). The High-Yielding Varieties Program (HYVP) was initiated during the 1966-67 kharif in well irrigated areas with minimal environmental hazards (Mandal and Ghosh 1976). Locally, improved varieties were first introduced, and credit was extended to help purchase fertilizers and pesticides (Muranjan 1968). IR8 was introduced in 1967 (IRRI I967a), and other IR varieties were distributed to farmers through the HYVP, usually with little field testing (Mukherjee and Lockwood 1971). In succceding years, MVs were recommended mostly for rabi because of insect and disease problems and inadequate irrigation control during kharif.

MV adoption increased steadily in India (Table 3). MVs were planted on 44% of the rice area in 1978, and although MV area diminished in 1979—attributed to a 1.5 million ha decline in total rice area—percentage of MVs did not decline. MV adoption has varied substantially across India. In Jammu, Kashmir, Punjab, Tamil Nadu, Andhra Pradesh, Kerala, and Maharashtra more than 60% of the area was

Table 3. Spread of MVs and their comparative yields with other rices. India, 1966-78 (India Directorate of Economics and Statistics 1978).

Year	Area (thousand ha)		% area in MVs	Comparative yield[a] (t/ha)		National average yields
	MVs	All rice		MVs	Others	
1966-67	888	35,598	2.4			1.3
1967-68	1,785	36,437	7.8			1.6
1968-69	2,681	36,966	7.2	3.1	1.6	1.6
1969-70	4,253	37,680	11.2	2.8	1.6	1.6
1970-71	5,454	37,592	14.5	3.1	1.6	1.7
1971-72	7,199	37,758	19.0	3.2	1.4	1.7
1972-73	8,107	36,688	22.0	3.0	1.2	1.6
1973-74	9,718	38,285	25.3	3.0	1.3	1.7
1974-75	10,780	37,888	28.4	1.7	1.0	1.6
1975-76	12,742	39,475	32.2	2.8	1.4	1.9
1976-77	13,731	38,511	35.6	2.5	1.2	1.6
1977-78	15,316	40,283	38.5	2.5	1.4	2.0
1978-79	17,619	40,482	43.5			2.0

[a] Area, production, and yield data are recorded separately for HYVs and other rices for some states each year. Thus the MV yield data do not include all rice grown in the country. The rice area included in the data ranges from 17 to 25 million ha over time. See Appendix Tables 4 and 5.

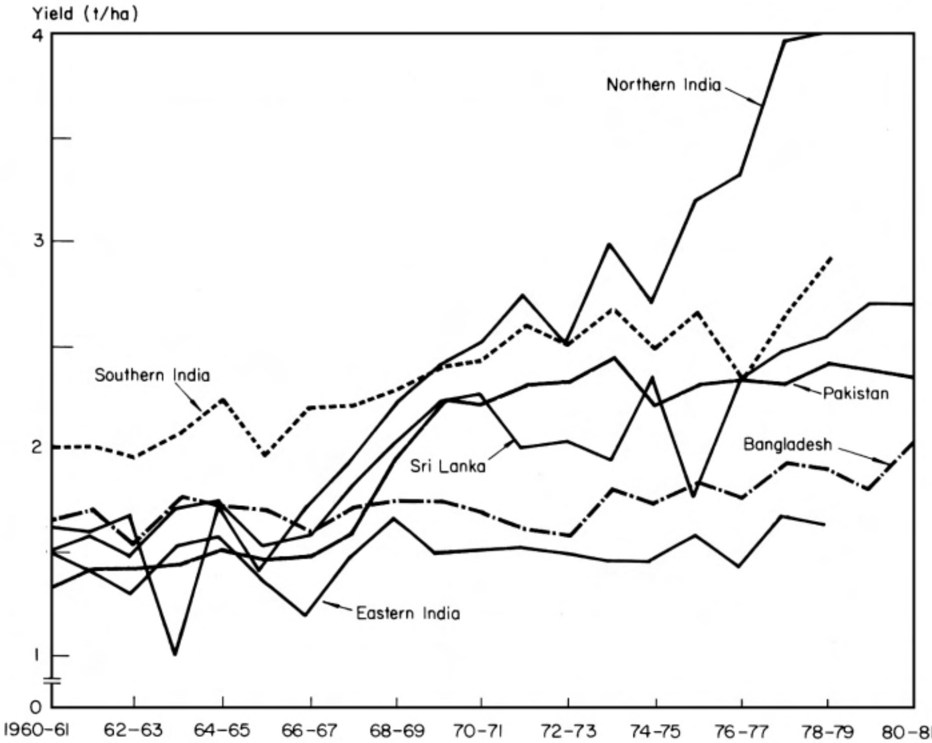
planted to MVs in 1978; Assam and Bihar had less than 30%. Other states had intermediate adoption rates (Appendix Table 4). Differences in adoption are reflected in yield differences across the states. Rice yields show a sharp steady rise in northern states Jammu, Kashmir, Punjab, and Haryana (Appendix Table 5, Fig. 3). In southern states Tamil Nadu, Karnataka, Andhra Pradesh, and Kerala yields have risen, but not as sharply as in the north. In eastern India yields have changed little, perhaps because Eastern India, like Bangladesh. requires better varieties to achieve increased rice production.

Indonesia

MVs were introduced for experimentation in East Java in 1965. It was only during the 1968 dry season, however, that there was large-scale adoption. New varieties were disseminated through the Indonesian rice intensification production program called *Bimas Baru,* and later the *Bimas Gotong Royong.* The first IRRI MVs were planted at the Central Research Institute of Food Crops (CRIFC). then the Central Research Institute of Agriculture (CRIA or LPPP, its Indonesian acronym).

IRRI and CRIFC cooperated to screen several IRRI lines in Indonesia in 1966. Two short, stiff-strawed cultivars, PB5 (IR5) and PB8 (IR8), were released in 1967. Two additional varieties from the Philippines, C4-63 and PB20, were released in 1969 and 1970. By 1971, Pelita I-1 and Pelita I-2, two varieties developed by Indonesian plant breeders, were released (Bernsten et al 1982). By 1971-72 these varieties had spread to about 16% of Indonesia's rice area (Table 4).

The combined use of new varieties, high fertilizer rates, and intensive cropping encouraged the emergence of the brown planthopper (BPH), a damaging rice pest found in many tropical countries. China, and Japan. BPH occurred in large numbers in 1972 and 1973 in Java. All rices grown in Java prior to 1975 were susceptible to this pest, so new genetic sources of resistance were introduced to limit



3. Rice yield trends in 3 regions of India, Bangladesh, Pakistan, and Sri Lanka, 1960-61 to 1980-81.

farmers' yield loss. PB26, grown on 300,000 ha in the 1975-76 wet season, was the first insect-resistant variety introduced (Appendix Table 6). However, soon after it was released scientists discovered a new BPH biotype (biotype 2) that attacked rices that were not damaged by the original BPH (biotype 1). A new variety, PB36 (IR36), that is resistant to biotype 2 was introduced in 1977, and continued to maintain its resistance through 1982. In 1983, however, a new BPH biotype emerged in Sumatra, and Indonesia requested IRRI to provide biotype 3 resistant variety IR56.

New varieties and the Bimas program have steadily increased area of MVs grown in Indonesia. By 1980, they covered nearly 60% of Indonesia's total rice area. PB36 was the most widely grown variety. Its dominance has caused substantial scientific and public concern based on experiences with BPH. Considerable scientific effort is being made to diversify the genetic background of the next generation of resistant rices so there will be a resistant variety available when a new RPH biotype evolves.

The Republic of Korea

Early in the 20th century, rices selected by Korean farmers began to be replaced by varieties introduced from Japan. Domestic rice breeding efforts started in Korea in 1919, and the first improved domestic variety was released in 1940, by which time Japanese varieties were grown on about 85% of Korea's rice area (Kim 1978). By the

Table 4. The spread of MVs in Indonesia (Bernsten et al 1982, Dalrymple 1978).

Year	Area in rice (thousand ha)					% of all rice area in MVs[a]
	MVs			Other varieties	All rice	
	Non-resistant	Resistant to BPH 1 biotype	Resistant to BPH 1, 2 biotypes			
1964-65	0	0	0	6,980	6,980	0
1965-66	0	0	0	7,328	7,328	0
1966-67	0	0	0	7,691	7,691	0
1967-68	0	0	0	7,516	7,516	
1968-69	198.0	0	0	7,823	8,021	2.5
1969-70	831.0	0	0	7,183	8,014	10.4
1970-71	902.6	0	0	7,232	8,135	11.1
1971-72	1,322.9	0	0	7,001	8,324	15.9
1972-73	1,913.8	0	0	5,984	7,898	24.2
1973-74	3,134.5	0	0	5,269	8,404	37.3
1974-75	3,387.4	0	0	5,150	8,537	39.7
1975-78	n.a.	n.a.	0	n.a.	8,489	n.a.
1976-77	2,456.3	1,579.0	13.8	4,320	8,369	48.4
1977-78	1,704.1	1,848.4	901.0	3,907	8,360	53.3
1978-79	1,518.2	1,109.6	2,354.2	3,947	8,929	55.8
1979-80	881.5	525.8	3,958.9	3,484	8,850	60.6
1980-81	570.3	n.a.	4,845.4	3,604	9,020	60.0

[a]Data on all rice from Bureau Pusat Statistik; area in other varieties was derived by subtraction.

late 1960s improved Korean varieties were widely grown. Despite national yields that were significantly higher than in South and Southeast Asia, Korea had a rice production deficit and was anxious to increase output.

Soon after IR8 was released, scientists in Korea became interested in crossing indica IR rices with japonica rices grown in Korea to obtain new sources of blast resistance and higher yield potential. By 1968, they had stabilized several lines and identified some with 30% higher yields than the leading domestic varieties. That same year, IRRI and Korea's Office of Rural Development (ORD) signed a formal cooperative agreement. By 1972, the first variety to emerge from this process, Tongil, was released (Kim 1978). It was "very resistant to rice blast. However, because it was developed from indica rice it was susceptible to damage from low temperature" (Shin 1981). Tongil was followed by other varieties developed using the same process of crossing indica and japonica rices. Through the late 1970s and early 1980s IRRI and ORD maintained close cooperation, with seeds of promising new Korean varieties and lines being multiplied at IRRI during the winter months when rice cannot be grown in Korea.

The ORD pursued a vigorous program to spread the new varieties. The number of extension workers was increased and they were given special training on cultivation practices for the new rices. Detailed classification of rice fields by temperature, soil, irrigation facilities, and other locational factors was made to ensure that recommendations were suited to local growing conditions (Shin 1981).

The impact of these efforts is reflected in the pace of adoption (Table 5). After 2 years the new varieties were being grown on 16% of the area; after 6 years they covered 44% and after 8 years, 76%. However, in 1978 MV yield dropped 12%

Table 5. Area and production of rice by variety types, Republic of Korea, 1965-80 (personal communication with Moo Nam Chung and Dong Wan Shin, Korean Office of Rural Development).

Year	Area (thousand ha)				Production[a] (thousand t)			
	Japonica	Indica/ japonica	Upland rice	All rice	Japonica	Indica/ japonica	Upland rice	All-rice
1965	1,198.9	–	29.2	1,228.1	4,811.6	–	51.1	4,862.7
1966	1,199.4	–	32.0	1,231.4	5,375.7	–	67.7	5,443.4
1967	1,204.3	–	31.0	1,235.3	4,960.9	–	43.4	5,004.3
1968	1,127.0	–	23.9	1,150.9	4,397.2	–	40.8	4,438.0
1969	1,198.1	–	21.5	1,219.6	5,634.9	–	46.3	5,681.2
1970	1,183.5	–	19.8	1,203.3	5,426.1	–	45.1	5,471.2
1971	1,175.5	2.5	12.5	1,190.5	5,507.5	13.8	31.0	5,552.3
1972	991.9	185.9	13.3	1,191.1	4,466.3	996.8	33.0	5,496.1
1973	1,048.5	121.2	12.0	1,181.7	5,009.4	809.6	30.4	5,849.4
1974	882.1	306.9	15.4	1,204.4	4,117.1	2,016.2	38.7	6,172.0
1975	924.0	274.1	19.9	1,218.0	4,510.6	1,916.2	58.0	6,484.8
1976	663.0	533.2	18.7	1,214.9	3,647.4	3,546.6	49.1	7,243.0
1977	548.2	660.1	21.7	1,230.0	3,218.3	5,066.8	56.1	8,341.2
1978	290.1	929.0	10.7	1,229.8	1,753.9	6,272.7	25.0	8,051.6
1979	479.9	744.3	9.1	1,233.3	2,912.8	4,789.7	26.5	7,729.0
1980	615.7	604.2	13.2	1,233.1	2,495.4	2,406.8	28.8	4,931.0
1981	891.0	821.3	11.6	1,223.9	5,051.4	2,062.3	35.0	7,148.7
1982	789.6	386.4	12.1	1,188.1	4,541.8	2,731.1	35.0	7,307.9

[a] Brown rice.

nationally, because blast pathogen races capable of damaging the varieties evolved. Area in MVs declined in 1979 and 1980 and MV yields dropped even lower because of cold weather and blast. These problems caused Korean national rice production to drop from 8 million t in 1978 to 5 million t in 1980. However, production recovered to 7.3 t in 1982 as varieties with different resistance sources were planted and weather conditions improved.

Malaysia

The Japanese introduced three photoperiod insensitive (short duration), varieties from Taiwan in 1942. Malaysia joined the FAO International Hybridization Scheme in 1950 and thus had access to varieties developed at Cuttack, India. In 1965, Malaysian scientists released Mahsuri, an intermediate height, moderately long-duration variety that resulted from the FAO program. Mahsuri has become popular in Malaysia and several other countries. It is adapted to water up to 60 cm deep and has a grain type many farmers prefer for personal consumption. Malaysian scientists also tested imported IR rices. IR8 was released as Ria in 1966 and a sister line of IR5 was released as Bahagia, an officially recommended variety which was fairly resistant to blast, in 1968 (Bhatti 1976).

Seed from the research experiment station was distributed to the State Agricultural Department, to chosen farmers (who received the seeds free), or to leading farmers (who bought and distributed the seeds to other farmers) (Bhati 1975). In the states of Kedah and Perlis, the MUDA irrigation scheme introduced the MVs to farmers. Each farmer was given 1 free gantang (2.25 kg) of seed for multiplication (Palmer 1976). Fertilizer was supplied by the cooperative at a 20% discount price and information regarding the technology was disseminated via the media, mobile

Table 6. The spread of MVs in West Malaysia (Dalrymple 1978, J. R. Cowan, pers. comm., Palacpac 19821).

Year	Area in new varieties (thousand ha)				% of area		
	Semi-dwarf [a]	Inter-mediate [b]	Total MVs	All rice (thousand ha)	Semi-dwarf	Inter-mediate	All new varieties
1964-65	n.a.	n.a.	42.3	566			7.5
1965-66	n.a.	n.a.	62.7	553			11.3
1967-68	n.a.	n.a.	90.7	542			16.7
1968-69	33.8	62.3	96.1	633	5.3	9.8	15.2
1969-70	78.4	54.0	132.4	685	11.4	7.9	19.3
1970-71	105.8	58.8	164.6	697	15.2	8.4	23.6
1971-72	112.9	84.5	197.4	705	16.0	12.0	28.0
1972-73	99.7	112.5	212.2	730	13.7	15.4	29.1
1973-74	119.6	97.4	217.0	751	15.9	13.0	28.9
1974-75	96.2	117.0	213.2	740	13.0	15.8	28.8
1974-76	113.6	108.7	222.3	750	15.1	14.5	29.6
1976-77	156.9	160.9	317.8	733	21.4	22.0	43.4
1977-78	134.1	182.0	316.1	723	18.5	25.2	43.7

[a]Ria, Bahagia, Sri Malaysia I, Sri Malaysia II, Jaya, Pulut, Malaysia I. [b]Malinja, Mahsuri.

units, and Farmers' Associations.

Recent data on MV spread in Malaysia have been impossible to obtain. MVs are included in three groupings — released, not released, and other varieties. Data that are available indicate 40-50% of Malaysia's rice area was planted to MV in 1977. More intermediate than semidwarf types were planted (Table 6).

Nepal

Rice is grown in the terai and hill areas of Nepal, but MV seem to have spread most widely in the terai, which produces much of the marketed surplus that has traditionally been exported to India. Farmers in the hills prefer to produce local varieties for personal consumption.

MVs were first planted on a signficant area in Nepal in 1968-69. but did not extend to more than 10% of the area until 1972-73 and continue to increase slowly (Table 7). By 1980 it was estimated that MVs may have covered 30% of Nepal's rice area, but the rate of increase was still slow. Nepal has one of the lowest levels of fertilizer availability among the countries considered. Few farmers except those in the Kathmandu valley have access to fertilizer so the value of the modern varieties is limited.

Pakistan

Rice is an export commodity for Pakistan. Prior to the independence of Bangladesh, much of the rice exported from Pakistan went to the "eastern wing." Since the early 1970s much of Pakistan's exported rice has gone to the Middle East, a market that is willing to pay premium prices for high grade, traditional, scented basmati rices. On the other hand, IR8 gives good yields in Pakistan's irrigated, high-sunlight environment. These factors seem to have influenced the rate and level of MV adoption in Pakistan.

Table 7. Estimated area and estimated percentage of area planted to MVs in Nepal, Pakistan, and Thailand, 1965-79 (Palacpac 1982; Dalrymple 1978; Nepal Department of Food and Marketing Services; Pakistan Ministry of Food, Agriculture, and Cooperatives; and Thai Extension Service).

Year	Nepal		Pakistan		Thailand	
	MV area (thousand ha)	% area in MVs	MV area (thousand ha)	% area in MVs	MV area (thousand ha)	% area in MVs
1965-66	0	0	0	0	0	0
1966-67	0	0	0.1	0	0	0
1967-68	0	0	4.0	0.3	0	0
1968–69	42.5	3.7	308.0	19.8	0	0
1969-70	40.8	4.2	501.4	30.9	3.0	0
1970-71	67.8	5.7	550.4	36.6	30.0	0.4
1971-72	81.6	6.3	728.5	50.0	100.0	1.4
1972-73	177.3	16.1	647.1	43.7	300.0	4.1
1973-74	205.1	16.7	636.1	42.0	400.0	5.0
1974-75	222.6	18.0	630.9	39.3	450.0	5.5
1975-76	21 6.4	17.2	665.3	38.9	600.0	7.1
1976-77	220.3	17.5	677.9	38.8	960.0	11.3
1977-78	290.5	23.0	852.0	44.9	960.0	11.2
1978-79	31 2.6	24.7	1,015.0	50.1	1,100.0	11.8
1979-80	314.9	25.1			800.0	8.5
1980-81	325.6	25.5				

The MVs were adopted rather rapidly after they were introduced into Pakistan in 1968. By 1971-72, they were planted on nearly 50% of the national area. Subsequently, however, acreage slipped to about 43% in 1976-77 but recovered to 50% in 1978-79. At this level, Pakistan seems to be meeting its export market for basmati rices and producing an adequate level of coarse MVs for domestic consumption. The Punjab produces most of the basmati, and most MVs (81%) are grown in Sind (personal communication with Tyler Biggs, Ford Foundation, Pakistan, 22 January, 1980).

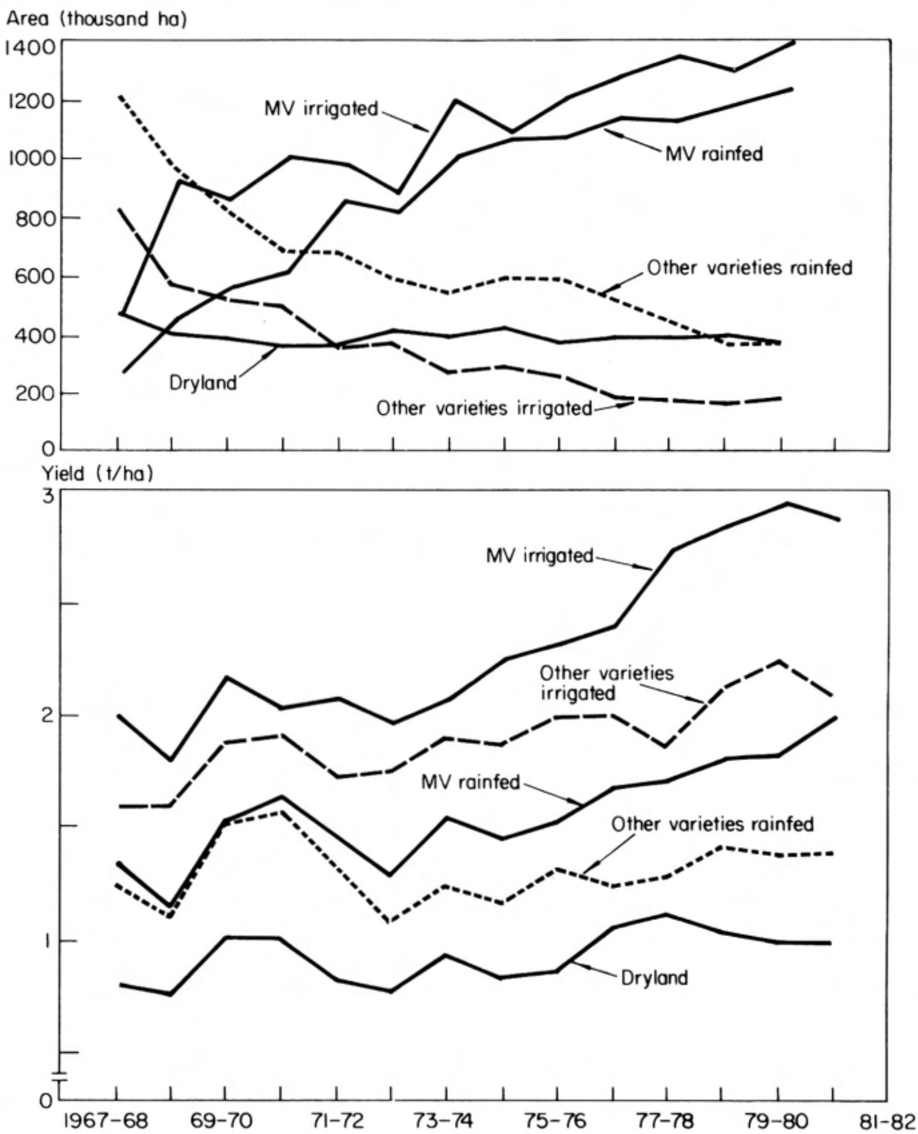
Philippines

In July 1966, IRRI released 50 t of IR8 to Philippine government agricultural agencies for distribution to farmers. Seeds were distributed to coincide with the *palagad* (wet season) planting and were concentrated in Nueva Ecija Province (Huke and Duncan 1969). Another 5 t were released to 2,359 farmers who personally requested the seeds from the Institute. Sumayao (1969) traced the introduction of IR8 in the Bicol region in 1966. One ton of the IRRI-released seed was distributed to governors and mayors of six provinces and two cities in Bicol, but the distribution system was confusing and seed movement was not closely monitored. Huke and Duncan (1969) ascribe the initial spread of IR8 in Tarlac Province to government agencies, private fertilizer manufacturers, and IRRI researchers who made the seed available to farmers selected by local extension agents. Demonstration plots in farmer fields were extensively used.

MVs were adopted more rapidly in the Philippines than in any other country (Table 8), which may not be surprising given that IRRI is located there and, as a consequence, IRRI research may be most relevant in the Philippines.

The Philippine Bureau of Agricultural Economics collects data on the area of rice by variety type, season, and irrigation status. The data in Figure 4 and Table 8 show that MVs were planted on 89% of irrigated rice land and 77% of the rainfed wetland rice area in 1979-80.

MVs spread rapidly after their release. While area increased in most years, in 1972-73 and 1974–75irrigated MV area fell slightly below that in the preceding year.



4. Area and rice yield in the Philippines by irrigation and variety type, 1967-68 to 1980-81.

Table 8. The spread of MVs[a] in the Philippines (Bureau of Agricultural Economics, Philippine Ministry of Agriculture, 1981).

Year	Area (thousand ha)					% in MVs
	Irrigated		Rainfed		All rice[b]	
	MVs	Other varieties	MVs	Other varieties		
1964-65	0		0			0
1965-66	0	960.5	0	1,542.9	3,109.2	0
1966-67	52.6	1,303.9	30.0	1,311.3	3,096.1	2.7
1967-68	445.1	863.9	256.4	1,257.6	3,303.7	21.2
1968-69	912.8	570.0	438.9	967.9	3,332.2	40.6
1969-70	826.6	519.1	527.4	828.3	3.113.4	43.5
1970-71	985.0	485.5	580.4	697.0	3,112.6	50.3
1971 -72	977.1	354.9	849.7	698.5	3,246.4	56.3
1972-73	872.8	368.1	807.1	629.4	3,111.8	54.0
1973-74	1,194.5	299.2	982.1	551.8	3,436.8	63.3
1974-75	1,108.9	302.8	1,066.1	608.2	3,538.8	61.5
1975-76	1,207.3	287.3	1,092.4	602.3	3,579.3	64.5
1976-77	1,285.5	204.1	1,131.2	526.2	3,547.5	68.1
1977-78	1,334.2	180.7	1,1 22.6	458.4	3,508.8	70.0
1978-79	1.31 5.0	157.0	1,196.6	384.0	3,468.9	72.4
1979-80	1,429.6	176.5	1,278.6	376.8	3,636.8	74.5
1980-81	1,441.6	189.6	1,236.8	343.0	3,459.1	77.4

[a] Includes IR varieties plus those developed by the Philippine Bureau of Plant Industry and the University of the Philippines College of Agriculture.[b]Difference between total of 4 types and all rice is the area planted to dryland (upland) rice (which is entirely in other varieties).

The national rice production program. Masagana 99, was introduced in 1973-74 and seems to have been associated with an upswing in production. but careful examination of the data fail to reveal any difference in the rate of MV adoption before and alter 1973. Data do seem to indicate a strong upward trend in irrigated MV yields. and a slighter upward trend in rainfed MV yield after 1973, perhaps traceable to increased fertilizer use.

Sri Lanka

By the the early 1960s a substantial area of Sri Lanka's rice was planted to the "H" series of improved rice varieties. These, called old improved varieties in Sri Lanka. had a somewhat higher yield capacity than traditional rices. In 1964-65, improved rices covered 40% of the total rice area, and this proportion continued to increase until 1969-70 when it reached over 70% (Table 9).

In 1967–68, Sri lanka imported 500 kg of IR8 seed, and in 1968-69 another 211 t (Dalrymple 1978). This was planted by farmers and used by researchers to produce a series of semidwarf varieties. These were designated ah "HG" and are called new-improved varieties within Sri Lanka. Although IR varieties covered less than 30,000 ha, the BG series spread rapidly, replacing the old H series to a large extent

Table 9. The spread of modern and improved rices in Sri Lanka (Sri Lanka Department of Agriculture).

Year	Area of rice (thousand ha)			% of total in	
	MVs[a]	Improved varieties[b]	Total rice	MVs	Improved varieties
1964-65	0	245.7	621.0	0	39.5
1965-66	0	292.2	503.0	0	58.0
1966-67	0	365.9	612.0	0	59.7
1967-68	0	389.3	634.0	0	61.4
1968-69	9.7	438.7	661.0	1.4	66.3
1969-70	31.2	447.1	623.0	5.0	71.7
1970-71	73.6	424.1	719.0	10.2	58.9
1971-72	118.6	31 1.6	602.0	17.1	45.0
1972-73	250.5	186.6	639.0	39.2	29.2
1973-74	396.2	162.7	824.8	48.0	19.7
1974-75	293.0	157.0	695.8	42.1	22.5
1975-76	320.1	166.7	717.1	44.6	23.2
1976-77	437.4	167.2	828.1	52.8	20.1
1977-78	495.7	147.3	875.4	56.6	16.8
1978-79	491.3	119.4	845.9	58.0	14.1
1979-80	562.4	141.9	844.7	66.5	16.7
1980-81	612.1	135.9	863.7	70.8	15.7

[a] Includes BG and IR varieties. [b] Includes H varieties.

(Appendix Table 7). By 1972-73, new-improved varieties covered about 40% of Sri Lanka's area, which gradually increased to 70% by 1980-81.

Thailand

Like Pakistan, Thailand has a large export market for high quality rice. This demand for high quality (long clear grains and intermediate amylose content) and the lack of such high quality among MVs is the main reason given by Thai agriculturists for the slow adoption of MVs. Even when MVs are grown, Thai farmers receive a slightly lower price for them than for traditional varieties.

IRRI varieties were imported in the late 1960s and used by scientists in Thailand's Rice Division as parents in crosses to develop semidwarf varieties with a grain quality like that demanded by the Thai market. Those varieties, designated as RD (for Rice Division), spread slowly. By 1978-79 only about 10% of Thailand's rice area was planted to MVs (Table 7).

Drought and deepwater conditions are common in the 90% of Thailand's rice area that is rainfed. These conditions severely restricted the area where the early MVs could be safely grown. However, the most recent MVs such as RD19 are tolerant to moderate deep water and drought. They may be able to make inroads into the rainfed areas.

THE CONTRIBUTION OF MVS TO INCREASED PRODUCTION

Given the data on the spread of MVs, what has been the impact of the new varieties on production? Some of the preceding tables and figures contain separate data on the yields of modern and other varieties, and data like those are a starting point for estimating MV impact. However, getting the complete picture is more complex than simply comparing yields. For one thing, the MV yields are higher because they receive more fertilizer, are grown on better land, and receive higher labor inputs than traditional varieties. Although it seems evident that economic returns to adopting farmers are higher with new than with old varieties, it is not clear how much of the increase should be attributed to new varieties and how much to the complementary factors.

Two different methods have been used to disentangle the effects: a production function approach, and an index number approach (Dalrymple 1975). The production function approach is theoretically elegant, but cannot be used here because the main factors of interest — varieties, fertilizer, and irrigation — are highly correlated. The index number approach depends on estimates or assumptions about elasticities of demand and supply and the shift caused by the new technology and "does not separate the precise effect of HYV's themselves from other factors influencing productivity" (Dalrymple 1975).

We have used a modified production function approach that can separate the impact of fertilizer and MVs. It relies on the assumption that the yield response of rice to fertilizer can be described by different response functions depending on irrigation, type of variety, and production season. The following response functions for the Philippines have been derived from a large body of research (David and Barker 1978).

Irrigated MVs: $Y_1 = C_1 + 18\ (\text{Fert}) - .09\ (\text{Fert})^2$

Rainfed MVs: $Y_2 = C_2 + 15\ (\text{Fert}) - .11\ (\text{Fert})^2$

Irrigated other varieties: $Y_3 = C_3 + 11\ (\text{Fert}) - .13\ (\text{Fert})^2$

Rainfed other varieties: $Y_4 = C_4 + 9\ (\text{Fert}) - .16\ (\text{Fert})^2$

Specific functions differ for various countries (Appendix Table 8). They were determined using available research information about fertilizer responsiveness of rice in the countries, and have been adjusted so the calculated output closely matches the reported output for 1965, 1970, 1975, and 1980. Fertilizer response functions are combined with several other behavioral relationships in a rice sector model for major producing countries.

To calculate the effect of all technology changes, the 1965 levels of irrigated land, fertilizer, and MV adoption were substituted for their actual levels and the model used to estimate 1980 production. All other variables were held at their actual 1980 levels. The difference between actual 1980 production and estimated production using the 1965 levels of the three factors is taken as the measure of the total impact of changes in irrigated land, fertilizer, and MV adoption. Actual change in output reflects the impact of all changes and includes the effects of increases in the three factors plus other, unmeasured factors like changes in land area, labor, and complementarity among factors.

The separate effects of irrigation, fertilizer, and MVs were calculated as follows. The 1965 level of irrigated area and fertilizer was substituted into the model with the

1980 level of all other factors to estimate production. Subtracting this production level from estimated production using I980 level of all factors gives a measure of MV contribution. Substituting the 1965 level of MVs and irrigated area and subtracting estimated production from the 1980 level gives a measure of the fertilizer contribution. Substituting the 1965 level of MVs and fertilizer and following a similar procedure yields a measure of the irrigation effect.

However, the sum ofthe three "effects" exceeds their total measured contribution because of their complementarity. To measure their separate contributions, the three estimated impacts were added and the proportion each contributed to their sum was computed. Results depend on the area in each land type, fertilizer applied, and MV area. For most countries, the data on fertilizer applied to rice were from *World Rice Statistics* (Palacpac 1982). Land categories used for individual countries are listed in Appendix Table 8.

Bangladesh

Land categories in Bangladesh are irrigated boro MVs, irrigated aus and aman MVs, rainfed MVs, irrigated TVs, and dryland. Analysis of fertilizer response experiments for Bangladesh showed that MVs grown in the boro season yield significantly higher than in other seasons, so we used the four response functions to represent boro MVs, other season MVs, boro local varieties (LVs), and other season LVs (Capule and Herdt 1981). Fertilizer inputs were relatively low in Bangladesh, barely averaging 10 kg/ha in 1977-78, but the contribution of fertilizer still was substantial. The contribution of MVs was small because of their modest area.

Burma

Land categories in Burma are irrigated MVs, irrigated improved varieties (IVs), rainfed MVs and IVs, rainfed traditional varieties (TVs) and dryland varieties. Estimates of the area planted to the four production categories were developed from various sources. Only about 10% of Burma's rice land is irrigated, although irrigation has gradually increased from 550,000 ha in 1965-66 to 870,000 ha in 1980-81 (Ministry of Planning and Finance). The area of MVs and IVs was less than the irrigated area until 1974, after which they exceeded irrigated area. Data sources do not separate irrigated MV area from rainfed MV area, but for our analysis, we assumed that 90% of the MVs were grown irrigated in the early years, remaining MVs were grown as rainfed rice, and that the balance of irrigated land was planted to other varieties.

China

Land categories in China are irrigated hybrids, irrigated MVs, irrigated TVs, rainfed, and dryland. Time series data on MVs are not available for China, and are not discussed in the previous sections. The available information indicates that by 1977 nearly all rice area was planted to semidwarfs except for the most favorable areas where a new generation of F_1 hybrid rites was being produced (IRRI 1978). Hybrid rices have about a 25% yield advantage over conventional modern rices. To separate fertilizer used on rice from fertilizer used on all crops it was assumed that the percentage of fertilizer used on rice equals the percentage that rice represents in total agricultural output. Data on irrigated land and fertilizer are from a recent comprehensive study (Tang and Stone 1980).

India

The four fertilizer response functions are for MVs in north, south, and northwest India; MVs in the rest of India; other varieties in north, and south, and northwest India; and other varieties in other states. Area data are official government statistics. Estimates of the fertilizer applied to rice are available, summarize in *World Rice Statistics* (Palacpac 1982). Yield data for MVs and other varieties are reported separately for some states in the country each year. These have been used to "tune" the model to approximate the Indian historical experience.

Indonesia

Land categories in Indonesia are technically irrigated MVs, other irrigated MVs, other irrigated TVs, rainfed TVs, and dryland. Published statistics do not show rice area or yield by variety, but several researchers have compiled useful data from official disaggregated statistics, such as those shown in Appendix Tables 6 and 9. "Intensification" in Appendix Table 9 refers to areas included in the Bimas and Inmas government production programs. In general those areas are irrigated and use MVs, while the nonintensification areas include rainfed and irrigated areas and generally do not use MVs or recieve credit for fertilizer puchase. From 1975 to 1978 the average yield in the intensification areas was 3.8 t/ha. Average yield was 2.5 t/ha in nonintensification areas. Estimates of the amount of fertilizer applied on rice were available (Palacpac 1982).

Philippines

Land categories in the Philippines are irrigated MVs, irrigated TVs, rainfed MVs, rainfed TVs, and dryland. Yield data are reported by the Bureau of Agricultural Economics for irrigated and rainfed areas planted to MVs and other varieties. From 1973 to 1978 irrigated MVs yielded 23% more than other varieties and 26% higher under rainfed conditions (Table 8). In 1967-1972, however, irrigated MVs had a 14% average yield advantage and rainfed MVs 5%.

Sri Lanka

Land categories in Sri Lanka are irrigated MVs in *yala* (second or dry) seasons, irrigated MVs in *maha* (first or main) season, irrigated IVs, rainfed, and dryland. Comparative data on MV yields are not available, but area data are. Sri Lanka introduced IVs before 1965, and the analysis assumes these were planted through 1980. Fertilizer use data are limited. Sri Lanka uses high fertilizer levels, partly because of the plantation sector.

Thailand

Land categories in Thailand are irrigated MVs dry season, irrigated MVs wet season, irrigated TVs dry season, irrigated TVs wet season, and rainfed (wetland and dryland). No comparative yield data are available and information on fertilizer use is sparse. Total area planted to MVs is minimal and irrigation has developed slowly. Lack of data may cause our computation to underestimate the increases due to modern technology.

Production and value of MVs

Table 10 shows the results of the response function exercise. The total values are quite large — rice output in these 8 countries increased nearly 120 million tons between 1965 and 1980. Variety, fertilizer, irrigation, and residual unmeasured factors contributed almost equally to increased production. Each factor increased production value by $4.5 to 5.0 billion (Fig. 5). Proportions of increase attributed to the four factors differ in each country, reflecting differences in the levels of MVs, fertilizer, and irrigation as well as productivity

Based on this method, if fertilizer, irrigation, land, labor, and other rice production factors had increased as they did over the period, but there were no MVs, annual rice production would be 27 million tons less than it was in 1980. In annual terms, MVs add roughly $4.5 billion per year to the value of output for these 8 countries, which produce 85% of Asia's rice. The monetary value of the annual production increase was calculated using the 1965 to 1980 average price of a low grade of rice (Broken AlSuper). This is $165/t when converted to a rough rice basis. This is substantial, as are the contributions of the other factors involved, but the contribution of varieties is different from that of fertilizer because it involves no direct expenditure by farmers.

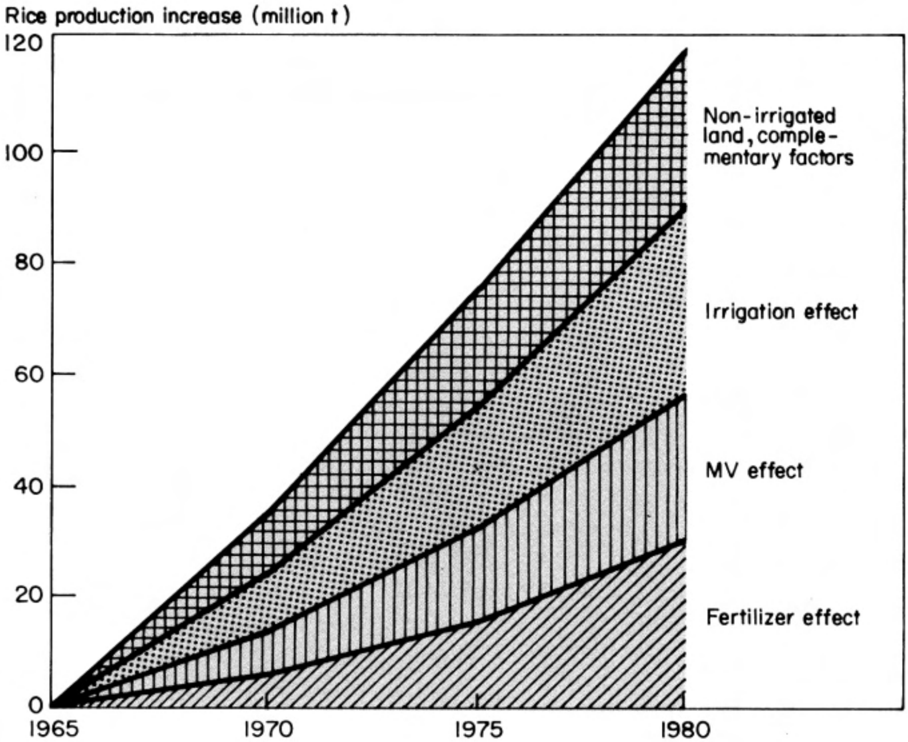
A REVIEW OF STUDIES ON MV ADOPTION

It is important to know which farmers in developing countries have adopted the new varieties. The following discussion reviews studies that address this question.

Table 10. Contribution of specified factors to rice production increases achieved from 1965 to 1980.

Year	Contribution of factors				
	MV effect	Fertilizer effect	Irrigation effect	Other factors (residual)	Total observed growth in output[a]
	Output increases (thousand t paddy)				
Burma	647	353	685	167	1,852
Bangladesh	420	1,284	1,091	2,759	5,554
China	13,231	11,507	16,153	9,609	50,500
India	7,998	10,867	11,209	5,078	35,152
Indonesia	3,162	2,680	2,773	4,998	13,613
Philippines	849	1,009	801	615	3,274
Sri Lanka	241	215	262	316	1,034[b]
Thailand	822	682	865	4,031	6,400
Total of above	27,370	28,597	33,839	27,573	117,379
	Value (US$ million)[c]				
	4,516	4,718	5,583	4,549	19,367

[a]Difference between 1980 and 1965 production (USDA FG38-80). [b]A 3-year average was used for 1965 because 1965 yields were unusually low. [c]Paddy was valued at $165/t.



5. Estimated contribution of 4 separate factors to rice production increases in 8 Asian countries, 1965-80.

Two broad types of adoption studies can be identified. The first describes patterns of adoption or diffusion, and the second attempts to identify factors associated with adoption. Review of the studies available for any country shows no sequence in the order of research. Sometimes description preceded the study of factors associated with adoption, and in other countries studies on associated factors preceded descriptive studies. This review first deals with descriptive studies, then briefly presents a theoretical framework that seems implicitly to underlie many of the studies. Lastly we review findings of analytical studies.

Descriptive adoption studies

Some adoption studies use a historical framework and others trace the spread of MVs spatially within villages, between villages, or across provinces and regions. Different studies use different measures of adoption. Some classify farmers as adopters and nonadopters while others quantify adoption as the proportion of area planted to MVs. Some studies include a range of improved practices associated with MVs, or with new rice technology in general. In these studies, adoption refers to the use by farmers of a number of improved practices and is usually measured by an adoption score (number of improved practices used) or by an adoption quotient (number of improved practices used over total number of recommended practices).

Scores may be arbitrarily scaled to arrive at some categorization of adoption. for example, low, medium, high (Ramaswamy, 1973). In studies that try to isolate causal factors, particularly those using regression analysis, adoption may be measured as a dummy variable with a value of 1 for farmers planting MVs or using fertilizer and a zero value for other farmers. These differences in the measure of adoption makes comparison across studies more difficult than it would be if all studies used the same measure.

Historical pattern of adoption. The historical diffusion of new varieties has been characterized: 1. as a sequence in which the proportion of farmers who behave in a given way is characterized through time, and 2. by classing farmers into stages of adoption at a given time.

One of the first studies of MV adoption in Asia is a 1965 survey of 270 farmers in 2 villages of South Kanara district, Mysore, India, in which diffusion curves were plotted for improved seeds, chemical fertilizers, and the "Japanese method of paddy cultivation" (Shetty 1966). The choice of the logistic curve to represent the adoption process was influenced by early diffusion studies in the developed countries (Pearl 1924, Griliches 1957, Mansfield 1961). It was hypothesized that a ***demonstration effect*** (also called a neighbor effect) would be generated by the initial adopters and lead to a spurt in adoption. The effect tapers off as late adopters catch up. Except for Shetty (1966) and Huke and Duncan (1969) who actually estimate the logistic curve, most adoption studies have simply plotted cumulative percentage adoption rates based on number of farmer-adopters against time.

The logistic shape of the growth curve is clear even when it is not estimated econometrically. Data from the following time sequence adoption studies have supported the S-shaped adoption curve: Huke and Duncan (1969), Sumayao (1969). Mangahas and Librero (1973), Palmer(1974); and for HYV and fertilizer use, Bhati (1976), Islam and Halim (1976), and Huke et al (l980). A more comprehensive body of data drawn from 30 Asian villages traces the adoption curve not only for MVs but

Table 11. Percentage of farmers adopting innovations a specified number of years after introduction (Huke and Duncan 1969, Liao 1968, Murshed and Alam 1978, Shetty 1966).

Number of years	Farmers (%)					
	Gapan, Nueva Ecija,[a] Philippines	Mymensingh,[b] Bangladesh			South Kamara, Mysore,[c] India	
		IR20	IR5	Pajam 2	Pre-MV seeds	Chemical fertilizer
<1	3.2					
1	13.7	30.0	2.5	42.5		
2	42.7				6	
3	18.1	30.0	20.0	12.5	5[d]	9[d]
4-5	–				13	28
>5	–	12.5	5.0	–		
8-10	–	–	–	–	30	46
11-13	–	–	–	–	29	11
14-16	–	–	–	–	13	2
>17	–	–	–	–	4	–

[a] For IR8 only, 1966-69. n = 2,217 farmers in 10 barrios. [b] n = 40. Period covered is September 1976-January 1977, [c] n = 201 for pre-MV seeds, 1946-63; n = 130 for fertilizer, 1951–64. [d] 3-4 year category.

for several other innovations: herbicides, tractors, insecticides, fertilizers, and mechanical threshers (Barker and Herdt 1978). The S-curve is most evident for MV adoption.

Studies conducted only a few years after MV introduction do not show the time path of the adoption process fully, but do show the beginning of the characteristic S-curve shape (Rahman and Weaver 1969, Mukherjee and Lockwood 1971, Diamante and Alix 1974, Chinnappa 1977, Fukui and Nishio 1979). A similar trend is implied by data from 6 IADP villages in Mandi District, India; adoption of improved seeds (rice, maize, etc) and fertilizer use jumped from almost 0 to 95% after the program started (Rajagopalan and Singh 1971). In 4 Korean villages, however, no such discernible trend was noted for the first 2 years of Tongil adoption (Cheong 1973).

A variation of the S-curve adoption studies measures the length of time before adoption. In the pre-MV period, adoption of many innovations took years (Shetty 1966). However, it took only 3-5 years for most farmers to adopt IR8 in Gapan, Nueva Ecija Province, Philippines, and IR5 or IR20 in Mymensingh District, Bangladesh (Huke and Duncan 1969, Murshed and Alam 1978). Only a very small percentage in Bangladesh adopted after 5 years (Table 11).

An interesting case study of a Bangladeshi farmer-innovator cites the case of a neighboring farmer who took 4 years to fully adopt the new technology. In the first year he opposed the idea for religious reasons, in the second he accepted seed and water only, and finally, in the fourth year he applied fertilizer (Bari 1974). The briefest interval reported between introduction and widespread MV adoption was 4 months for 3 towns in Laguna Province, Philippines (Liao 1968).

Many sequence studies use adopter categories. Categories are not unique and may be dichotomous (early vs late adopter or continuer vs discontinuer). Other scholars use multidimensional categories that may include initial adopter, persistent adopter, new adopter, dropout, and re-adopter. Still others use innovator, early adopter, later adopter, and nonadopter. Liao (1968) presents data which show an almost even spread among farmer-adopters who plant MVs fully, in part, or not at all (Table 12). In Bangladesh, as shown in the same table, the distinction between early and late adopters is more pronounced than between innovators and early adopters.

There seems to be no consistent pattern for continued planting of MVs based on date of first adoption. Data do indicate some kind of demonstration effect at work

Table 12. Distribution of farmers by adoption class (Liao 1968, Islam and Halim 1976).

Philippines[a], 1967 wet sawn (n = 155)		Bangladesh[b], 1965-70 (n= 90)	
Adopter category	Farmers (%)	Adopter category	Farmers (no.)
Full adopter	39	Innovators	13
Partial adopter	31	Early adopter	13
Nonadopter	30	Late adopter	40
		Nonadopters	24
Total	100		90

[a]Refers to farmers who planted IR8, BPI-76, or C18. Full or partial adoption is based on area planted. Sample is from 3 municipalities in Laguna: Biñan, Cabuyao, and Calamba. [b]Refers to farmers who planted IR paddy introduced in 1965. Sample is from Khagdahar Union, Kotwali thana, Mymensingh, Bangladesh. Number of farmers is computed from percentages published in the paper. Categories are based on innovativeness scores which are computed as months between December 1970 and seasons of first IR cultivation.

among new and persistent adopters and nonadopters, and between early and late adopters, a result that supports S-curve studies. Some studies show that farmers sometimes shift to non-MVs within a 3-4 year period (Diamante and Alix 1974), but the aggregate data in the first part of the paper indicate that this is not widespread.

Adoption studies have also attempted to identify time-related stages in adoption, based on Heal and Bohlen's (1957) 5-stage theory of innovation diffusion. The stages theory was elaborated and popularized by Rogers (1962) and brief discussions map be found in Ramaswany (1973) and Islam and Halim (1976). The stages are: awareness, interest, evaluation, trial, and adoption. They are thought to be continuous.

Numerous studies that evaluate the effectiveness of communication media and extension to farmer adoption are reported in the sociological literature. Many studies ofthe adoption of improved practices have been reviewed by Pal (1969), but surprisingly few empirical investigations deal directly with modern varieties. Some that do include works by Hossain et al (1972) Islam and Halim (1976), Battad (1973), Lao (1968), and Pal (1969).

The clearest work on the subject is by Islam and Halim (1976). They document the adoption behavior of 90 IR rice variety users in Kotwalithana, Bangladesh, between 1965, when IR varieties were first introduced, and 1970. It took 7 years for more than half the sample farmers to enter the awareness stage (Table 13). Forty-nine farmers sought information about the MVs within 120 days; 11 farmers took as long as 360 days to show interest. A 2-year evaluation period followed during which 75 of 90 farmers observed demostration plots. For 22 of these farmers, however, there was no clear passage from interest to evaluation. Only 5 farmers planted a trial before large-scale planting. Actual adoption took from 6 months to 5 years, based on farmers' response to whether they would plant the MV next season. Some farmers who were first aware of the MVs took the longest time to adopt. Those who became aware of the MVs much later took only a year, on the average, to adopt. The authors attributed this behavioral pattern to a demonstration effect exerted on late adopters. Data suggest that adoption response is not immediate and that the time lag offers late adopters a chance to observe and evaluate MV performance on neighbors' fields, thus encouraging their own adoption.

Battad (1973) distinguished adoption stages among a sample of 213 rice farmers from 4 ethnic groups in the Philippines: 62 Moslems, 50 Visayans, 51 Tagalogs, and

Table 13. Distribution of sample farmers in various stages of MV adoption in Bangladesh (Islam and Halim 1976).

Year	Farmers (no.) in each stage				Av years from awareness to adoption by farmers aware in the year specified
	Awareness	Evaluation	Trial	Adoption	
1965	2	2	0	–	3.5
1966	15	14	3	–	2.2
1967	50	39	2	13	2.0
1968	21	19	0	13	1.8
1969	2	1	0	4	1.0
1970				36	

50 Ilocanos. More than 60% of the Moslems registered awareness of 9 listed practices, including MV use, fertilizers, seed selection, etc. Forty percent tried the MVs and 55% adopted. The Ilocanos showed a similar adoption pattern but more Visayans and Tagalogs tried and adopted. The adoption pattern for fertilizer shows lower adoption rates and suggests a notable difference between Moslem and non-Moslem groups.

In another Philippine study, Mangahas and Librero (1973) report a pattern of rejection after trials with the MVs. All sample farmers in Camarines Sur Province, none in Cotabato, and more than a third of Iloilo farmers discontinued planting MVs 3 to 4 years after trial plantings. However, aggregate data available for these Philippine provinces show that by 1980 about 70% of all rice area was planted to MVs in those provinces (BAEcon 1981). The annual number of adopters was not recorded in the Korean study (Cheong 1973) but data indicate that 50% of the farmers made aware of MVs planted them.

Few studies have described the spatial pattern of adoption. Some studies may have assumed that adoption follows a rapid, even path of diffusion over space, but there are many areas where little adoption has occured. The only microlevel study diagrammatically tracing the pattern of spatial diffusion was done by Huke and Duncan (1969). They traced the spread of IR5, IR8, and C4 among 2,217 farmers in 10 barrios of Nueva Ecija from 1966 to 1969. In a series of diagrams, they depict four stages in spatial adoption: the concentration of early adopters within a small core area, the dramatic radial extension from the core, the elaboration of stage 2, and finally, a renewed outward extension with a decline in adopters in the intermediate stages.

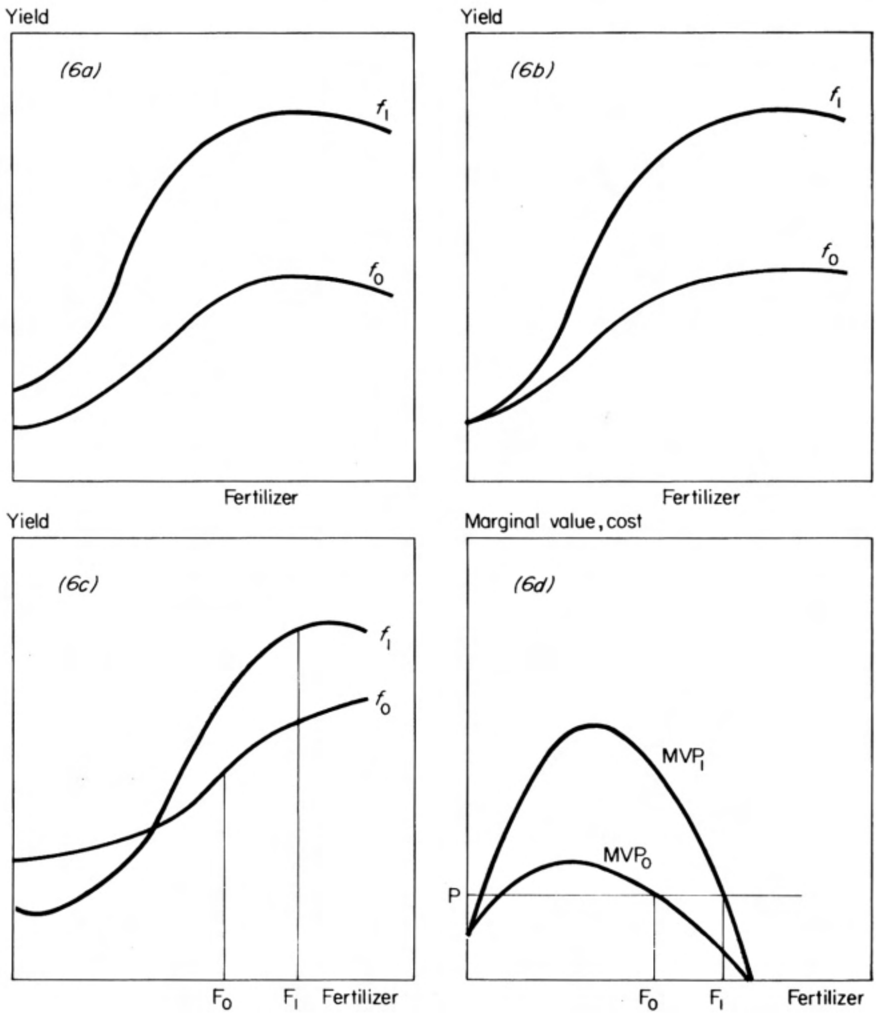
Spatial studies have also explicitly documented wider variation in adoption rates across than within villages (Cheong 1973, Suh 1976, Barker and Herdt 1978) or have indirectly shown this tendency (Palmer 1974, Chinnappa 1977, Rajagopalan and Singh 1971, Asaduzzanan and Islam n.d., Huke and Duncan 1969). Government-supported production programs (IADP in lndia and BIMAS in Indonesia, for example) push adoption to unprecedented levels but do not necessarily eliminate village differentials in adoption. Appendix Table 4 shows a similar wide range in adoption across Indian states.

Factors associated with adoption

The literature on factors associated with new technology adoption has two broad themes: one focuses on the characteristics of individuals or groups making adoption decisions, and the second attempts to quantify the economic forces affecting their production decisions. A third theme, seldom explored but perhaps of more importance, is the performance of the technology under local conditions. Unfortunately, there is a lack of literature on this theme.

A theory of varietal adoption. A theoretical framework is useful because it provides a means for classifying the many factors that are potentially important to the adoption process. The following is an outline of a simple economic model for a varietal adoption theory.

Focus on a farmer decision maker who may choose to continue using a pre-



6. Alternative patterns of existing (f_0) and new technology (f_1).

existing technology or switch to a new technology. Suppose he produces rice using the fixed factor land (L), and a variable factor, fertilizer (F).

$$Q = f_0\,(F, L)$$

Other inputs like labor need not be explicitly mentioned because they can be subsumed within the model by assuming they are used in fixed proportion to land. A technological change such as a new variety is represented by a discrete shift of the production function.

$$Q = f_1\,(F, L)$$

The possible differences between old and new technologies are shown in Figure 6. In 6(a) the new technology yields higher than the old at all levels of variable input. In

6(b) both technologies have the same positive output with zero variable input. Case 6(c) is more complex. At low fertilizer levels the new variety gives a lower yield; at high levels it yields higher than the old. Although other situations could occur, these are adequate to show that in all cases of a more productive variety, the marginal productivity of fertilizer is higher with the new variety than with the old at any fertilizer level. It is usually assumed that 6(a) represents the situation but that 6(b) and 6(c) may also exist. The precise shape of the curves is an empirical question. However, to illustrate our point it is sufficient to assume that the response functions have identical slopes and differ only in their intercept, in which case their marginal product curves are as represented in 6(d).

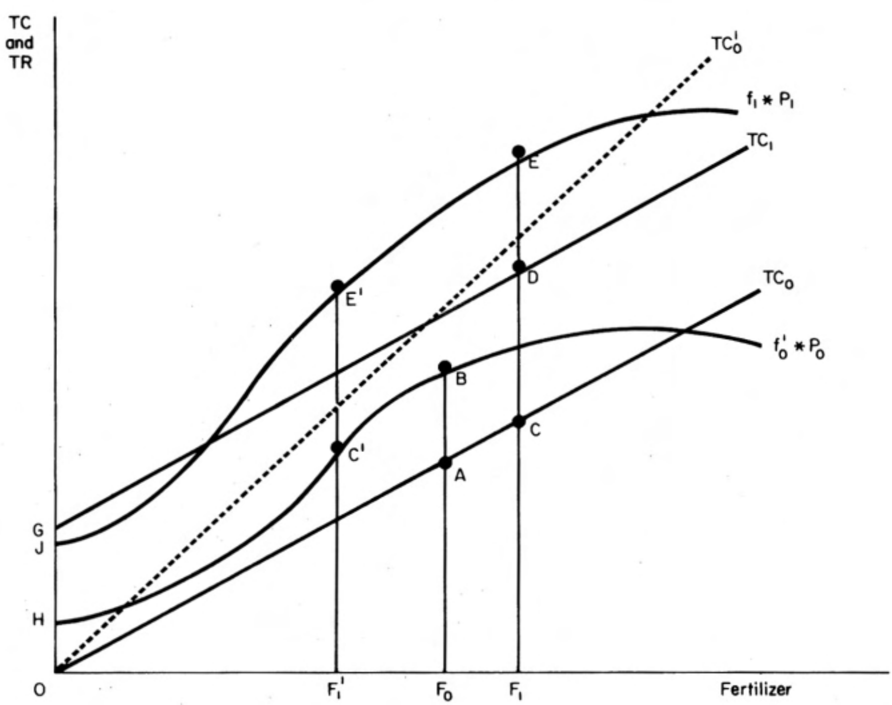
The farmer uses a combination of variety and fertilizer level. Variable returns are maximized when the marginal value product (MVP) of fertilizer equals its effective marginal opportunity cost. These levels are shown as F_0 and F_1, respectively, in Figure 6d and indicate that the optimal level of fertilizer is identical for all three situations.

Using P_q to represent the output price and P_f the fertilizer price, profit with the old technology is:

$$R_0 = P_q Q_0 - P_f F_0 = P_q f_0 (F, L) - P_f F_0.$$

Suppose that using the new technology requires greater knowledge or some other fixed input costing K such that profit with the new technology is

$$R_1 = P_q Q_1 - P_f F_1 - K.$$



7. Total cost and total revenue curves of alternative technologies.

The usual profit maximiring rules show that the optimal level of fertilizer to use with the technology is that where the MVP of fertilizer equals the cost of fertilizer. Figure 7 shows the total revenue ($f_0 * P_0$ and $f_1 * P_1$) and total cost curves (TC_0 and TC_1) of the two technologies for 6a. The profit maximing fertilizer levels of the two technologies are F_0 and F_1 with corresponding total profits of *AB* and *DE*.

If the extra fixed cost associated with the new technology is zero, then profit with f_1 equals CE, and adoption would be expected. The larger the extra fixed cost associated with the new technology (K, which equal OG in Figure 7), the less attractive is the new technology. If K is large enough, f_0 will be preferred to f_1 and the new technology may not be adopted. If some individuals or groups incur the extra fixed costs and others do not, some probably will adopt and others will not.

The same figure can illustrate the situation where there is no additional fixed cost associated with the new technology but the effective cost of fertilizer differs for different groups of farmers. Let TC_0 be the cost for one group and TC_0^2, the cost for a second group. The second group will find fertilizer use has no economic advantage with technology f_0 because profit is maximized at zero *F with OH* profit. Farmers paying TC_0 would find fertilizer use profitable at the *F* level, even with the old technology. With the new technology ($f_1 * P_1$) farmers paying TC_0^2 will find it optimal to use only F_1' fertilizer to obtain E´C´ profit while farmers paying TC_0 will find it optimal to use F_1 fertilizer to obtain maximum profits of EC. This reflects the well-known result that the higher the unit cost of variable inputs, the lower the optimal level of use. If output is shared between the decision making farmers and someone else (landlord or laboorers), then the total revenue curve for either technology is reduced in proportion to the share. Likewise, the cost of the variable input may be shared. Then profit for the old technology is

$$R_0 = (1 - s)\ TR_0 - (1 - r)\ TC_0$$

and profit for the new technology is

$$R_1 = (1 - s)\ TR_1 - (1 - r)\ TC_1 - K$$

where (1- *s*) is the farmer decision maker's output share, and (1- *r*) is his share in costs. Substituting the production function and following profit maximizing rules shows that if $r = s$, the optimal fertilizer adoption level is predicted to be the same as in the absence of sharing, while if farmer's share of costs exceeds the farmer's share of output ($1 - r > 1 - s$) then the optimal level of fertilizer will be reduced to obtain a higher marginal productivity. Sharing is not shown to affect the adoption incentive for varieties although it can reduce the optimal level of fertlizer input.

If Figure 6(b) shows the yield response to fertilizer, then at any price of rice the optimal fertilizer level is lower for the old than the new technology, but the new technology would be preferred because it yields higher profits. At some high price, zero fertilizer will be optimal, and farmers may be indifferent to new and old technologies. Again, an additional fixed cost associated with the new technology may cause the old technology to be more attractive.

If 6(c) shows the yield relationship between old and new technology, then even if there is no extra fixed cost tied to the new varieties and there are no differences in fertilizer prices between groups of farmers, a rational decision maker may choose f_0 if the amount of fertilizer available is limited. The limitation may be caused by lack of investable capital or credit within the farm unit or by nonavailability of fertilizer where the farm is located.

It is important to recognize that farmers, like all people, act on what they believe, which may differ from reality. If they believe the cost and yield response functions of a new technology will yield lower benefits they will not adopt the new technology regardless of the objective reality.

Based upon this analysis, the factors likely to be associated with modern variety adoption are those that affect the fixed and variable costs of adoption, the availability of complementary inputs like fertilizer, and the type of change in the production function.

Personal variables. Fixed costs associated with adoption are most likely to arise from the greater knowledge needed to use the new technology. For farmers who have more education, more experience, greater contacts with extension education, or similar characteristics these fixed costs are relatively lower, and a positive correlation between adoption and such factors may be hypothesized.

There are seven personal characteristics often studied for their impact on new technology adoption: farmer's age, level of schooling, extension contacts, level of

Table 14. Summary of results of regression and correlation studies on the impact of personal variables on the adoption of MVs and fertilizer.

Study		Impact of variables on adoption[a]							
Area	Year	Age	Education	Extension	Technical knowledge	Class	Family size	Organization	Reference
				Adoption of modern varieties					
Mysore	1965	+	+						Shetty 1966
Bangalore	1972		-		+	+		+	Ramaswamy 1973
Korea	1974	0		+			0		Suh 1976
Korea	1974	0		0			0		Suh 1976
West Malaysia	1976	0	0				-		Yim 1978
Nepal	1978		+	+					Rawal 1979
				Adoption of fertilizer					
Mysore	1965	0	0						Shetty 1966
West Malaysia	1976	0	0						Yim 1978
Thailand	1970[b]				+			+	Kolshus, 1972
Central Luzon	1974		0		+			+	Bernsten 1976
Sri Lanka	1975			+					Amerasinghe 1976

[a] 0 = no significant impact, + = significant positive, - = significant negative, blank indicates variable was not tested. [b] Also found significant association with lack of conservatism.

technical knowledge, social class or caste, family size, and participation in organizations. Most studies test only three or four. These effects may be tested by comparing contrasting groups or through regression analysis. Table 14 summarizes the regression studies, and others are discussed in the text.

The influence of schooling on adoption is best documented. Many studies show that more literate, better educated farmers are higher adopters (Mangahas 1970, Rajagopalan and Singh 1971, Kolshus 1972, Hossain et a1 1972, Bhati 1975, Librero and Mangahas 1975, Islam and Halim 1976, Chinnappa 1977, Flinn et al 1980). In a pre-MV study, education was a significant variable in improved seed adoption but not for chemical fertilizer (Shetty 1956). Education enhances farmer innovativeness (Liao 1968), but a high level of education is not required for adoption. Librero and Mangahas (1975) found that Filipino farmers in 3 provinces with intermediate schooling (at least 4 years of primary education) had the highest adoption rates. Indian data support the same finding: 28% of adopters had elementary or higher education compared with 9% of the adopters who had no formal schooling (Chinnappa 1977). Other variables correlated with schooling—information search and frequency, of extension—sometimes overwhelm the schooling effect in regression studies (Ramaswamy 1973, Yim 1978).

The farmer's technical knowledge is a product of extension education. Islam et al (1972). Kolshus 1972, and Bhati 1975 confirm that technical knowledge is a positive influence on MV and fertilizer adoption. This variable is the foremost factor in adoption of improved practices among a sample of Indian farmers (Ramaswamy 1973). All three variables associated with knowledge tend to have the hypothesized effect, supporting the idea that greater knowledge reduces fixed costs associated with MV adoption.

Much of the literature on the impact of social and behavioral variables in adoption discusses communication, particularly demonstrations and information dissemination about new rice technology.

Evidence shows that friends, relatives, and neighboring farmers are the primary sources of information and of initial MV seeds for farmer-adopters (Hossain et al 1972, Librero and Mangahas 1975, Islam and Halim 1976, Wirasinghe 1977).

Extension agents are primary information sources in the awareness and interest stages of adoption (Hossain et al 1972). Their influence diminishes at the trial and adoption stages because more informal personal sources which are more available and accessible, exert a demostration effect. The positive influence of extension agents on MV adoption is, however, recognized and empirically supported (Pal 1969, Shim and Shin 1974, Mizuno 1977, Suh 1976). Extension agents have been reported to be more reliable sources ofinformation on fertilizer use than on MVs in Sri Lanka (Wirasinhe 1977).

Quality of the extension service is a major factor in farmer adoption. Poor extension may lead to discontinued MV use and general farmer apathy (Rahman and Weaver 1969, Kalijaran 1979). Infrequent contact and lack of follow-up home and farm visits were implied to have been important adoption factors in the responses of 90 IR rice growers in Bangladesh (Hoque et al 1972). One study has attempted to relate quality of extension to the personal characteristics of the extension agents (Battad 1973).

In addition to formal and informal personal information sources, impersonal communication sources such as the media and cooperative offices provide information to farmers. The media is a minor source, compared to the others. Cooperatives are directly related to adoption behavior of their members while nonmembers depend on demonstration effects from other farmers' trials (Hamid 1975).

Because cooperatives provide both information and credit, membership encour-, ages adoption. Credit may lower variable costs associated with adoption while information lowers fixed costs. Participation of farmers in cooperatives has been positively related to MV adoption in several studies (Wang 1967, Hossain et al 1972, Ramaswamy 1973, Mahbub-e-Illah 1974, Islam and Halim 1976, Bhati 1975). Farmers' organizations facilitate the implementation of national production programs and consequently, MV adoption. Various workers draw this conclusion from the correlation between membership and participation in production programs. Among them are: Sajogyo and Collier (1972) for the BIMAS program in Indonesia; Wirasinghe (1977) and Muranjan (1968) for the HYVP in India; and Lu (1968), Gupta and Singh (1966), and Cheong (1973) for Tongil adoption in Korea.

Other personal characteristics that have been hypothesized to encourage MV adoption are farmers' age, years of farming experience, family size, and social class or caste. Adoption is generally unrelated to the farmer's age (Liao 1968, Mangahas 1970, Hossain et al 1972, Librero and Mangahas 1975, Suh 1976, Islam and Halim 1976, Chinnappa 1977, Yim 1978).

Years of farming experience is either unrelated (Islam and Halim 1976) or positively associated with adoption (Mangahas 1970). Wang (1967) reports that the relation between adoption of improved practices and farming experience is indeterminate.

The relationship between family size and adoption is inconsistent. Bhati (1975) and Yim (1978) find a positive effect on MV adoption. Suh (1976) and Flinn et al (1980) find no significant impact. Further, Yim (1978) reports that family size is an insignificant variable in fertilizer use.

There seems to be an association between caste or ethnic grouping and adoption (Rajagopalan and Singh 1971, Battad 1973, Chinnappa 1977). But because other factors are associated with class and caste, the effect may be more apparent than real. For instance, extension in Moslem areas in the Philippines is not as intensive as in non-Moslem areas and Moslem farmers have poorer quality land (Battad 1973). In India, caste differentials are related to income and size of land holdings.

Several factors appear to affect the variable costs of fertilizer needed to obtain the yield benefits of MVs. Farm size and tenure are among the most frequently studied factors. It is often hypothesized that big farmers pay less for fertilizer or have lower cost credit than small farmers. That would mean that large farmers operate with TC_0 in Figure 7 and small farmers operate with TC'_0 and F'_1, rather than F_1 fertilizer, which large farmers would find optimal. If the difference in the production functions was as in Figure 6(b). then small farmers would choose to operate with zero fertilizer. Tenure arrangements where the tenant pays all costs and receives a share of output will have the same net effect, although a diagram of that case would show a total revenue curve of lower slope and a total cost curve of equal slope for tenants compared to owners.

Table 15. Summary of results of regression and correlation studies on the impact of factors that affect the variable costs of MV and fertilizer adoption.

Area	Year	Impact[a] on adoption						Study
		Farm size	Tenure	Wealth	Technology experience	Fertilizer availability	Credit availability	
Adoption of modern varieties								
Mysore	1965	0	0	0				Shetty 1966
Bangalore	1972	-						Ramaswamy 1973
Korea	1974	+						Suh 1976
Korea	1974	+						Suh 1976
West Malaysia	1976	0	+		+			Yim 1978
East India	1966-8	+						Schluter and Vander-Veen 1976
Nepal	1978	-			+		+	Rawal 1979
Sri Lanka	1975		+					Amerasinghe 1976
Adoption of fertilizer								
Mysore	1965	-	+	-	+			Shetty 1966
West Malaysia	1976	-	+					Yim 1978
Central Luzon	1974	0	-		0	0		Bernsten 1976
Nepal	1978				+	+		Rawal 1979
Sri Lanka	1975	+	+					Amerasinghe 1976
Bangladesh	1969	+						Hossain 1977
Bangladesh	1973	+						Hossain 1977

[a]0 = no significant impact, + = significant positive, - = significant negative; a blank indicates variable was not tested.

The literature summarized in Table I5 presents no conclusive evidence, although even in the pre-MV period, some thought that adoption would begin on larger farmers and trickle down to small farms (Panse and Singh 1966). One group of studies concludes that farm size is positively related to adoption because more large farmers tend to plant MVs (Mangahas 1970, Frankel 1971, Rajagopalan and Singh 1971, Mukherjee and Lockwood 1971, Islam et al 1972, Hossain et al 1972, Shim and Shin 1974, Islam and Halim 1976, Chinnappa 1977, Parthasarathy and Prasad 1978).

Other studies show that smaller farms tend to lead in MV adoption (Muqtada 1975, Mandal and Ghosh 1973, Franke 1972, Palmer 1977, Barker and Herdt 1978, Ramaswamy 1973). A third group of studies indicates that adoption is equal among all size groups (Liao 1968, Mukherjee 1970, Barker et al 1971, Hamid 1975, Mandal and Ghosh 1976, Kalimjan 1979, Flinn et al 1980). Frankel (1971) finds that farmers with 2-4 ha farms adopted, but farmers with more than 4 ha adopted sooner. Early MV and fertilizer adopters tend to be large farmers (Khan 1975), but more recent data culled from various village studies indicate that MV adoption tends to be concentrated on the medium or intermediate size farms (Table 16).

Misleading generalizations regarding adoption and farm size. The impression that farm size is a major factor affecting adoption and successful use of modern rice

Table 16. Distribution of MV or fertilizer adopters by farm size in various Asian countries.

Village, country	Sample farmers (no.)	Innovation	Period covered	Farm size category	Farms (no.)	Adopters (no.)	adopters (%) of size category	Source
4 villages/ Bangladesh	628	IR5/IR20	Unspecified	<1 acre	127	32	25.1	Asaduzzanan and Islam (n.d.): Table 4, p. 15
				1-3 acres	267	144	53.9	
				3-5 acres	168	107	63.1	
				5-7.5 acres	46	34	73.9	
				^{3}7.5 acres	20	10	50.0	
				Total	628[a]	327		
Mymensingh district, Bang-ladesh	105	MVs	1969-70	0-2.5 acres	53	13	24.5	Muqtada (1975): Table 4.pp. 408,411
				2.5-4 acres	43	14	32.6	
				4-6 acres	31	14	45.2	
				6-10 acres	17	5	29.4	
				> 10 acres	6	1	16.1	
				Total	150	47		
							%area to Tongil	
Hwasung-tum, Central region, Korea [b]	100	Tongil	1974	Small (0.9 ha)	-	-	25.9	Suh (1976): Table 5.7 p. 108
				Large (1.7 ha)	-	-	18.6	
							% area to Tongil	
Kimje-gun, SW region, Koreab	82	Tongil	1974	Small (1.1 ha)	-	-	52.0	Suh (1976): Table 5.7 p. 108)
				barge (2.8 ha)	-	-	30.6	

Table 16........./2

Village, country	Sample farmers (no.)	Innovation	Period covered	Farm size category	Farms (no.)	Adopters (no.)	adopters (%) of size category	Source
10 barrios, Cota-bato province, Philippines	213	MVs	Unspecified	.25-1 ha	83	54	65.1	Battad (1973): Table 26 p. 94
				1.25-2 ha	85	56	65.9	
				2.25-3 ha	24	19	79.2	
				3.25-4 ha	12	9	75.0	
				>4.25 ha	9	5	55.6	
				Total	213	143		
					% farms			
North Arcot district, India	545	MVs	1972-73	<.4 ha	21	15		Chinnappa (1977): Table 8.10 p. 109
				.4-1 ha	29	19		
				1.1-2 ha	33	33		
				2.1-3 ha	8	51		
				3.14 ha	4	61		
				>4 ha	4	67		
					100%			
3 villages, Amphoe Manorom, Chainat province,	142	Fertilizer	Pre-1967 to 1988[c]	0-1.6 ha		50		Greene (1970): Table 9 p. 32
				1.6-3.2 ha		51		
				3.2-4.1 ha		68		
				4.8-6.3 ha		76		
				6.4-7.9 ha		63		
				8-9.5 ha		100		
				>9.6 ha		80		

[a]Number of farms computed from percentages given in Muqtada (1975). [b]Small and large farm size classification is based on *average* farm size. [c]Sample farmers started using fertilizers in 1966 at an average rate of 9-15 kg N/ha. Between 1967 and 1969, LVs were mainly planted in the sample area.

technology has been encouraged by studies that apparently examine data carefully, but then reach unsupported conclusions. One study of the new technology in India reviews 7 microlevel studies, 19 evaluation reports conducted by Indian agroeconomic research centers, and Planning Commission studies with large samples from all the relevant states in India for individual crops for 3 years beginning in 1968-69. Ten cross-tabulations of MV adoption rates by farm size are presented (the volume contains more than 125 tables). Four tables show adoption rates for rice: two show that small farmers lag behind in adoption, and two show the opposite. The concluding section to the chapter has *only* the following to say about adoption and size: “The rate of adoption of new seeds is usually higher among the larger farms; but over time, particularly in wheat areas, there is a tendency for the differences between farm size to diminish. On the other hand, the smaller adopting farms have a higher intensity of adoption than their larger adopting counterparts.” Data in the report show little support for the hypothesis that farm size affects adoption.

The subsequent chapter, devoted to new technology and the small farmer, has the written objectives of examining:

“1. Why do the small farmers show a low propensity to adopt the new high-yielding varieties? . . . . .

2. Given that the small farmers are at a serious disadvantage vis-a-vis the larger farmers, what measures should be taken?. . . . .”

There is little in the study that supports the premises behind these questions, but the technique has been used by many authors.

Another study reviews the conclusions of new rice technology studies in Indonesia, the Philippines, Malaysia, and Thailand. In a volume containing40 tables, there is no table relating adoption to farm size. Adoption is related to province, year, organizational membership, and source of information but not to farm size. The chapter on MV adoption has no section on size and adoption and the chapter on agrarian reform and farm size has no section on adoption. The report contains a chapter on tenurial status and adoption but does not have a chapter that deals with size and yields. However, the concluding chapter of the volume states that “over a wide range of reports larger farmers tended to be more intensive adopters of HYVs in the long run.” Such unsupported generalizations have been accepted by many observers.

Recent data on size and adoption. The National Council of Applied Economic Research of India has recently conducted a national survey of fertilizer use in India. Their sample includes over 22,000 farmers in all states. The sampling design used was developed to measure, within an error margin of 15%, the input of fertilizers per unit area for major crops in each state (NCAER 1978). The data tables report results for specific crops by irrigation, variety type, and farm size. It is a valuable set of data for many purposes, and bears directly on the issue of adoption of MV and fertilizer by farm size.

NCAER data showing distribution of MV rice area by farm size are given in Table 17. They show a different picture from that conveyed by the unsupported generalizations. Of the 17 states in India, only 6 show any pattern of greater MV adoption by large farmers. In 4 states 40% of the rice area owned by farmers with less than 1 ha was in MV while 66% of the rice area owned by farmers with 10 ha or more was in MV — hardly an overwhelming difference. In the other states, which included the important rice growing states of Bihar, Karnataka, Tamil Nadu, and Uttar Pradesh, small farmers were growing the same percent MVs as large farmers. The study showed that in 8 states large farmers fertilized a higher proportion of their rice fields than small farmers, but in 9 states that did not hold. And finally, in 13 states the small farmers used rates of fertilizer per hectare as high as or higher than those used by big farmers (Table 18).

Other studies relating fertilizer use and farm size are also inconclusive. Palmer (1977) and Barker and Herdt (1978) find that large farmers use more fertilizer. This is true for some Indian, Indonesian, and Pakistani villages. No relation between size and fertilizer is found in other studies (Quasem 1978, Barker et al I971). Therefore, it must be concluded that there is no consistent evidence that MV adoption is linked with farm size.

Tenure: The relation between tenure and adoption is equally inconclusive. Several authors find that more owners than tenants tend to adopt (Islam et al 1972, Islam and Halim 1976, Rajagopalan and Singh 1971, Shin 1981, Bhati 1976, Mangahas 1970, IRRI 1978), but others find no relation at all (Mukherjee 1970, Librero and Mangahas 1975, Chinnappa 1977, IRRI 1978, Mangahas 1970) or are unable to make any definite conclusion (Sajogyo and Collier 1972. Flinn et al 1980, Azaduz-zanan and Islam [n.d.]). Barker et al (1971) found that more tenants tend to be MV adopters and that owner-cultivators tend to apply more fertilizer than other tenure groups. Quasem (1978) reports Bangladeshi data which show that in one tillage. fertilizer use by owners and part-tenants is almost the same, but in other other villages tenure was associated with fertilizer use. In 10 barrios in Gapan, Nueva Ecija, surveyed in 1969, tenure status had no effect on adoption (Huke and Duncan 1969). In contrast, among 160 farmers in West Malaysia, tenure did make a significant difference in both MV and fertilizer adoption (Yim 1978).

Other economic variables. Many other variables that may affect the variable costs associated with new technology use have been studied. Each is examined by several but not all authors. When the farmer's wealth or economic resource base is considered, those with higher incomes tend to be the main adopters (Rajagopalan and Singh 1971, Shim and Shin 1974, Islam and Halim 1976). This is apparently related to the farmer’s ability to get credit as well as to credit institution and program bias against small farmers who usually have the lowest incomes. High inputs to achieve high yields necessitate some source of funds to buy fertilizer and other chemicals, but small farmers can substitute labor for some inputs to achieve high yields. A positive relationship between credit and adoption is welldocumented (Liao 1968, Hossain et al 1972, Chinnappa 1977, Subbarao 1980, Flinn et al 1980). These studies support the hypothesis that differences in variable costs are important but do not support the assertion that adoption will not occur in the absence of a government-run credit program.

There was considerable concern about low market prices of MVs when they were

Table 17. Distribution of area by rice variety type and farm size, India, 1975-76 (NCAER 1978).

State	% of rice area in MV (irrigated and unirrigated)				
	below 1 ha	1-2 ha	24 ha	4-10 ha	> 10 ha
Andhra Pradesh [a]	34.3	43.0	53.5	53.7	49.1
Assam [a]	6.9	2.7	6.3	2.9	11.2
Bihar [b]	34.0	36.4	39.5	25.0	29.2
Gujarat	12.1	2.5	19.8	6.0	2.1
Harayana	72.5	92.5	92.8	86.2	92.6
Himachal Pradesh	3.4	1.8	3.6	3.1	–
Jammu and Kashmir	88.0	75.1	74.9	80.1	–
Karnataka [a]	40.5	49.6	37.9	56.3	23.0
Kerala	48.7	39.8	50.7	100.0	–
Madhya Pradesh	1.7	0.2	1.2	0.6	1.1
Maharashtra	9.8	21.0	8.3	17.9	–
Orissa [a]	28.4	30.5	33.6	35.6	37.9
Punjab	98.9	99.9	100.0	100.0	100.0
Rajasthan	–	–	1.6	11.5	55.6
Tamil Nadu [a]	65.3	59.6	50.5	67.1	19.2
Uttar Pradesh	35.0	33.9	25.6	33.1	21.1
West Bengal [a]	21.3	14.8	19.8	20.9	50.0

[a] Average of summer, winter, and autumn crops. [b] Average of autumn and winter crops.

Table 18. Percent of rice area fertilized and fertilizer (NPK) consumption per ha of rice, India, 1975-76 (NCAER 1978).

State	% of rice area fertilized					Nutrients (kg/ha of fertilized area)				
	below 1 ha	1-2	24	4-10	> 10 ha	below 1 ha	1-2	24	4-10	> 10 ha
Andhra Pradesh [a]	70.4	73.9	87.8	79.6	68.8	112.0	117.9	109.4	101.4	119.5
Assam [a]	1.6	8.6	5.6	3.6	67.0	108.6	43.9	58.7	48.4	8.4
Bihar [b]	27.9	47.0	61.1	46.0	48.2	54.6	51.6	37.0	36.4	31.0
Gujarat	49.1	56.0	64.9	55.8	95.3	72.1	49.1	62.3	63.4	43.9
Haryana	83.2	93.2	96.1	95.0	99.0	91.1	91.7	77.9	96.7	116.8
Himachal Pradesh	41.9	31.2	9.0	40.2	–	38.1	20.1	25.7	28.0	–
Jammu & Kashmir	77.7	72.0	72.2	61.3	–	46.1	46.7	47.8	34.6	–
Karnataka [a]	79.8	85.6	89.3	96.4	100.0	194.2	165.8	133.4	142.3	72.1
Kerala [a]	84.0	86.3	85.4	100.0	–	100.4	103.0	117.4	173.6	–
Madhya Pradesh	0.9	6.6	13.2	15.5	42.2	52.6	50.3	35.8	23.1	17.4
Maharashtra	43.1	53.2	55.9	52.8	63.1	83.5	76.5	53.5	64.3	62.6
Orissa [a]	33.2	38.4	42.6	46.0	60.9	81.2	82.2	85.1	105.9	106.5
Punjab	56.9	71.8	88.4	97.1	100.0	102.8	87.3	92.3	96.0	114.7
Rajasthan	2.1	7.6	32.4	48.2	100.0	143.3	63.1	32.0	44.4	50.5
Tamil Nadu [a]	82.2	89.0	91.3	92.2	100.0	134.7	137.4	121.1	122.6	108.2
Uttar Pradesh	21.6	30.8	44.0	55.2	28.5	47.9	46.1	39.3	38.8	71.4
West Bengal [a]	40.4	38.5	46.5	44.7	100.0	99.9	95.7	77.2	63.4	133.2

[a] Average of summer, winter, and autumn paddy crops. [b] Average of autumn and winter paddy crops.

first introduced (Lao 1968, Mencher 1974, Yoo 1972, Bhati 1974, Rhati 1976), caused in part by the poor taste and eating quality of the early MVs, particularly IR8. In Malaysia, the 1971 withdrawal of the government fertilizer subsidy coincided with low IR5 prices (Bhati 1976), resulting in a cost-price squeeze. The situation was aggravated by the high variability of IR5 prices (which had a coefficient of variation of 7% vs 4.8% for Mahsuri). In this case, risk and cost-price considerations led to the widespread discontinuance of MVs. Low rice prices and the ability of the larger farmers to shoulder higher expenditures are also related (Chourasia and Singh 1972). If rice prices decline, fertilizer will be used, but at lower than recommended levels (Amerasinghe 1974).

The precise difference in the production function of modern and traditional varieties may affect the choice of technology by different farmers. Some observers feel that, contrary to conventional economic theory, farmers rely more on yield than on profit (Bari 1974). In many cases, farmers report that it is high yield that induced them to plant the MVs (Lia 1968, Sajogyo and Collier 1972, Bari 1974, Choi 1974, Bhati 1975, Palmer 1976, Wirasinghe 1977, Fukui 1978, Murshed and Alam 1978). These subjective responses of farmers may, of course, simply be their way of identifying the source of higher incomes. To minimize risks, they may plant more than one MV (Murshed and Alam 1978, Bari 1974, Rochin 1973) and some traditional varieties simultaneously. In many situations, however, farmers have switched to MVs completely.

Empirical studies in all Asian countries agree than irrigation facilities and water control are essential to MV adoption: Liao 1968, Huke and Duncan 1969, Mangahas 1970. Barker et al 1971, Bari 1974, Kumar 1974, Tyagi 1973, Khan 1975, Librero and Mangahas 1975, Palmer 1976, Suh 1976, Palmer 1977, Miruno 1977, Chinnappa 1977, Fukui 1978, IRRI 1978, Yim 1978, Flinn et al 1980. Irrigation water use is independent of farm size (Palmer 1976). Within villages there are usually soil and water differences that distinguish high and low adopters (Suh 1976, Yim 1978). The macrodata discussed in the first part of the paper confirm the importance of irrigation for MV use — those countries and regions within countries with better developed irrigation systems have had faster and more complete MV adoption. Despite this observation, MVs and fertilizer are used in nonirrigated areas of the Philippines, Burma, and India, indicating that irrigation is not a requirement for adoption.

REFFERENCES CITED

Amerasinghe, N. 1974. Efficiency to resource utilization in paddy production on settlement farms in Sri Lanka. Modern Ceylon Studies 5:77-92.

Amerasinghe, N. 1976. Adoption of modern rice technology under peasant farming conditions in Sri Lanka. Farm management Notes tor Asia and the Far East No. 3. July 1976.

Azaduzzanan, Md., and Fazidul Islam. n. d. Adoption of HYVs in Bangladesh: some preliminary hypotheses and tests. Res. Rep. (new) Ser. 23, Bangladesh Institute of Development Studies, Dacca, Bangladesh,

BAEcon (Bureau of Agricultural Economics). 1981. Reports on 15 priority provinces. Philippines, unpublished, annual.

Bangladesh Bureau of Statistics. 1976. Agricultural production levels in Bangladesh (1947-1972). Ministry of Planning, Dacca.

Bangladesh Bureau of Statistics. 1978. The yearbook of agricultural statistics of Bangladesh, 1976-77. Ministry of Planning, Dacca.

Bangladesh Bureau of Statistics. 1979a. 1979 Statistical yearbook of Bangladesh, 1976-77.

Bangladesh Bureau of Statistics. 1979b. Monthly statistical bulletin of Bangladesh. Ministry of Planning, Dacca.

Ban, F. 1974. An innovator in a traditional environment. Comilla, Bangladesh Academy for Rural Development.

Barker, R., and M. Mangahas. 1970. Environmental and other factors influencing the performance of new high yielding varieties of wheat and rice in Asia. *In* The Indian Society of Agricultural Economics. 1971. Papers for discussion at the International Seminar on Comparative Experience of Agricultural Development in Developing Countries since World War II. New Delhi, Oct. 25-28, 1971.

Barker, R., G. Dozina, Jr., and Liu Fu-shan. 1971. The changing pattern of rice production in Gapan, Nueva Ecija, 1965-1970. IRRI Saturday Seminar, December 11, 1971.

Barker, R. and R. W. Herdt. 1978. Equity implications of technology changes. *In* International Rice Research Institute. Interpretative analysis of selected papers from changes in rice farming in selected areas of Asia. Los Baños, Philippines

Battad, F. A. 1973. Factors associated with the adoption of rice technology in Cotabato. Ph D. dissertation, University of the Philippines at Los Baños. (unpubl.)

Beal, G. M., and J. M. Bohlen. 1957. The diffusion process. Iowa State Agricultural Experiment Station Spec. Rep. 18. Ames, Iowa.

Bernsten, R. 1976. Rice farming in Central Luzon: input usage, cultural practices. and yield constraints. International Rice Research Institute Agric. Econ. Pap. 76-6.

Bernsten, R. H., B. H. Siwi, and H. M. Beachell. 1982. The development and diffusion of rice varieties in Indonesia. IRRI Res. Pap. Ser. 71.

Bhati, U. N. 1974. Adoption of modern rice technology and factor product prices. Paper presented at the International Rice Research Conference, International Rice Research Institute, April 22-25, 1974.

__________ . 1975. Use of high-yielding rice variety in Malaysia. The Developing Economies 13(2):187-207.

__________ . 1976. Some social and economic aspects of the introduction of new varieties of paddy in Malaysia: a village case study. Geneva: United Nations Research Institute for Social Development.

Burma Ministry of Planning and Finance. Report to the Pyithu Huittaw, Government of Burma, annual.

Capule, C., and R. W. Herdt. I98 I. Response of non-irrigated rice to fertilizer in farmers' fields in Bangladesh, 1970-75. IRRI Agric. Econ. Dep. paper 81-01.

Chandler, R. F. 1973. The scientific basis for the increased yield capacity of rice and wheat, and its present and potential impact on food production in the developing countries. Pages 25-43 in Thomas T. Poleman and Donald K. Freebairn, eds. Food, population and employment: the impact of the Green Revolution. New York, Praeger Publishers.

Cheong, Chija Kim. 1973. Communication and adoption of family planning and rice production innovation in selected Korean villages. Ph D dissertation, University of the Philippines at Los Baños. (unpubl.)

Chinnappa, B. Nanjuma. 1977. Adoption of the new technology in North Arcot District. Pages 92-123 *in* Farmer, B. H., ed. Green Revolution technology and change in rice-growing areas of Tamil Nadu and Sri Lanka. Boulder, Colorado, Westview Press.

Choi, Min-ho. 1974. An analysis of factors associated with adoption of rice farms practices and yield. J. Korean Agric. Ed. 6(1):34.

Chourasia, R. R., and V. N. Singh. 1972. Economics of local and HYV of paddy and wheat in Panagar Village of Madhya Pradesh. Indian J. Agric. Econ. 27(1):93-98.

Dalrymple, D. G. 1975. Measuring the Green Revolution: the impact of research on wheat and rice production. USDA Foreign Agricultural Economic Rep. 106.

Dalrymple, D. G. 1978. Development and spread of high-yielding wheat and rice in the less developed nations. Foreign Agricultural Report 95. 6th ed. Washington: USDA/ USAID.

David, C. C., and R. Barker. 1978. Modern rice varieties and fertilizer consumption. *In* International Rice Research Institute. Economic consequences of new rice technology. Los Baños, Philippines.

Diamante, T., and J. C. Alix. 1974. An analysis of crop shifting and farm practices of IAS sample farmers in the Philippines. Res. Rep. 3. Bureau of Ag. Economics. Quezon City.

Flinn, J. C., B. Karki, T. Rawal, P. Masicat, and K. Kalirajan. 1980. Rice production in the tarai of Kosi Zone, Nepal. IRRI Kes. Pap. Ser. 54. 15 p.

Franke, D. 1972. The Green Revolution in a Japanese village. Ph D thesis, Harvard University.

Franke, F. R. 1971. India's Green Revolution: economic gains and political costs. New Jersey, Princeton University.

Fukui, H. 1978. Paddy production technology, present and future. Pages 246-271 *in* Yoneo Ishii, ed. Thailand: a rice-growing society Peter and Stephanie Hawkes (trans.). Honolulu, the University Press of Hawaii.

Fukui, H., and T. Nishio. 1979. Environment and technology, paddy growing. *In* Kuchiba. Masuo et al. eds. Three Malay villages: a sociology of paddy growers in West Malaysia. Peter and Stephanie Hawkes (trans.). Honolulu. The University Press of Hawaii.

Griliches, Zvi, 1957. Hybrid corn an exploration in the economics of technological change. Econometrica 25(4):501-522.

Gupta, S. B. Lal. and S. H. Singh. 1966. Impact of development activities on technological changes in Varanasi District. Indian J. Agric. Econ. 21(1): 154-160.

Hakim, Rusli, and H. Nataatmadja. 1980. Targeting research for critical problems. A paper presented at the Symposium on Food Situation and Potentia1 in the Asian and Pacific Region, FFTC, Taipei. Taiwan.

Hamid, M. A. 1975. HYV and IRDP in North Bengal: a case study in natore and Gaibandha TCCAs. *In G. D.* Wood and M. Ameer-ul Huq. The socio–economic implications of introducing HYV in Bangladesh. Proceedings of the international seminar held in April 1975 Comilla: Bangladesh Academy for Kurai Development.

Hayami, Y. 1971. Elements of induced innovation: a historical perspective of the Green Revolution. Paper presented at the 28th International Congress of Orientalists held in Canberra, Australia. Jan. 6-12. 1971.

Hayami, Y. 1975. A century of agricultural growth in Japan: its relevance to Asian development. Tokyo: University of Tokyo Press.

Herdt. R. W., and J. W. Mellor. 1964. The contrasting response of rice to nitrogen: India and the United States. J. Farm Econ. 46(l):150-l60.

Hoque, Md Mahfuzul, A. M. Anwarul Karim, and A. F. M. Serajul Islam. 1972. Information sources used by the IRRI rice growers of Thakurgaon Thana Cooperative Tube-well Project. Graduate thesis summarized in Bangladesh Agricultural University. Research in Agricultural Extension Education. Mymensingh: People's Republic of Bangladesh.

Hossain, Md. Amir, A. M. Anwarul Karim, and Shaikh Golam Mahboob. 1972. Adoption of improved farm practices by the transplanted aman rice growers in Gouripur Union of Mymensingh District. Graduate thesis summarized in Bangladesh Agricultural University. Research in Agricultural Extension Education. Mymensingh: People's Republic of Bangladesh.

Hossain, M. 1977. Farm size, tenancy and land productivity: an analysis of farm level data in Bangladesh agriculture. Bangladesh Dev. Stud. 5(3):285-348.

Huke, R. E. 1982. Rice area by type of culture: South, Southeast, and East Asia. International Rice Research Institute, Los Baños, Philippines.

Huke, R. E., and J. Duncan. 1969. Spatial aspects of HYV diffusion. Paper presented at the Seminar on Economics of Rice Production in the Philippines, IRRI,

Huke, R. E., V. Cordova, and S. Sardido. 1980. San Bartolome: beyond the Green Revolution. IRRI Saturday Seminar, June 7, 1980.

India Directorate of Economics and Statistics. All India estimates of rice. Annual.

India Directorate of Economics and Statistics. Agricultural situation in India. Annual.

IRRI (International Rice Research Institute). 1966. Annual report for 1965. Los Baños, Philippines.

________. 1967. Annual report for 1966. Los Baños, Philippines.

________. 1967a. Annual report for 1967. Los Baños, Philippines.

________. 1975. Changes in rice farming in selected areas of Asia. Los Baños, Philippines.

________. 1978. Interpretative analysis of selected papers from changes in rice farming in selected areas of Asia. Los Baños, Philippines.

IRRI/CAAS (International Rice Research Institute and Chinese Academy for Agricultural Sciences). 1980. Management practices on hybrid rice in China: a proposal.

Islam, Md. Monirul, A. N. M. Shamsuzzoha and Shaikh Golam Mahboob. 1972. Adoption of innovations in the primary agricultural cooperative societies of Commilla Kotwali Thana and its relationship with the characteristics of their leaders. Graduate thesis summarized in Bangladesh Agricultural University. Research in Agricultural Extension Education. Mymensingh: People's Republic of Bangladesh.

Islam, Md. M., and A. Halim. 1976. Adoption of IRRI paddy in a selected union of Bangladesh. Bangladesh Agricultural University.

Kalirajan, K. P. 1979. An analysis of the performance of the high-yielding programme for paddy in Coimbatore District, Tamil Nadu, India. Ph D dissertation, Australian National University. (unpubl.)

Khan, Mahmood Hasan. 1975. The economics of the green revolution in Pakistan. New York, Praeger Publishers.

Kikuchi, M., and Y. Hayami. 1978. Agricultural growth against a land resource constraint: a comparative history of Japan, Taiwan, Korea and the Philippines. J. Econ. History 38(4):839-864.

Kim, In Hwan. 1978. Green Revolution in Korea: development and dissemination of new varieties. English ed. Association for Potash Research, Seoul, Korea.

Kolshus, H. J. 1972. Modernization of paddy rice farming in Northeast Thailand with special reference to use of fertilizer. Ph D dissertation, University of Kentucky. (unpubl.)

Kumar, Praduman. 1974. An economic study of water management programme in Sambalpur District (Orissa). Indian J. Agric. Econ. 29(2):43-51.

Kuo, Leslie T., 1972. The technical transformation of agriculture in Communist China. New York, Praeger Publishers.

I.iao, D. S. N. 1968. Studies on adoption of new rice varieties. Paper presented at the IRRI Saturday Seminar, 9 November 1968.

Librero A., and M. Mangahas, 1975. Socioeconomic implication of high-yielding varieties: evidence from primary data. IEDR discussion Paper 75-10. UP School of Economics, Diliman, Quezon City

Lu, Hsueh-Li, 1968, Some socioeconomic factors affecting the implementation at the farm level of rice production program in the Philippines, Ph D dissertation, University of the Philippines at Los Baños. (unpubl.)

Mahbub-e-Illah, Shahjada. 1974. Farmers' knowledge of modern agriculture and adoption of improved practices. Comilla, Bangladesh Academy for Agricultural Development.

Mandal, G. C. and M. Ghosh. 1973. Social and economic implications of the large scale introduction of high-yielding varieties of food grains in the eastern region of India Santiniketan Agro-economic Research Center.

___________ . 1976. Economics of the Green Revolution: a study in East India. Bombay, Asia Publishing House.

Mangahas, M. 1970. An economic analysis of the diffusion of new rice varieties in Central Luzon, Ph D dissertation, University of Chicago (unpubl.)

Mangahas, M., and A. Librero, 1973. Study on the social and economic effects of the introduction of HYVs: Part II. Geneva: United Nations Research Institute for Social Development.

Mansfield, F., 1961. Technical change and the rate of imitation. Econometrica 29(4):741-766.

Mencher, Joan P. 1974. Conflicts and contradictions in the Green Revolution: the case of Tamil, Nadu, Econ. Pol. Weekly 9(6-8):309-323.

Mizuno, Koichi. 1977. Comparative analysis of rural development-rice-growing villages in Thailand and Malaysia, South East Asian Stud. 15(3):398-420.

Mukherjee, P. K. 1970. The HYV Programme: variables that matter. Econ. Pol. Weekly 5(49):1980.

Mukherjee, P.K., and B. Lockwood. 1971. High-yielding varieties programme in India assessment. Paper presented at the 28th International Congress of Orientalists, Can berra, January 6-12, 1971

Muqtada, M. 1975. The seed-fertilizer technology and surplus labor in Bangladesh agriculture, Bangladesh Dev. Stud. 3(4):403-428.

Muranjan, S. W. 1968. Study of high yielding variesties programme in a district in Maharashtra (Paddy 1966-67). Gokhale Institute Monogr. Ser. 4. Poona: Gokhale Institute of Politics and Economics

Murshed, S. M. M., and M. S. Alam. 1978. Farmer's preferences for different varieties of aman paddy and the uses of production inputs in an area of Bangladesh, Bangladesh J. Agric. Econ. 1(1):114-122.

NCAER (National Council of Applied Economic Research). 1978. Fertilizer demand study interim report. Vol. 2-6. New Delhi.

Pal, A. G. 1969. The adoption of a new variety (IR8) in a Philippine community. MS thesis, University of the Philippines at Los Baños, June 1969, (unpubl.)

Palacpac, A. 1982. World rice statistics, International Rice Research Institute, Los Baños, Philippines.

Palmer, I. 1974. The new rice in monsoon Asia. United Nations Research Institute for Social Development. Geneva (draft in 3 vols.)

Palmer, I. 1976. The new rice in Asia: conclusions from four country studies. United Nations Research Institute for Social Development. Geneva.

Panse, V. G. and D. Singh. 1966. Promotion and assessment of technological change in Indian agriculture. Indian J. Agric. Econ. 26(1):121-131.

Parthasarathy, G., and D. S. Prasad. 1978. Response to the impact of the new rice technology by farm size and tenure, Andhra Pradesh, India. Page 111-128 *in* International Rice Research Institute. Interpretative analysis of selected papers from Changes in rice farming in selected areas of Asia. Los Baños, Phillippines.

Pearl, R. 1924. Studies in human biology. Baltimore.

Pray, C. 1980. An assessment of the accuracy of the official agricultural statistics in Bangladesh, Bangladesh Dev. Stud. 8(1&2): 1-38.

Quasem, Md. Abul. 1978. Factors affecting the use of fertilizer in Bangladesh. Bangladesh Dev. Stud. 6(3):331-338.

Rahman, Radzuan bin Abdul, and T. F. Weaver. 1969 lnnovation and the adoption process in rice double-cropping. Paper presented at the Agricultural Institute of Malaysia Rice Symposium held August 8–9, 1969) in Kuala Lumpur, Malaysia.

Rajagopalan, C., and Jaspal Singh. 1971. Adoption of agricultural innovations:a sociological study of the lndo German project. Mandi. Delhi: National Publishing House.

Ramaswamy, Dwarakinath. 1973. Adoption incentives related to packages of practices of high-yielding varieties in Mysore State. India. Ph D dissertation. Cornell University. (unpubl.)

Rawal, Tilak. 1979. Analysis of factors affecting adoption of modern varieties in southern belt of Kosi Zone. Nepal. MS thesis, University of the Philippines at Los Baños, Laguna. Philippines.

Rochin, R. 1973. A study of Bangladesh farmers' experience with IR20 rice variety and complementary production inputs. The Bangladesh Econ. Rev. 1(1):71-Y4.

Rogers, E. M. 1962. Diffusion of innovations. Free Press of Glencoe, New York.

Sajogyo, and W. L. Collier. 1972. Adoption of high-yielding varieties by Java's farmers. Res. Note 7 (May 1972), Agroeconomic Survey, Indonesia.

Samson, Robert L. 1970. The economics of insurgency in the Mekong Delta Vietnam. Massachusetts: The M IT Press.

Savale, R. S. 1966. Technology change in agriculture: study of source of its diffusion, efficacy of these sources and the economic factors affecting the adoption of improved practices Indian J. Agric. Econ. 21(l):l99-208.

Schutjer, Wayne A. and Marlin G. Vander Veen. 1976. Economic constraints on agricultural technology adoption in developing nations. Dept of Ag. Economics and Rural Sociology Paper 124. Penn. State University.

Sharma, J. S. and S. K. Terwari. 1980. Economic constraints at farm level in transfer of technology in Indian Agricultural Research Institute. Economic Problems in Transfer of Agricultural Technology. Research Bulletin No. 27:21-35.

Shen, Jin-Hua. 1980. Rice breeding in China. Pages 9-30 *in* International Rice Research Institute and Chinese Academy for Agricultural Sciences. Rice improvement in China and other Asian countries. Los Baños, Philippines.

Shetty, N. S. 1966. Inter-farm rates of technological diffusion in Indian agriculture. Indian J. Agric. Econ. 21(1):189-198.

Shim, Young Ko and Dong-wan Shin. 1974. Effects of the spread of Tongil rice variety. Office of Rural Development: 11-45.

Shin, Dong Win. 1981. The Korean experience of agricultural extension work with emphasis on rice production. Paper presented at the World Hank Symposium, Washington, D. C. January 5-6.

Subbarao, K. 1980. Institutional credit, uncertainty and adoption of HYV technology: a comparison of East U.P. with West U. P. Indian J. Agric. Econ. 35(1):69-90.

Suh, Wan Soo. 1976. Factors affecting the rate of adoption of Tongil rice variety in selected locations of Korea. MS thesis, University of the Philippines at Los Baños, Philippines. (unpubl.)

Sumayao, B. R. 1969. The Bicolano farmer's response to an improved rice variety — IR8-288-3. University of the Philippines College of Agriculture, Laguna.

Tang, A. M., and B. Stone. 1980. Food production in the People's Republic of China. IFPRI Res. Rep. 15, Washington, D. C.

Tyagi, B. N. 1974. A study of the impact of Green Revolution on the regional development of agriculture in Uttar Pradesh. Research note. Indian J. Agric. Econ. 29(4):44–54.

Wang, In-Keun. 1967. Relationship of recommended farm practices with selected variables in three Korean communities. Suweon, Korea, Dept. of Agricultural Economics, Seoul National University.

Wirasinghe, Suranimala. 1977. Adoption of high-yielding rice farming practices by the rice farmers in the Ampara District, Republic of Sri Lanka. MS thesis, University of the Philippines at Los Baños, (unpubl.)

Win, Kin U, U Nyi Nyi, and E. C. Price. 1981. The impact of a special high-yielding rice program in Burma. IRRI Res. Pap. Ser. 3.

Yim, Kong Ming. 1978. An economic analysis of factors affecting HYV and fertilizer adoption in the province of Negeri Sembilan, Peninsular Malaysia. MS thesis, University of the Philippines at Los Baños, Philippines. (unpubl.)

Yoo, Chul-ho. 1972. Farm income and resource use of Tongil rice farm in selected villages. MS thesis, College of Agriculture, Seoul National University. (unpubl.)

Appendix Table 1. Area of rice in Bangladesh by season and variety group, 1966-67 to 1979-80 (Bangladesh Bureau of Statistics 1976, 1978. 1979a, b).

	Aman			Aus			Boro			All rice crops		
	Local	HYV[a]	Total	Local	HYV	Total	Local	HYV[a]	Total	Local	HYV[a]	Total
1966-67			5,689.4			2,818.6			562.5			9,070.5
1967-68			5,941.5			3,326.9	557.6	63.1	620.7	9,826.0	63.1	9,889.1
1968-69			5,827.4	3,092.2	6.5	3,098.7	670.1	145.7	815.8	9,589.7	152.2	9,741.9
1969-70	5,994.1	11.7	6,005.8	3,407.0	17.4	3,424.4	649.1	234.7	883.8	10,050.2	263.8	10,314.0
1970-71	5,659.0	80.9	5,739.9	3,158.5	32.4	3,190.9	634.5	346.8	981.3	9,452.0	460.1	9,912.1
1971-72	5,158.0	253.3	5,411.3	2,952.9	49.0	3,001.9	562.5	321.7	884.2	8.673.4	624.0	9,297.4
1972-73	5,156.4	558.1	5,714.5	2,863.9	66.4	2,930.3	544.7	440.3	985.0	8,565.0	1,064.8	9,629.8
1973-74	4,892.6	826.8	5,719.4	2,975.2	133.1	3,108.3	461.7	588.4	1,050.1	8,329.5	1,548.3	9,877.8
1974-75	4,949.2	501.4	5,450.6	2,896.7	282.9	3,179.6	502.6	659.2	1,161.8	8,348.5	1,443.5	9,792.0
1975-76	5,204.2	556.8	5,761.0	3,067.5	352.9	3,420.4	505.8	642.2	1,148.0	8,771.5	1,551.9	10,329.4
1976-77	5,385.9	423.3	5,809.2	2,853.0	364.6	3,217.6	313.2	541.5	854.7	8,552.1	1,329.4	9,881.5
1977-78	5,272.6	498.6	5,771.2	2,776.5	385.7	3,162.2	452.0	641.8	1,093.8	8,501.1	1,526.1	10,027.2
1978-79	5,120.0	685.9	5,805.9	2,820.2[b]	415.2[b]	3,235.4	404.7	667.3	1,072.0	8,344.9	1,768.4	10,113.3
1979-80	5,102.1	871.9	5,974.0	2,634.7	402.4	3,037.1	425.1	723.7	1,148.8	8,161.9	1,998.0	10,159.9
1980-81	5,075.5	961.6	6,037.1	2,625.9	485.6	3,111.5	413.6	746.7	1,160.3	8,115.0	2,193.9	10,308.9
1981-82	5,055.6	955.6	6,011.2	2,674.2	471.9	3,146.1	404.9	897.6	1,302.5	8,134.7	2,325.1	10,459.8

[a]Including area of Pajam, which is similar in characteristics, yield, and appearance to "official" HYVs, but is recorded separately in official Statistics. [b]Derived from published figures on HYV aman, HYV boro, and total HYV area for 1978-79, data provided by C. G. Swenson and C. Miller.

Appendix Table 2. Production of rice (milled) in Bangladesh by season and variety groups, 1966·67 to 1981·82 (Bangladesh Bureau of Statistics 1976, 1978. 1979a, b).

Year	Aman			Aus			Boro			All rice crops		
	Local	HYV[a]	Total	Local	HYV[a]	Total	Local	HYV[a]	Total	Local	HYV[a]	Total
1966·67			5,369.6			2,425.8			753.9			8,549.3
1967·68			6,179.7			2,784.1	797.4	213.2	1,010.6		213.2	9,974.4
1968·69			6,232.3	2,412.2	21.8	2,434.0	988.8	472.6	1,461.4		412.6	10,127.7
1969·70	6,270.4	33.6	6,304.0	2,637.2	50.8	2,688.0	947.1	779.3	1,726.4	9,854.7	863.7	10,718.4
1970·71	5,170.9	192.3	5,363.2	2,501.1	96.2	2,597.3	911.7	1,076.8	1,988.5	8,583.7	1,365.3	9,949.0
1971·72	4,535.0	630.5	5,165.5	2,006.7	117.0	2,123.7	700.3	876.3	1,576.6	7,242.0	1,623.8	8,865.8
1972·73	4,179.4	889.0	5,068.4	1,911.4	151.5	2,062.9	663.1	1,215.6	1,878.7	6,753.9	2,256.1	9,010.0
1973·74	4,301.8	1,775.3	6,077.1	2,196.3	345.6	2,541.9	552.5	1,461.5	2,014.0	7,050.6	3,582.4	10,633.0
1974·75	4.471.5	971.6	5,443.1	1,963.1	630.5	2,593.9	563.4	1,477.8	2,041.2	6,998.0	3,079.9	10,077.9
1975·76	5,295.2	1,095.9	6,391.1	2,151.8	778.4	2,930.2	592.4	1,481.4	2,073.8	8,039.4	3,355.7	11,395.1
1976·77	5,450.3	814.6	6,264.9	1,983.1	748.4	2,731.5	318.4	1,178.4	1,496.8	7,751.8	2,741.4	10,493.2
1977·78	5,694.3	1,038.7	6,733.0	2,011.2	804.7	2,815.9	578.8	1,452.4	2,031.2	8,284.3	3,295.8	11,580.1
1978·79	5,383.2	1,356.2	6,739.4	2,113.7[b]	869.1[b]	2,982.8	379.2	1,370.7	1.749.9	7,876.1	3,596.0	11,472.1
1979·80[c]	5,594.8	1,708.0	7,302.8	1,979.2	830.1	2,807.3	545.5	1,881.4	2.426.9	8,119.5	4,419.5	12.539.0
1980·81	5,902.0	2,060.1	7,962.1	2,213.6	1,074.8	3,288.4	640.4	1,989.6	2,630.0	8,756.0	5,124.5	13,880.5
1981·82	5,540.5	1,667.6	7,208.1	2,246.9	1,022.5	3,269.4	636.8	2,515.1	3,151.9	8,424.1	5,205.2	13,629.4

[a]Includes Pajam variety. [b]Derived from published figures on HYV aman, HYV boro, and total HYV rice production for 1978·79. [c]Data for 1979-80 to 1981-82 provided by C. Miller.

Appendix Table 3. Sown area and production of high yield varieties and all rices, Burma (Dalrymple 1978, Burma Ministry of Planning and Finance).

Year	Area (thousand ha)		Production (thousand t)		All rice		Yields (t/ha)		
	MVs[a]	IVs	MVs	IVs	Area (thousand ha)	Production (thousand t)	MVs	IVs	Others
1965-66	0	-	n.a.	n.a.	4,848	8,258	n.a.	n.a.	1.70
1966-67	0	-	n.a.	n.a.	4,513	6,285	n.a.	n.a.	1.39
1967-68	3.4	-	n.a.	n.a.	4,706	7,941	n.a.	n.a.	1.69
1968-69	166.9	-	n.a.	n.a.	4,764	8,200	n.a.	n.a.	1.72
1969-70	143.0	-	n.a.	n.a.	4,954	7,129	n.a.	n.a.	1.44
1970-71	190.9	190.2	457.4	345.4	4,975	7,287	2.40	1.82	1.41
1971-72	185.1	216.4	478.8	399.7	4,978	7,299	2.59	1.85	1.40
1972-73	199.2	280.3	474.7	542.1	4,862	6,568	2.38	1.93	1.27
1973-74	245.6	319.1	632.1	615.7	5,089	7,680	2.57	1.93	1.42
1974-75	327.7	369.6	847.0	629.5	5,177	7,664	2.58	1.70	1.40
1975-76	407.3	487.7	1,026.7	943.7	5,204	8,221	2.52	1.94	1.45
1976-77	449.9	410.3	1,185.6	832.5	5,078	8,320	2.64	2.03	1.49
1977-78	495.8	511.1	1,317.3	1,041.3	5,136	8,449	2.66	2.04	1.47
1978-79	650.6	885.9	1,825.2	2,012.6	5,244	9,400	2.81	2.27	1.50
1979-80[b]	948.4	777.4	2,619.3	1,541.4	5,026	9,329	2.76	1.98	1.57
1980-81[b]	1,501.8	909.1	4,346.7	2,156.0	5,117	11,890	2.89	2.37	1.99

[a]Main MVs include Yagyaw 1 (lR8). Yagyaw 2 (IR5). C4-63, Ngwetoe, Marawhari (Mashuri), Shwe War Hun (a mutant of IR5). [b]Provisional actual. [c]Provisional.

Appendix Table 4. Area of rice and area under MVs in India, 1966-78 (India Directorate of Economics and Statistics).

State	Rice area (thousand ha)													
	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	% of total [a]
							Modern varieties							
Andhra Pradesh	275	351	205	522	542	725	1,200	1,811	2,413	2,477	2,400	2,425	2,500	63
Assam	2	21	61	101	134	200	274	280	321	328	400	450	520	23
Bihar	67	256	269	324	340	440	452	600	645	768	1,000	1,300	1,700	30
Gujarat	–	54	27	28	49	60	86	88	94	172	194	200	220	47
Havana	–	4	11	20	30	70	92	125	144	169	190	230	250	54
Jammu and Kashmir	8	51	119	121	109	109	140	160	165	180	193	200	230	94
Karnataka	24	45	75	121	156	160	202	280	334	575	400	500	600	55
Kerala	70	21	220	136	159	168	190	275	167	150	325	360	500	63
Madhya Pradesh	53	32	132	209	276	400	407	801	900	1,150	1,194	1,500	1,700	35
Maharashtra	76	68	129	185	216	232	217	393	363	539	869	918	1,000	67
Orissa	46	121	146	173	182	253	400	360	313	482	530	800	1,100	25
Punjab	7	17	27	72	130	311	378	412	481	517	525	740	750	71
Tamil Nadu	152	442	639	1,142	1,819	2,245	2,245	2,144	1,860	2,170	2,200	2,200	2,250	82
Uttar Pradesh	69	150	331	561	677	994	925	978	1,425	1,593	1,651	1,800	1,900	37
West Bengal	26	131	226	460	527	704	690	786	871	1,053	1,290	1,600	1,975	41
All India	888	1,785	2,681	4,253	5,453	7,199	8,107	9,718	10,780	12,742	13,731	15,516	17,619	44
							Total rice							
All India	35,598	36,437	36,966	37,680	37,592	37,758	36,688	38,285	37.888	39,475	38,511	40,283	40,482	

[a] For 1978-79.

Appendix Table 5. Estimated yields of MVs and other rices in selected states of India (India Directorate of Economics and Statistics).

	Paddy yield[a] (t/ha)																			
	1968-69		1969-70		1970-7 1		1971 -72		1972-73		1973-74		1974-75		1975-76		1976-77		1977-78	
	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others	MVs	Others
Andhra Pradesh	3.02	2.07	2.84	2.00	3.15	1.84	3.38	2.00	3.08	1.56	2.96	1.93	2.94	1.27	2.99	1.60	2.70	1.26	2.73	1.46
Assam																	1.69	1.42	2.83	1.28
Bihar									2.48	1.31	1.95	1.11	2.33	1.16	2.12	1.26	2.15	1.15	1.84	1.36
Gujarat	0.91	0.69	2.82	1.26	3.52	1.64	2.91	1.45	1.26	0.35					3.78	0.72	2.24	1.57	2.71	1.85
Haryana					3.57	2.44	3.69	2.47	2.81	2.19	4.13	1.75	2.16	2.11	4.07	1.85	4.35	2.83	4.15	3.39
Himachal Pradesh																			2.24	1.09
Jammu & Kashmir	3.57	2.54													3.17	0.89				
Karnataka	4.04	2.41	3.90	3.01	3.80	2.33	3.82	2.64					3.94	1.98	3.32	2.39				
Kerala	4.69	1.51	2.74	1.97	3.14	2.02	3.48	2.04	2.84	2.23	2.36	2.06	2.70	2.17	2.72	2.15	2.40	2.16	2.99	2.00
Madhya Pradesh	1.80	1.00	1.30	1.10	1.76	1.23	1.65	1.19	1.63	0.95	1.86	1.06			1.57	1.15			1.94	1.20
Maharashtra	3.42	1.30	2.42	1.41	3.38	1.55	2.84	1.27	2.76	0.49			2.60	1.22	3.04	1.98	2.63	1.03	2.72	1.46
Orissa	2.20	1.62	2.23	1.41	2.56	1.40	2.63	1.08	2.20	1.25			1.68	1.02	1.82	1.41	1.76	1.04	1.87	1.42
Punjab	3.20	1.94	3.12	2.04	3.45	2.25	3.85	1.30	3.31	1.84	4.06	1.02								
Tamil Nadu	2.77	2.14	3.04	2.14	3.21	2.44	3.42	0.59	3.53	0.71	3.49	1.61			3.46	0.73			3.22	1.93
Uttar Pradesh																			1.99	1.12
West Bengal											3.47	1.35								

[a] Some states do not have data for MV yield for some years.

Appendix Table 6. Area planted to wetland rice varieties by major type, 1971-79 wet and dry seasons, Indonesia (Bernsten et al and H. Oka, pers. communication).

Year	Prea (ha)							
	Local			MVs				All varieties
	Traditional[a]	Improved[b]	Total	Nonresistant[c]	Biotype 1[d]	Biotypes 1+2[e]	Total	
				Wet Seasons				
1971-72	1,676,685	915,971	2,593,604	1,161,011	-	-	1,161,011	5,753,667
1972-73	2,141,601	716,247	2,857,848	1,227,019	-	-	1,227,019	4,084,867
1973-74	1,600,829	524,740	2,125,569	2,082,643	-	-	2,082,643	4,208,212
1974-75	1,531,904	440,098	1,972,002	2,243,669	-	-	2,243,669	4,215,671
1975-76	1,770,899	441,311	2,212,210	2,118,068	304.374	1	2,422,443	4,634,653
1976-77	1,694,388	399,718	2,094,106	1,503,655	1,170,475	13,229	2,687,359	4,781,465
1977-78	1,861,660	342,511	2,204,171	1,075,422	1,078,059	836,985	2,990,466	5,194,637
1978-79	1.81 1,579	293,798	2,105,377	989,605	567,633	1,614,343	3,201,581	5,306,958
1979-80	1,525,949	122,315	1,648,264	489,229	303,965	2,558,023	3,352,023	5,000,287
1980-81	1,414.904	97,261	1,512,165	370,469	n.a.	3,195,732	3,340,082	5,078,360
				Dry seasons				
1972	965,751	551,600	1,517,351	685,855	-	-	686,855	2,204,206
1973	1,083,678	342,736	1,426,414	1,051,934	-	-	1,051,934	2,478,348
1974	1,059,340	347,513	1,406,853	1,143,762	-	-	1,143,762	2,550,615
1976	943.1 13	169,605	1,112,718	952,698	408,503	680	1,361,881	2,474,599
1977	779,203	167,271	946,474	628,759	770,454	64,112	1,463,325	2,409,799
1978	936,209	119,930	1,056,139	528,605	542,034	739,952	1,810,591	2,866,730
1975	832,801	79.656	912,357	392,287	221,926	1,400,110	2,014,323	2,926,780
1980	840,775	75,140	915,915	199,837	n.a.	1,649,736	1,769,100	2,765,488

[a] Traditional varieties. [b] Improved = national improved varieties. [c] Susceptible to brown planthopper (BPH) biotypes 1 and 2; including Pelita I-1, Pelita 1-2, C4-63, PB5, PB8. [d] Resistant to biotype 1, but susceptible to biotype 2; includes PB26, PB28, PB29, PB30, PB34, Brantas, Serayu, Citarum, and Asahan. [e] Resistant to biotypes 1 and 2; includes PB32, PB36, and PB38.

Appendix Table 7. Area planted to 3 MV types in Sri Lanka (Sri Lanka Department of Agriculture).

Year	MV and IV area planted (thousand ha)									
	Maha				Yala				Total all seasons	Total all rice
	H[a] series	IR[b] series	BG[c] series	Total	H[a] series	IR[b] series	BG[c] series	Total		
1964-65	189.0	–	-	189.0	56.7	–	–	56.7	245.7	621.0
1965-66	214.1	–	–	214.1	78.1	–	–	78.1	292.2	503.0
1966-67	265.1	–	–	265.1	100.8	–	–	100.8	365.9	612.0
1967-68	286.9	–	–	286.9	102.4	–	–	102.4	389.3	634.0
1968-69	324.6	6.9	–	331.5	114.1	2.8	–	116.9	448.4	661.0
1969-70	332.6	22.3	–	354.9	114.5	8.9	–	123.4	478.3	623.0
1970-71	294.6	20.2	1.2	316.0	129.5	12.5	39.7	181.7	497.7	719.0
1971-72	262.6	17.8	40.5	320.9	49.0	7.7	52.6	109.3	430.2	692.0
1972-73	155.4	9.3	144.9	309.6	31.2	3.2	93.1	127.5	437.1	639.0
1973-74	136.8	5.3	221.4	363.5	25.9	2.0	167.5	195.4	558.9	824.8
1974-75	123.8	1.6	163.1	288.5	33.2	1.6	126.7	161.5	450.0	695.8
1975-76	140.4	2.4	189.8	332.6	26.3	1.6	126.3	154.2	486.8	717.1
1976-77	136.8	1.6	271.9	410.3	30.4	1.2	162.7	194.3	604.6	828.1
1977-78	123.8	0.8	305.9	430.5	23.5	0.04	189.0	212.5	643.0	875.4
1978-79	103.2	0.8	325.0	429.0	16.2	0.04	165.5	181.7	610.7	845.9
1979-80	120.3	0	366.1	486.4	21.6	0	196.3	217.9	704.3	844.7
1980-81	114.1	0	404.3	518.4	21.8	0	207.8	229.6	748.0	863.7

[a] "H" series: H6, H7, H8, H9, H10. [b] IR series: IR8, IR26, IR262. [c] BG series: BG/11-11, BG/348, BG/34-8, BG/34-11, BG/34, BG13-5, BG/33-2, BG/90-2, BG/94-1, BG/94-2.

Appendix Table 8. Land types and fertilizer response functions used for each type in the model estimating separate effects of specified factors.

Country	Land, variety, type	Response function kg/kg		
		Constant	Coeff of N	Coeff of N^2
Burma	Irrigated, modern	2,500	20.0	–.065
	Irrigated, improved	2,100	18.0	–.065
	Rainfed, modern and improved	1,800	15.0	–.110
	Rainfed, traditional	1,700	12.0	–.085
	Dryland	800	0	0
Bangladesh	Irrigated, boro, modern	2,600	18.0	–.065
	Irrigated, aus, aman, modern	2,200	17.0	–.065
	Rainfed, all seasons, modern	2,100	15.0	–.110
	Irrigated, all seasons, traditional	2,000	14.0	–.075
	Dryland	1,600	0	0
China	Irrigated, hybrid	3,400	22.0	–.045
	Irrigated, modern	3,100	18.0	–.004
	Irrigated, traditional	2,800	14.0	–.005
	Rainfed, all types	2,000	9.0	–.045
	Dryland	800	0	0
India	Irrigated, modern, north, south, west	2,300	18.0	–.065
	Irrigated, modern, other regions	2,000	17.0	–.065
	Rainfed, modern, all states	1,900	15.0	–.110
	Irrigated, traditional, all states	1,800	14.0	–.075
	Dryland	850	0	0
Indonesia	Tech. irrigated, modern	2,600	20.0	–.060
	Other irrigated, modern	2,300	16.0	–.080
	Other irrigated, traditional	2,300	14.0	–.100
	Rainfed, other varieties	1,600	10.0	–.120
	Dryland	1,200	0	0
Philippines	Irrigated, modern	2,000	19.0	–.090
	Irrigated, traditional	1,600	11.0	–.130
	Rainfed, modern	1,200	16.0	–.110
	Rainfed, traditional	1,200	9.0	–.160
	Dryland	800	0	0
Thailand	Irrigated, modern, dry season	2,600	18.0	–.065
	Irrigated, modern, wet season	2,200	16.0	–.095
	Irrigated, traditional, dry season	2,100	15.0	–.110
	Irrigated, traditional, wet Season	2,000	14.0	–.075
	Rainfed wetland and dryland	1,600	0	0
Sri Lanka	Irrigated, modern, yala	2,700	20.0	–.065
	Irrigated, modern, maha	2,500	18.0	–.075
	Irrigated, old improved	2,300	16.0	–.100
	Rainfed, all types	1,800	14.0	–.120
	Dryland	800	0	0

Appendix Table 9. Rice production and intensification program, Indonesia, 1964-78 (R. Hakim and H. Nataatmadja 1980).

Year	Harvested area (thousand ha)			Yield [a] (t/ha)		Aggregate	Total production (thousand t)
	Internsi-fication	Non-intensi-fication	Total	Intensi-fication	Non-intensi-fication		
1964	.1	6,980	6,980	3.69	1.21	1.21	8,420
1965	10	7,318	7,328	2.57	1.21	1.22	8,877
1966	540	7,351	7,691	2.55	1.15	1.21	9,339
1967	522	6,994	7,516	2.28	1.12	1.20	9,047
1968	1,597	6,423	8,020	1.51	1.39	1.45	11,667
1969	2,130	5,884	8,014	1.89	1.40	1.53	12,249
1970	2,153	5,982	8,135	2.18	1.41	1.62	13,140
1971	2,788	5,537	8,325	2.05	1.45	1.65	13,724
1972	3,160	4,729	7,898	2.26	1.27	1.67	13,183
1973	3,988	4,415	8,403	2.20	1.32	1.74	14,607
1974	3,723	4,786	8,506	2.27	1.42	1.80	15,276
1975	3,637	4,858	8,495	2.22	1.43	1.80	15,185
1976	3,614	4,754	8,368	2.38	1.52	1.90	15,845
1977	4,249	4,111	8,360	2.27	1.52	1.88	15,876
1978	4,834	4,059	8,893	2.34	1.55	1.98	17,598

[a] Milled rice.

Errata

Page 9 In Table 3 caption, insert *paddy* to read *comparative paddy yields.*
In the last column, add *(t/ha)* after *National average yields.*

Page 10 In Figure 3 caption, insert *paddy* to read *Rice paddy yield trends.*

Page 13 In the first column of Table 6, the first two rows should read:
1965-66
1966-67

Page 16 In Table 8 caption, the second line should read: *Ministry of Agriculture).*
In the tablefootnote, the last line should read *all rice is the area planted to dryland (upland)* rice.

Page 23 In line 2 of paragraph 3, change *Kanara* to *Kinara.*
In Table 11, change the heading *South Kamara* to *South Kinara.*

Page 38 In row 5 of Table 17, change *Harayana* to *Haryana.*

Page 39 In line 10, change *Lia to Liao.*
The BAEcon entry in References Cited should read: BAEcon (Bureau of Agricultural Economics). Palay: Area harvested by crop type and variety by region, Philippines. (unpubl. mimeo.)

Page 40 In the Burma reference, change *Huittaw* to *Hluttaw.*

Page 46 In Appendix Table 1 caption, change *1979-80* to *1981-82.*
In column 1, change *1979-80* to *1979-80*[c]*.*
In footnote [b], delete *and C. Miller,*
Add the following footnote: 'Data for 1979-80 to 1981-82 provided by C. **Miller.**