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THE DEVELOPMENT AND DIFFUSION OF RICE VARIETIES IN INDONESIA

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ABSTRACT

The area planted in the major rice environments of Indonesia is reported and the rice breeding objectives for each environment are described. The procedures in the present rice breeding efforts are outlined and the institutional setting for varietal improvement is discussed. The history of varietal improvement is reviewed and the introduction and diffusion of modern semidwarf, fertilizer-responsive rice varieties in Indonesia is discussed in detail. Extensive tables of data show the proportion of area planted to the most widely grown varieties for the major rice-growing provinces of Indonesia from 1976 to 1979. Indonesia's BIMAS (extension) program and the impact of modern rices on yields and production are discussed in the final sections of the paper.

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THE DEVELOPMENT AND DIFFUSION OF RICE VARIETIES IN INDONESIA

Since 1965, the rice economy of Indonesia has undergone a transformation attributable to numerous interacting factors. New technology, in the form of modern rice varieties, inorganic fertilizers, rehabilitation and expansion of irrigation systems, and improved management practices made a major contribution. Much credit must also go to the accelerated production program (Bimas), which took research results to farmers' fields and provided effective organization of farmers' groups. Finally, government input and output pricing policies created incentives for farmers to apply the available technology.

In combination these factors enabled Indonesia, with higher yields and cropping intensification, to substantially increase total rice production.

As a consequence of the changes since 1965, Indonesia's agricultural milieu has changed substantially. Researchers and policy makers face problems that did not exist when farmers planted a single crop of a local variety and kept inputs low. Because the development and diffusion of new technology is a complicated process, other problems will arise in the next decade.

RESEARCH OBJECTIVES FOR MAJOR RICE ENVIRONMENTS

Rice is grown on a wide variety of land in Indonesia. The relative proportion of the land in each rice environment on each island is shown in Figure 1.

The varietal improvement program of the Central Research Institute for Food Crops (CRIFC) has identified high yield, intermediate amylose content, and disease and insect resistance as breeding objectives in all rice environments. Within each the varietal development program attempts to incorporate specific traits that will increase productivity in that environment.

Irrigated wetland

Irrigated wetland constitutes about 53% of Indonesia's rice area, 86% of which is in Java-Bali and Sumatra (Table 1). Irrigation systems in Indonesia are classified as technical, semitechnical, or simple. About 66% of the irrigated area has technical and semitechnical systems managed by the Public Works Department and characterized by a well developed infrastructure. Those areas usually grow at least two rice crops/year (Nyberg and Prabowo 1979). The simple systems (sederhana) have small command areas and are maintained and managed at the village level. They have no measurement of water flow.

For the irrigated wetlands, the breeding goals are to develop varieties with strong seedling vigor, moderately high tillering ability, erect leaves, intermediate to short height (100-130 mm), lodging resistance, 90-135 day maturity, intermediate threshability, and responsiveness to 90-135 kg N/ha. Also, because increased disease and insect problems have developed with intensified production, high priority is placed on developing rices with resistance to bacterial leaf blight, grassy stunt, ragged stunt, tungro virus, and brown planthopper (Siwi and Beachell 1980).

Rainfed wetland

Rainfed wetland rice covers 26% of Indonesia's total rice land (Table 1). A single rainfed wetland crop is planted at the beginning of the wet season and intermediate- to late-maturing varieties are usually grown.

In most of Indonesia, irrigation is not needed for the first rice crop. In years when the rains start late, however, land preparation and transplanting are delayed (Effendi et al 1979a). Also, some areas frequently have early flooding. To reduce crop damage from late rains or flooding, dry seeding (gogo rancah) is practiced on rainfed and poorly irrigated farms in parts of Java and Madura. For gogo rancah, seed is dibbled directly into the dry soil at the beginning of the rainy season and the crop grows as dryland rice until rainfall is sufficient to submerge the fields. During the rest of the season, the crop grows as wetland rice (Partohardjono and Harahap 1979).

Table 1. Areas of major rice growing environments, Indonesia, 1976.[a]

Environment	Estimated area[b] (1,000 ha)					Total
	Java-Bali	Sumatra	Kalimantan	Sulawesi	Nusa Tenggara	
Irrigated wetland	2,505 (72)	493 (14)	78 (2)	234 (7)	156 (5)	3,466
Rainfed wetland	925 (54)	366 (21)	233 (14)	157 (9)	40 (2)	1,721
Rainfed dryland	254 (22)	486 (42)	230 (20)	100 (9)	83 (7)	1,153
Tidal swamp	5 (2)	103 (41)	140 (55)	4 (2)	1 (0)	253
Total	3,689	1,448	681	495	280	6,593

[a] Source: BPS Luas Tanah Sawah in Nyberg and Prabowo (1979); nonirrigated dryland from BPS (1977). [b] Figures in parenthesis are percentages of row total.

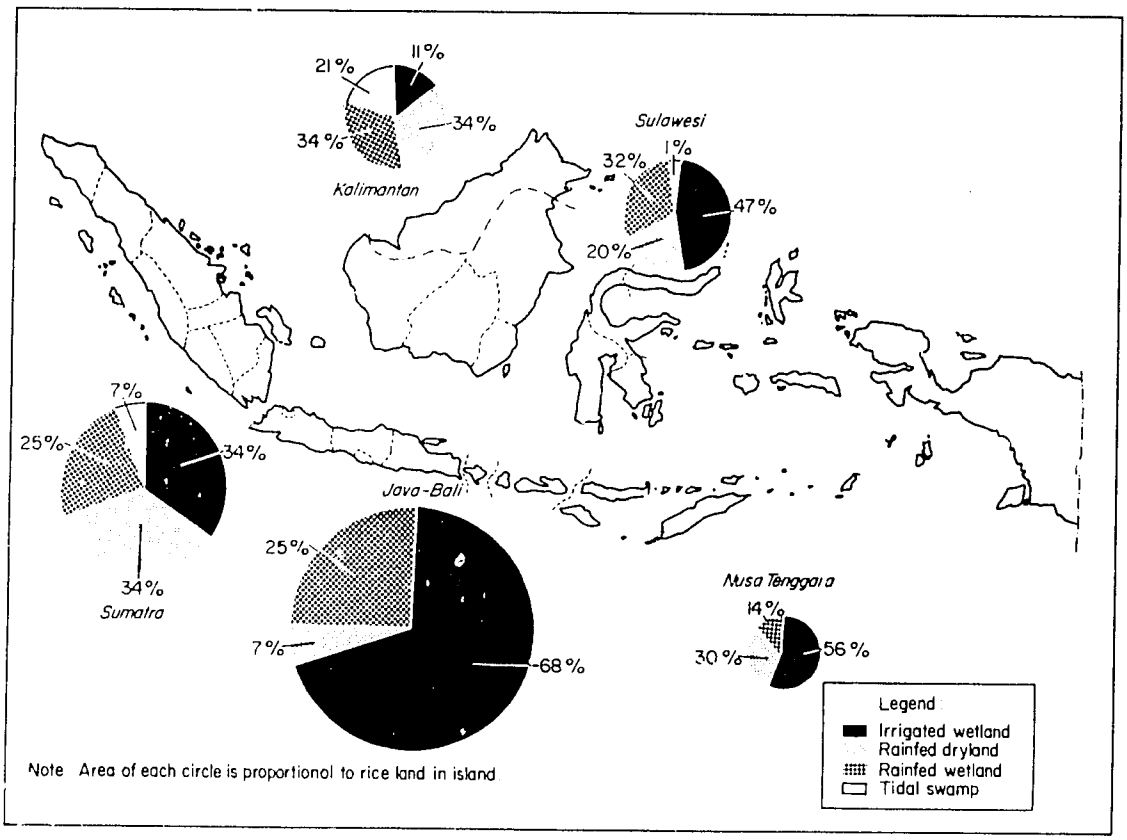


Fig. 1. Percent of rice land in major rice environments, Indonesia, based on a 1976 survey by the Central Bureau of Statistics and Department of Agriculture.

Many of the breeding goals for rainfed wetland rice are the same as those for irrigated rice. Yet, some differences are important. Because water control in rainfed rice is unreliable, weed problems are greater. As a result, varieties with moderately erect leaves and as tall as or taller than Pelita (120-150 cm) are needed to shade and compete with weeds. Also, risk associated with uncertainty of water supply implies the need for varieties that are yield responsive at lower fertilizer rates (60-90 kg N/ha), and are drought and submergence tolerant (Siwi and Beachell 1980). For dry-seeded rice, early seedling vigor, early maturity (110-120 days), and drought and submergence tolerance are especially important (Partohardjono and Harahap 1979.)

High elevations

Within Indonesia's irrigated and rainfed wetland rice environments are an estimated 250,000 ha of rice grown above 500 m elevation. In those areas, modern varieties take longer to mature and frequently have high levels of sterility. Consequently, farmers in the areas prefer their traditional varieties.

The primary breeding objective for high-elevation areas is to identify modern varieties that have desirable agronomic characteristics, but perform well in the climate prevailing in the high-elevation areas. A primary need is for cold-tolerant rices.

Rainfed dryland

Rainfed dryland is the third most important rice growing environment. It includes 17% of the land planted in rice. Most of this area lies in Sumatra, Java-Bali, and Kalimantan (Table 1). Dryland rice is planted in the wet season on dry upland. The dryland rice is often interplanted with maize, cassava, sweet potato, and soybean.

For dryland rice, breeding objectives are similar to those for rainfed. Goals include slightly drooping leaves to compete against weeds, responsiveness at 45-90 kg N/ha, and most important, resistance to blast (Siwi and Beachell 1980).

For the intensive cropping systems being developed by the CRIFC cropping systems program, very early (95-105 days) maturing, nitrogen-responsive varieties of moderate height (110-120 cm) are required.

Tidal swamps

The tidal swamps encompass two types of rice-growing environments. Coastal swamps (pasang-surut) include areas with both the direct and indirect -- via water infiltration through the soil -- influence of the tides. The freshwater areas behind the tidally influenced areas are known as monotonous swamps (lebak). Our data suggest 4% of the rice area is tidal swamp with 140,000 ha in Kalimantan and 103,000 ha in Sumatra. Our figures may be low. Collier (1980) cites 135,000 ha in Sumatra and 165,000 ha in Kalimantan for tidally influenced rice land. The tidal swamps typically flood deeply as the rainy season progresses. Varieties grown in the areas are often double transplanted and mature in 9-10 months (Anwarhan 1980).

Within the general class tidal swamp, rice production varies widely. Research goals include developing varieties tolerant of low soil pH, acid sulfate soils, submergence, drought, and salinity. In some subenvironments, short varieties are needed but for deeply flooded areas, elongating ability is needed (Siwi and Beachell 1980, Anwarhan 1980).

Expansion of rice production

It is estimated that 39.6% of the increase in rice output during 1963-74 was from area expansion and 60.4% was from increased yields (Barker et al 1977). Although it is difficult to estimate future sources of growth, some conclusions are possible.

Almost all of the expansion of area will occur outside of Java-Bali. In Indonesia's Third Development Plan (1979-80 to 1983-84) targets have been set for developing 766,140 ha of irrigated wetland and 535,000 ha of tidal swamp area (Nyberg and Prabowo 1979). This is only a small portion of the estimated 4 million ha for gravity irrigation and 1.3 million ha for tidal swamp that could be developed (World Bank 1979). But for the tidal-swamp areas a great deal of research is required to identify technologies appropriate for sustained crop production.

About 14.2 million ha of upland are identified as having an agricultural potential. Fifty percent of these are in Sumatra (World Bank 1979). Field research by CRIFC suggests that high yields and profitable food crop production can be achieved on these largely red-yellow podzolic soils (McIntosh and Effendi 1979). The cost of developing these areas -- excluding human resettlement costs -- is substantial, however. In Sumatra, it is estimated that US$3,000/ha for river diversion irrigation systems, US$1,500/ha for tidal reclamation, and US$1,000/ha for grassy upland areas are required (World Bank 1979; pers. comm.)

These data refer only to land area in each environment but there appears to be ample opportunity to increase cropped area through intensification. For example, the rice cropping intensity on Java was estimated at 1.4 in 1976-77 -- wetland area harvested divided by wetland area used. With the introduction of shorter-duration varieties, dry seeding, and minimum tillage for land preparation for the second rice crop, it should be possible to significantly expand cropped area in the irrigated wetland and rainfed wetland areas (Effendi et al 1979b).

BREEDING AND SELECTION OF IMPROVED VARIETIES

Specific modern varieties differ from specific traditional types in several ways, including height, growth duration, disease and insect resistance, and tolerance for various soil conditions. In addition, when grown in suitable environments, they have a greater capacity than traditional varieties to convert fertilizer nutrients into grain.

Generally, if the specific modern variety is appropriate for the environment in which it is grown, it will give the same or greater yield at zero fertilizer than traditional varieties and a higher yield at all fertilizer application rates. Based on data collected in 85 trials in farmers' irrigated fields in Central Java (1973-74 wet season) where Pelita I, C4-63, and PB5 were grown, an average response to nitrogen was estimated by the relationship:

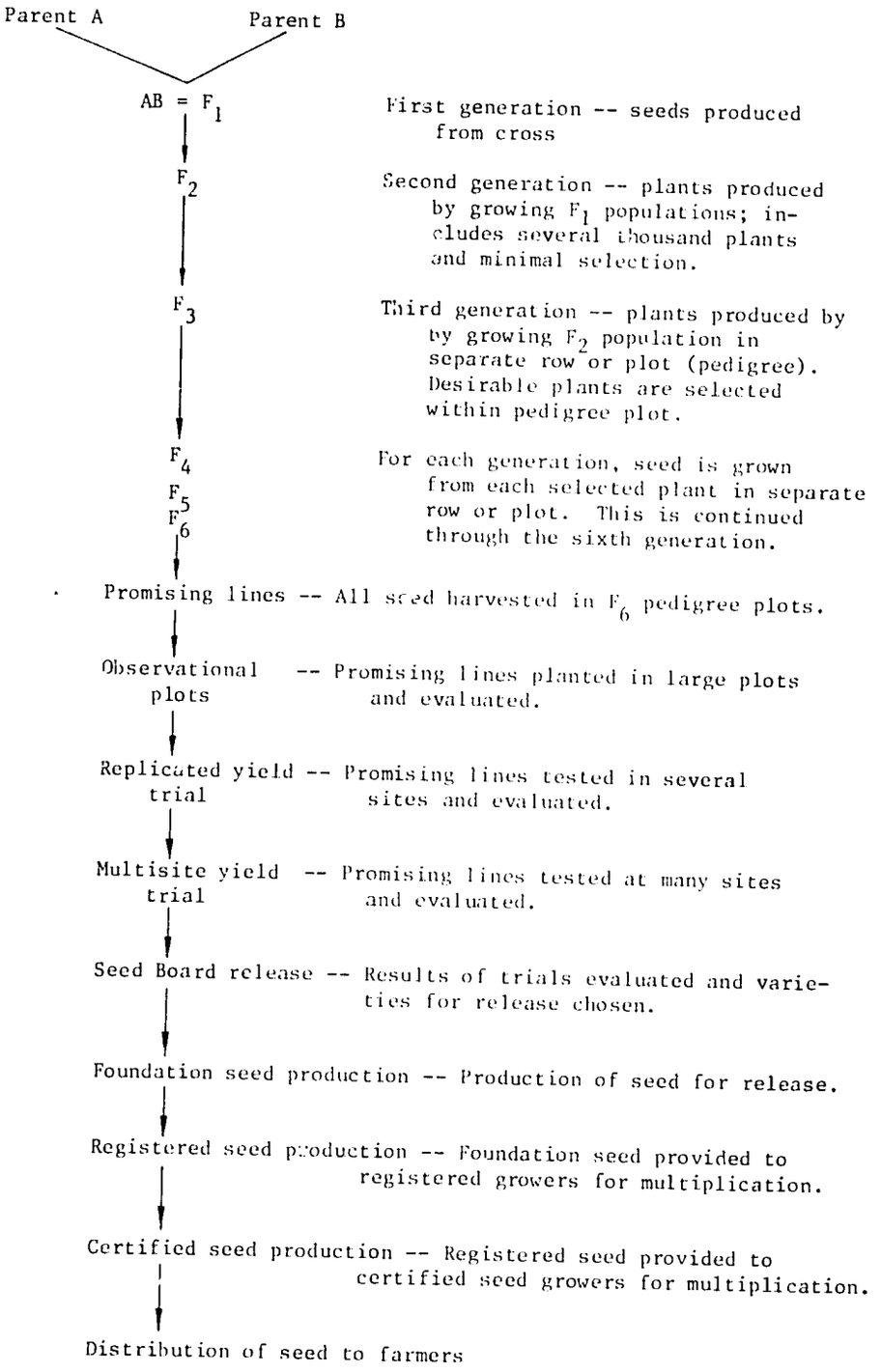
$$Y = 3100 + 19.63\ N - 0.43\ N^2 \text{ (FAO 1979).}$$

The development of new varieties with desired characteristics is systematic. After deciding the attributes required in a variety, existing genetic resources are reviewed to identify sources of these characteristics. With this information, a crossing and selection plan is developed (Fig. 2). From the F_6 population, a group of true breeding plots (lines) are selected by harvesting all seed in each pedigree plot to obtain the promising lines.

During the F_3 through F_6, the individual lines are screened for various problems, stresses, and characters (e.g. brown planthopper, green leafhopper, tungro, and blast resistance; salinity, drought, and submergence tolerance, etc). Only the plants that perform well move to the next generation for further evaluation. In addition to the stresses listed, the material is continually selected for growth duration, plant type, plant height, eating quality, and many other visual and measurable traits.

The Directorate of Plant Protection, Ministry of Agriculture, plans multisite yield trials in close cooperation with CRIFC. Several hundred trials are conducted annually by the local extension agents in farmers' fields throughout the country. The plots are 15 m^2, replicated 4 times, have 12 entries, including a popular local or modern variety as a check. Other inputs are set at standard levels.

Fig. 2. Steps in the development of new rice varieties.



Data from these trials go to the Directorate of Plant Protection for analysis. The results guide varietal release by the National Seed Board Committee. A minimum of 7 years from the time a cross is first made to the time certified seed is available for farmers to grow is generally required.

INSTITUTIONAL SETTING FOR VARIETAL IMPROVEMENT

Rice breeding work in Indonesia began in 1905 with the establishment of the General Agricultural Research Station (GARS) at Bogor. GARS included the Agronomy, Pests and Diseases, Soils, Botany, and Industrial Crops Institutes. In 1956 the rice program was given higher priority with the creation of the Rice Institute, focusing primarily on

breeding and agronomy. In 1963 a reorganization of the research program integrated rice, maize, and sorghum breeding, and agronomy research, into the Cereals Institute. In 1966 research on tubers, legumes, insects and diseases, and physiology were added to the Cereals Institute, which was renamed the Central Research Institute for Agriculture (CRIA) with branches since 1971, in Sukamandi, West Java; Padang, West Sumatra; Maros, South Sulawesi; Malang, East Java; and Banjarmasin, South Kalimantan. This reorganization strengthened the rice program by forming, within CRIA, a multidisciplinary team of scientists, including breeders, agronomists, entomologists, plant physiologists, and economists. In 1981 CRIA was expanded to include horticultural research, and renamed the Central Research Institute for Food Crops (CRIFC). CRIFC's regional institutes were given autonomy, enabling each to better respond to local research priorities.

Success in varietal improvement requires a well-trained staff. After independence, Indonesia faced an extreme shortage of trained personnel to manage the research system. In response to that shortage, a 3-year academy course was established in 1952. The first class of 30 researchers completed the course in 1956. After the initial intensive program, staff development was pursued through short courses, university training, and in-service training. Over the past decade staff development was given high priority, with the number of Ph D and MS degree holders increasing from 2 and 5 in 1970 to 20 and 13 in 1980. In addition, 22 staff members in 1980 were studying for a Ph D; 8 for a MS degree (Table 2).

Because varietal improvement requires an interdisciplinary approach, the strengthening of staff capabilities in all fields has contributed to the development of improved varieties. In addition, 42 CRIFC staff members have participated in a 6-month varietal improvement course at the International Rice Research Institute (IRRI).

The genetic evaluation and utilization approach

Varietal improvement at the CRIFC involves scientists from several disciplines. With the severe outbreaks of brown planthopper, ragged stunt, and grassy stunt in the mid-1970s, the need for better coordination of breeding activities became apparent. In response, a national multidisciplinary varietal improvement program was established in 1975 and named the Genetic Evaluation and Utilization (GEU) program.

The GEU program provides varieties for the more than 8 million ha of Indonesia's extremely diverse rice-growing environments. Because it is impossible to breed a single variety suitable for all environments research goals were established for each group.

The GEU program is coordinated by a national team leader at Sukamandi with close linkages between the regional units at Bogor, Padang, Sukamandi, Malang, Maros, and Banjarmasin. Extension service subject-matter specialists, national seed corporation representatives, and representatives from other institutions frequently attend the monthly GEU meetings.

A diverse germplasm collection is required as a genetic source of desirable characteristics for the GEU program. Collection of indigenous germplasm started in the 1930s (Siwi and Kartowinoto 1976) but much of the collection was lost due to improper storage. Most of the collection was, however, sent to IRRI in the 1960s and is in the IRRI germplasm bank.

With the increased planting of modern varieties, there has been a rapid genetic erosion in many areas of Indonesia during the past 10 years. Because both traditional varieties and introductions are important sources of the required genetic characteristics a systematic collection

Table 2. Staff development by discipline for crop research at the Central Research Institute for Agriculture (CRIA), Indonesia, 1970 and 1980.[a]

Discipline	1970				1980			
	MS		Ph D		MS		Ph D	
	Complete	In process	Complete	In process	Complete	In process	Complete	In process
Agronomy	0	0	0	0	1	26	6	4
Breeding	4	1	1	1	5	13	7	6
Plant pathology	0	0	1	0	2	7	2	4
Entomology	1	1	0	0	2	10	3	4
Physiology	0	1	0	0	2	17	0	1
Socioeconomics	0	0	0	0	1	4	2	1
Postharvest technology	0	0	0	0	0	4	0	2
Total	5	3	2	1	13	81	20	22

[a] Source: CRIFC Secretariate, Bogor.

program was initiated in 1970 (Siwi and Harahap 1977). Presently, the CRIFC germplasm collection has 3,496 local indicas and 1,491 javanicas (bulus). Cooperation with IRRI's germplasm collection work continues and all collected cultivars are stored at both Bogor and IRRI.

Indonesian rice scientists are capable of screening breeding lines for most of the characteristics to be incorporated into improved varieties. Due to a shortage of greenhouses and personnel, Indonesia has been assisted by IRRI in screening for brown planthopper and grassy stunt virus resistance, eating quality evaluation, and other information. Some cold-tolerance screening of Indonesian lines is done in Korea and the Philippines. Thailand has assisted in screening deepwater breeding material for elongation ability and submergence tolerance.

In turn, Indonesia has reciprocated by screening materials from IRRI and other countries for rice tungro virus, blast, and gall midge.

The strong organizational foundation laid through the establishment of the GEU program has enabled CRIFC to produce an extremely large amount of breeding material. In 1979, the program produced 711 crosses, 4,116 bulk hybrid populations, 91,472 pedigree nursery entries, 2,018 observational trial entries, and 501 replicated yield trial entries grown in varietal improvement nurseries.

International linkages: progress through cooperation

An important component of the GEU program is its participation in the International Rice Testing Program (IRTP), which annually distributes about 20 uniform nurseries for growing in more than 50 countries. The participating countries and IRRI provide the entries for the nurseries. IRRI coordinates preparation and distribution of seed of the nurseries to interested countries, summarizing of results, and the reporting of results to the participating countries. The nurseries are divided into yield trials, observational trials, and stress screening trials (disease and insects, low temperature, drought, salinity-alkalinity, and other soil deficiencies or toxicities). Since 1976 Indonesia has annually grown an average of 9 yield trials, 9 observational trials and 20 stress screening trials (Table 3).

The fact that IRTP nurseries are grown in many countries each year give country programs the benefit of varietal reactions to insects and diseases and stress tolerances that would require several years' testing if each country had to depend only on its own facilities. Indonesia has entered more than 50 strains annually in IRTP nurseries for evaluation throughout the network. This has reduced considerably the number of years required for the evaluation of promising lines.

Indonesia has used several hundred IRTP entries as parents in the national breeding program. Many

Table 3. International Rice Testing Program nurseries grown in Indonesia, 1976-80.

Nursery type	No. grown 1976	1977	1978	1979	1980
Yield trials	6	9	9	7	12
Observational trials	8	9	10	6	12
Stress screening					
Cold, drought, problem soils	4	4	2	2	6
Diseases, insects	16	21	12	13	19
Total	34	43	33	28	49

IRTP entries have also been evaluated for new variety potential and with good success. These included IR26, IR28, IR29, IR30, IR32, IR34, IR36, IR38, and IR42, all IRTP entries that were ultimately released as varieties in Indonesia.

Lines developed in Indonesia have been released as varieties in several countries of Asia, Africa, and Latin America. Likewise Indonesia's contribution in providing test information on material from other countries has been helpful to other national programs, especially the tungro evaluation of breeding lines.

HISTORY OF VARIETAL IMPROVEMENT

Indonesia has a long and distinguished record in rice varietal improvement. A high percentage of the improved-plant-type varieties released by IRRI and national programs during the 1960s and the 1970s trace to at least one and sometimes several Indonesian varieties (Hargrove et al 1979). The Indonesian varieties Peta, Intan, and Sigadis were used by IRRI primarily as sources of sturdy stems, erect leaves, and plant vigor (Harahap et al 1981).

Varieties grown in Indonesia may be classified as traditional, national improved, and modern. Among the last group, varieties susceptible to brown planthopper are differentiated as modern nonresistant, those resistant to BPH biotype 1 but not to biotype 2 as modern biotype 1 resistant, and those resistant to both BPH biotypes 1 and 2 as modern biotypes 1 + 2 resistant.

Traditional varieties

Traditional varieties (TV) grown in Indonesia number more than 8,000 (Siwi and Harahap 1977). Historically, the bulus or javanica varieties were found only in Java, Bali, and hill terraces of Banaue, Philippines. These varieties have long panicles, low tillering capacity, stiff straw, bold and nonshattering grains, wide leaves, low

photoperiod sensitivity, awned glumes (except for a subclass of bulus known as gundils), and intermediate amylose content (Siwi and Harahap 1977). The bulu varieties were probably preferred by early inhabitants of the inner islands because they were high yielding and did not lodge when planted on the fertile volcanic soils. They were grown almost exclusively on Bali and Lombok but were grown in equal proportion to indicas in Java, Southern Sumatra, and Southern Sulawesi (Parthasarathy 1972).

In the early years at the General Agricultural Research Station, breeders focused on screening local material at many sites and on mass selection and purifying of strains of local varieties. Indica types were also introduced from other countries (Harahap et al 1972) but most of those were never released because they were photoperiod sensitive and had undesirable agronomic characteristics. On the other hand, a successful example was Tjina (from China in 1914), which was adopted over a wide area due to its photoperiod insensitivity, yield, and high grain quality (Parthasarathy 1972). Tjina was later used in the hybridization program and progenies from Tjina/Latisai crosses led to the development of such varieties as Bengawan, Peta, Intan, and Mas.

National improved varieties

Rice hybridization in Indonesia started about 1920 using the gene pool that had been built up through foreign acquisitions (Harahap et al 1972). During the period 1926-45, six regional branch stations were established, each representing a major soil type area. Selections made at each station were tested at all stations and numerous trials were conducted in farmers' fields (Parthasarathy 1972). During World War II and the Indonesia War of Independence, research progressed slowly. The founding of the Food and Agriculture Organization (FAO) and the establishment of the International Rice Commission in 1949 gave a new impetus to rice research. In the 1960s Indonesian breeders participated in international activities, including training and germplasm exchange. Indonesia's leading rice breeder, Dr. Hardrian Siregar, introduced several modern breeding procedures, such as the pedigree method, which led to the more rapid development of new varieties. During the period 1940-65, many national improved varieties were selected and released.

Modern varieties (nonresistant)

The strategy followed in the current breeding program dates to the early 1960s. Before then, varieties in Indonesia were developed for cultivation on soils with moderate to low fertility (Harahap et al 1972). In the early 1960s breeders came to realize the importance of nitrogen fertilizer in increasing yields in tropical Asia (Parthasarathy 1972). With the development of Taichung Native 1 -- the first indica that responded to fertilizer--as well as the japonica varieties (ponlais) from Taiwan, - breeders saw it was possible to breed short, stiff-strawed nitrogen-responsive varieties that were resistant to lodging (Dalrymple 1974).[2/] In 1962, the progeny of a backcross between Bengawan and Sigadis was crossed with Randa Tjupak (pedigree breeding method) to produce the first Indonesian moderately short-strawed variety, Dewi Ratih, which was released in 1969 (Harahap et al 1972).

Many modern varieties were released from the late 1960s to the early 1970s (Table 4). After being screened in Indonesia, two short or intermediate height stiff-strawed cultivars (PB5 and PB8)[3/] developed by IRRI were released in 1967. The success of these varieties, especially PB5, led Indonesian breeders to concentrate their efforts toward the development of intermediate-stature (100 to 130 cm), fertilizer-responsive cultivars with taste characteristics preferred by local consumers. Before these efforts were successful, two additional modern varieties (C4-63) from the Philippines' national program and PB20 from IRRI were released. C4-63 was particularly popular among farmers because of its good eating quality. In 1971 Pelita I-1 and Pelita I-2 -- selections from a cross between IR5 and national improved Syntha -- were released and widely adopted by farmers. These two introductions established CRIFC's capacity to breed modern varieties acceptable to Indonesian consumers.

Modern variety
(resistant to BPH biotype 1)

With the the introduction of modern varieties in the late 1960s farmers applied higher rates of nitrogen fertilizer to tap the increased yield potential. In addition, government investment in irrigation infrastructure made it possible for a greater proportion of the lowland area to produce two or three wetland rice crops per year, eliminating the traditional dry fallow period between crops in many areas. This required varieties that matured earlier.

Although the brown planthopper (BPH) was first recorded in 1854, heavy infestation did not occur until around 1970 in Java and in 1972 and 1973 in North Sumatra. By 1977 almost all parts of Indonesia, except Maluku and Irian Jaya, were affected (Mochida 1979). Because all varieties grown in Indonesia before 1975 (traditional, national improved, and modern) were BPH susceptible, genetic source of resistance had to be found. After evaluation by CRIFC scientists, PB26 was found to yield

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2/Nitrogen-responsive japonica varieties (ponlais) were developed in Taiwan in the early 1920s, but were not widely accepted outside Taiwan due to disease susceptibility and undesirable grain characteristics.

3/IRRI varieties released in Indonesia were named Peta Baru (PB) meaning new Peta.

as much as Pelita in most areas and to be resistant to the BPH biotype 1, which was widespread at the time PB26 was officially released to farmers in the 1975-76 wet season. In the next 2 years, 4 additional varieties from IRRI were found resistant to BPH biotype 1 (PB28, PB29, PB30, PB34) and were released to broaden the varietal resistance base. Simultaneously with the testing of introduced materials, CRIFC breeders were developing BPH-BPH-resistant varieties in their crossing program. In 1977 these efforts resulted in the identification of four high yielding lines (Brantas, Serayu, Asahan, and Citarum) from the Indonesian research program. Those were resistant to BPH biotype 1 and were released in 1978 (Oka 1979).

Modern variety
(resistant to BPH biotypes 1 and 2)

As increasingly large areas were planted to BPH biotype 1-resistant varieties, the probability of the evolution of a new biotype increased. This was expected because only those few BPH individuals surviving on the resistant varieties produced the next generation of hoppers. By 1976 BPH biotype 2 had appeared in the intensively cultivated fields of PB26 in North Sumatra and on both PB26 and PB28 in Bali and parts of East Java (Oka 1979). The hectarage attacked by BPH and grassy stunt or ragged stunt (virus diseases carried by the BPH) increased yearly, with damage to an estimated 347,000 ha in the 1976-77 wet season and 216,000 ha in the 1977 dry season (Mochida 1979). This brought about the rapid evaluation and release in 1976 of PB32, which was resistant to the new biotype, followed by PB36 and PB38 in 1977 (Mochida 1978). With the widespread adoption of these varieties BPH losses were reduced, except where farmers planted traditional or other susceptible varieties (Harahap et al 1981).

Because PB32, PB36, and PB38 are wetland varieties, they were not adopted in high-elevation areas. The CRIFC varietal improvement program responded to this need, releasing in 1980, Semeru -- a variety resistant to BPH biotypes 1 and 2 and suitable for high-elevation (below 1,000 m) agroclimatic zones. Cimandiri, a variety with good eating quality, Ayung, a glutinous variety, and Cisadane (intermediate amylose), a locally bred

Table 4. Data for major varieties released in Indonesia, 1967-80.

Variety	Year released	Maturity (days)	Stature (cm)	Disease reaction[a]				Insect reaction[a]					Amylose content (%)
				BLB	BLS	RTV	GSV	BPH biotype 1	BPH biotype 2	BPH biotype 3	GLH	GM	
Modern (nonresistant)													
PB5	1967	135	130	MR	MS	S	S	S	S	S	MR	S	27
PB8	1967	125	100	S	-	S	S	S	S	S	MR	S	27
C4-63	1969	125	115	MR	S	MR	S	S	S	S	MR	S	22
PB20	1970	120	90	R	MS	MR	S	S	S	S	R	S	25
Pelita 1-1, I-2	1971	135	130	MR	MR	S	S	S	S	S	MR	S	23
Gemar[b]	1976	145	125	R	R	S	S	S	S	S	S	S	24
Adil[b]	1976	135	101	R	R	S	S	S	S	S	S	S	28
Makmur[b]	1976	135	100	R	MR	S	S	S	S	S	S	S	27
Gata[c]	1976	120	75	R	R	S	S	S	S	S	S	S	23
Gati[c]	1976	115	80	R	MR	S	S	S	S	S	S	S	26
Modern (resistant to BPH biotype 1)													
PB26	1975	125	85	MR	MR	MR	S	R	S	R	R	S	27
PB28	1975	109	80	R	MS	R	R	R	S	S	R	S	27
PB30	1976	112	73	MR	MS	MS	MS	R	S	S	R	S	27
PB34	1976	130	117	R	MR	R	R	R	S	S	R	S	28
Brantas	1978	127	109	R	S	MR	R	R	S	R	S	S	27
Serayu	1978	126	105	MS	S	S	R	R	S	R	S	S	27
Citarum	1978	129	110	MS	S	MR	MS	R	S	MR	MR	S	22
Asahan	1978	130	90	R	MR	R	R	R	S	MR	S	S	16
Modern (resistant to BPH biotypes 1 and 2)													
PB32	1976	140	88	R	MR	R	R	R	R	S	R	R	27
PB36	1977	118	81	R	R	R	R	R	R	S	R	R	27
PB38	1977	128	97	R	R	R	R	R	R	MR	R	S	25
Semeru	1980	130	85	R	-	-	MR	R	MR	-	R	-	28
Cisadane	1980	140	110	R	-	-	S	R	MR	R	-	-	20
Cimandiri	1980	125	103	R	-	-	R	R	MR	R	-	S	-
Ayung	1980	136	108	R	-	-	R	R	MR	R	-	S	-

[a] BLB = bacterial leaf blight, BLS = bacterial leaf streak, RTV = tungro virus, GSV = grassy stunt virus, BPH = brown planthopper, GLH = green leafhopper, GM = gall midge. R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible. A dash indicates data not available. [b] Also for dryland areas. [c] Also for high-elevation areas.

variety with superior eating quality were released in 1980 for wetland areas. Cisadane's superior eating quality has been confirmed by the pr -- comparable to the price of C4-63 -- that farmers receive for it.

Modern variety
(resistant to BPH biotypes 1 and 3)

BPH biotype 3 has not yet evolved in farmers' fields in Indonesia, but CRIFC scientists have anticipated this possibility. By screening breeding lines for BPH-3 resistance, four varieties (Brantas, Serayu, Asahan, and Citarum) were identified and released in 1978. Research to develop additional BPH biotype 3-resistant varieties is in progress.

THE DIFFUSION OF MODERN RICE VARIETIES

Studies on the diffusion of agricultural technology are typically done by social scientists who investigate characteristics of adoptors and nonadoptors in an attempt to better understand how these phenomena influence adoption. Such factors as age, education, farm size, social position, resources, and similar social dimensions are often considered. In Indonesia, many farm-level adoption studies of modern varieties have been reported. Several of these were reviewed by Palmer (1977).

In diffusion studies, the perspective of the biological scientists who participated in developing the technology has seldom been considered. Without denying the importance of social phenomena, primary emphasis is given here to identifying the biological and agroclimatic factors affecting the adoption of modern varieties in Indonesia during the 1970s.

Data sources

During the period 1971-72 through 1975, data were collected by Bimas authorities. Beginning in the 1975-76 wet season, the Directorate for Plant Protection (Direktorat Perlindungan Tanaman Pangan) assumed responsibility for data compilation. With this transfer of responsibility, the quality of the raw data improved substantially and the area planted to each variety was published by districts (Kabupatens) at the end of each season. Unfortunately, in each season some districts failed to file reports. Consequently, provincial summaries -- particularly for Indonesia's outer islands -- sometimes underestimated the total area planted. Yet, in most seasons the data are relatively complete and missing data do not seriously affect their interpretation. The area in dryland rice was not included in the data.

New varieties before 1970

In 1966 IRRI sent CRIFC 5 kg of PB8 and PB5. They were tested by CRIFC scientists at 18 substations in 5 provinces. After multiplication on 300 extension seed farms, these varieties were released in 1967 and became a key component of the government's production program (Bimas Baru). By the 1968 dry season 21,300 ha were planted to PB5 and PB8 (Hawes 1970). PB5 spread more rapidly than PB8 because of PB5's intermediate plant height, suitability to Indonesian conditions, superior milling quality, greater resistance (moderately resistant) to bacterial leaf blight, better adaptability to diverse environments, and superior eating quality (Siwi 1976).

In 1968 President Ferdinand E. Marcos of the Philippines visited Indonesia and gave 88 kg of C4-63 to the government (Hawes 1970). C4-63 was officially released in 1969 and spread rapidly. Although moderately susceptible to bacterial leaf blight and neck blast, farmers accepted it because of its earlier maturity (125 days compared to 135 days for IR5), excellent milling, and superior eating quality -- compared to both PB5 and PB8 (Siwi 1976).

In 1969, a severe tungro virus outbreak occurred in South Kalimantan and South Sulawesi. PB20 was released and adopted in these and other areas because it was resistant to tungro. In addition, PB20 was popular in West Sumatra where consumers prefer high amylose-type (dry cooking) varieties (Siwi 1976).

By 1971 CRIFC's effort to breed modern fertilizer-responsive varieties was successful, resulting in the release of Pelita I-1 and Pelita I-2. These varieties were selections from the same cross (PB5/Syntha), but differed slightly -- Pelita I-1 was higher yielding and performed better across a wider range of environments. Farmers accepted these varieties because they were intermediate in height, like PB5, but had greater resistance to bacterial leaf blight and satisfied Indonesian taste preferences better.

Leading varieties throughout Indonesia in the 1970s

The proportion of the rice area planted to specific widely adopted varieties shifted substantially over the 1970 decade (Tables 5 and 6).

PB5. Just 5 years after its release (1971-72 wet season) PB5 had spread to 23.3% of the area (Table 5). PB5's widespread adaptability and compatibility with farmers' preferences was confirmed by the fact that until the 1979-80 wet season, no other single variety was grown on a larger percentage of the land area during a single wet season. PB5 remained the top variety until 1974-75. After that it was rapidly replaced by new releases, especially the Pelitas.

PB8. PB8, released in the same year as PB5, was never widely accepted by Indonesian farmers. The adoption level never exceeded 2% of the area and PB8 dropped from among the top 5 varieties by 1975-76. During the early years when the only modern varieties were PB8 and PB5, farmers discriminated against PB8 because of its poor eating

quality and short stature. Later, as production intensified, the short rices such as IR36 were not discriminated against.

C4-63. The variety C4-63 never became extremely popular and reached its maximum adoption level in 1974-75 -- 6 years after its release. C4-63 was, however, among the top 5 rices in 6 out of the 9 wet seasons considered (Table 5). During these years, it commanded on the average of 7% of the area. Consequently, it was the most persistent variety after Pelita I-1. The early popularity of C4-63 was due to its superior taste characteristics and earlier maturity, when compared to PB5 and PB8. Even though C4-63 was tungro susceptible it continued to be grown in the dry season because tungro was a problem only in the wet season. When Pelita I-1 became available, C4-63 consistently covered fewer hectares than Pelita I-1.

Table 5. Indonesia's most widely planted modern varieties and percentage of total planted area (in parenthesis), 1971-72 through 1979-80 wet seasons.[a]

Rank	1971-72[b]	1972-73[c]	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
1	PB5 (23.3)	PB5 (16.3)	PB5 (17.0)	PB5 (21.6)	P.I-1 (18.0)	P.I-1 (14.5)	PB30 (8.6)	PB36 (19.6)	PB36 (36.0)
2	C4-63 (6.4)	C4-63 (6.2)	P.I.-1 (15.8)	P.I.-1 (20.6)	PB5 (9.7)	PB26 (12.8)	PB36 (8.1)	P.I-1 (7.1)	PB38 (10.4)
3	PB8 (1.2)	P.I-1 (4.5)	C4-63 (8.6)	C4-63 (9.2)	C4-63 (7.8)	PB30 (5.2)	P.I-1 (7.9)	PB38 (5.6)	PB32 (4.6)
4	P.I-1 (0.1)	P.I-2 (2.1)	P.I-2 (6.4)	P.I-2 (5.2)	PB26 (6.4)	C4-63 (5.2)	PB32 (7.5)	PB32 (5.1)	P.I-1 (3.1)
5	-	PB8 (1.0)	PB8 (1.5)	PB8 (1.0)	P.I-2 (4.9)	PB5 (5.0)	PB26 (7.1)	PB30 (4.5)	Citarum (2.2)
Total area (%)	30.1	30.1	49.3	57.6	46.8	42.7	39.2	41.9	56.3

[a] Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production; 1975-76 through 1979-80 Sub-Direktorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors. [b] A dash indicates less than 0.1%. [c] P.I-1 = Pelita I-1, P.I-2 = Pelita I-2.

Table 6. Indonesia's most widely planted modern varieties and percentage of total planted area (in parenthesis), 1972-79 dry seasons.[a]

Rank	1972[b]	1973	1974	1975[c]	1976	1977	1978	1979
1	PB5 (19.7)	PB5 (17.4)	P.I-1 (14.1)	-	P.I-1 (15.6)	PB26 (13.7)	PB36 (17.0)	PB36 (30.5)
2	C4-63 (8.4)	P.I-1 (9.7)	PB5 (13.9)	-	PB26 (13.3)	PB30 (10.2)	PB30 (8.1)	PB38 (10.4)
3	PB8 (1.7)	C4-63 (8.4)	C4-63 (8.3)	-	C4-63 (7.0)	P.I-1 (10.2)	PB26 (6.7)	PB32 (6.8)
4	P.I-1 (1.1)	P.I-2 (4.5)	P.I-2 (6.1)	-	PB5 (6.7)	C4-63 (5.3)	PB32 (5.6)	PB26 (2.8)
5	P.I-2 (0.3)	PB8 (2.1)	PB8 (1.3)	-	P.I-2 (4.4)	PB5 (4.6)	P.I-1 (5.2)	P.I-1 (2.0)
Total area (%)	30.9	42.1	44.0	-	47.0	44.0	42.6	52.5

[a] Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production; 1975-76 through 1979-80 Sub-Direktorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors. [b] P.I-1 = Pelita I-1, P.I-2 = Pelita I-2. [c] Data not available.

Pelita I-1 and I-2. The sister Pelita selections were the most popular releases during the 1970s. Farmers preferred the Pelitas because they yielded higher and performed well across a wider range of environments than previous releases. Also, farmers accepted them because they were intermediate in height (130 cm) like PB5, had greater resistance to bacterial leaf blight, and had a preferred eating quality. By the 1974 dry season and the 1975-76 wet season they replaced PB5 as the most widely grown single variety. Unfortunately, both Pelitas were susceptible to tungro virus, BPH, and grassy stunt virus and as a result, declined in popularity as these problems became more widespread. In 1978-79, however, after 4 years of intensive BPH infestation throughout Indonesia these Pelita varieties still occupied more than 7% of the wet-season area.

PB26. PB26 was released in 1975-76 in an attempt to control BPH in areas experiencing heavy damage. Although the area planted doubled the following wet season, the BPH biotype 2 developed and PB26 was rapidly replaced by PB32, PB36, and PB38.

PB30. In an attempt to broaden the base of genetic resistance to BPH biotype 1, PB30 was released in 1976 -- a year after PB26. PB30 is similar to PB26, but matures about 2 weeks earlier, is slightly shorter in height, and is more resistant to grassy stunt virus. Consequently, adoption of PB30 was especially rapid in the double-cropped irrigated area. One year after it was introduced, it surpassed PB26. Yet, as biotype 2 became more extensive, PB30 was also replaced by biotype 2-resistant varieties.

PB32. With the evolution of BPH biotype 2, there was an immediate need for a new source of genetic resistance. PB32, released in the 1976-77 wet season, was the first variety to meet this demand. After spreading to 7.5% of the area in 1977-78, it declined in importance, partly due to its long maturity (140 days), a tendency to lodge, and the almost simultaneous release of 2 additional BPH biotype 2-resistant cultivars -- PB36 and PB38.

PB34. PB34, a BPH biotype 1- and tungro-resistant variety with a plant height similar to that of Pelita, was released in 1976. However, because of its tendency to lodge and the appearance of biotype 2 soon after PB34's release, it had only limited planting.

PB36. First available to farmers in the 1977-78 wet season, PB36 spread rapidly, covering 36% of the area in 1979-80. In fact, PB36 was planted on a larger share of the rice area in a single season than any previously released variety. Its popularity was primarily due to its resistance to BPH biotype 2 indicated by its concentration in Java and Bali where biotype 2 was most important. In addition farmers preferred PB36 because it matured almost 3 weeks earlier than PB32 (the previously introduced BPH biotype 2-resistant variety), reduced the risk of drought damage in double-cropped rice, and allowed farmers to grow a third nonrice crop such as soybean.

PB38. PB38 was released at the same time as PB36 and also had BPH biotype 2 resistance. It was never as popular as PB36 because PB38 matured almost 2 weeks later.

General trend. The total percentage of the area planted to the top five varieties each season is an indicator of the genetic diversity prevailing in each season. The percentage of the area in the top 5 varieties increased from 1971-72 to 1974-75 when modern varieties covered 57.6% of the area. From 1974-75 to 1978-79, the percentage share in the top 5 varieties declined. Apparently, as new varieties were introduced, some farmers preferred to continue to plant the earlier releases such as C4-63 and Pelita I-2. Figure 3 indicates that from 1974-75 to 1975-76, the percentage share in traditional rices actually increased, probably out of the erroneous belief that only the modern varieties were susceptible to BPH. Yet, these reverse adoptors soon learned that the local varieties were not resistant. With the protection against BPH biotype 2 provided by the introduction of PB32, PB36, and PB38, the total area in modern rice again increased. In fact, in 1979-80 the widespread adoption of PB36 led to the highest concentration (36%) in a single variety ever observed in Indonesia). Although the extensive planting of PB36 contributed substantially to the record production level achieved in 1980, the narrowing of the genetic diversity also created a potentially dangerous situation because a new BPH biotype or disease to which PB36 has limited resistance could spread rapidly throughout Indonesia.

Although the general pattern of varietal replacement in the dry season (Table 6) was the same as in the wet season (Table 5), one difference should be noted. There was little change in the total area share planted to the top five varieties from 1975 to 1979 dry seasons.

Fifteen Indonesian-bred varieties have been released by CRIFC since 1971. Only Pelita was widely adopted. As most of the other releases became available, a new BPH biotype appeared and forced farmers to plant a new PB variety with resistance to the new biotype. Although not appearing in the list of top varieties, because it was released in 1980, Cisadane, a superior quality biotype 2-resistant variety, is expected to be widely adopted over the next few years.

Distribution by varietal class in the 1970s

By grouping varieties into classes as traditional, national improved, modern (nonresistant), modern (resistant to BPH biotype 1), and modern (resistant to BPH biotype 2) it is possible to better understand the overall pattern of varietal adoption during the 1970s.

Wet seasons. By the 1971-72 wet season, the first season for which time series data are available, nonresistant modern varieties were already widely adopted and covered almost 1.2 million ha or more

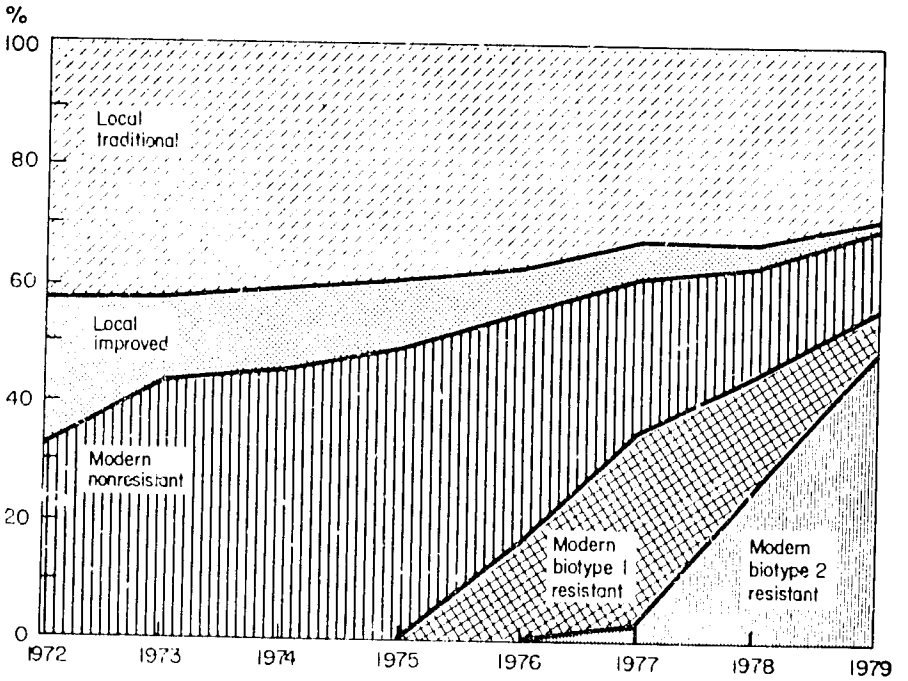

Fig. 3. Percentage of reported area in wetland rice varieties grown in Indonesia, 1971-72 through 1979-80 wet seasons. Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production, 1975-76 through 1979-80 Sub-Direktorat Pembinaan Mutu Benih, Direktorat Perlindungan Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Table 7. Area planted (1,000 ha) to major types of wetland rice varieties in Indonesia, 1971-72 through 1979-80 wet seasons. Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production; 1975-76 through 1979-80 Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Year	Local			Modern				All varieties
	Traditional[a]	Improved[b]	Total	Non-resistant[c]	Resistant to biotype 1[d]	Resistant to biotypes 1 & 2[e]	Total	
1971-72	1,677	916	2,593	1,161			1,161	3,754
1972-73	2,142	716	2,858	1,227			1,227	4,085
1973-74	1,601	525	2,126	2,083			2,083	4,209
1974-75	1,532	440	1,972	2,244			2,244	4,216
1975-76	1,771	441	2,212	2,118	304		2,422	4,634
1976-77	1,694	400	2,094	1,504	1,170	13	2,687	4,781
1977-78	1,862	343	2,205	1,075	1,078	836	2,989	5,194
1978-79	1,812	294	2,106	990	598	1,614	3,202	5,308
1979-80	1,526	122	1,648	489	304	2,559	3,352	5,000

[a] Traditional varieties indigenous to Indonesia. [b] Improved - national improved varieties selected prior to 1968. Includes Bengawan, Sigadis, Syntha, Remaja, Jelita, Dewi Tara, and others. [c] Susceptible to brown planthopper (BPH) biotypes 1 and 2. Includes Pelita I-1, Pelita I-2, C4-63, PB5, PB8, PB20, Gemar, Adil, Makmur, Gata, Gati, and other lines. [d] Resistant to BPH biotype 1 but susceptible to biotype 2. Includes PB26, PB28, PB29, PB30, PB34, Brantas, Serayu, Citarum, and Asahan. Introduced in 1975. [e] Resistant to BPH biotypes 1 and 2. Includes PB32, PB36, PB38, Semeru, and Cisadane. Introduced in 1976.

than 30% of the rice area (Table 7). In each successive wet season, the area in modern varieties increased, reaching 67% in 1979-80.

While the area planted to both traditional and national improved varieties declined over the decade, the greatest change occurred with respect to the national improved varieties falling from 24 to 2% of the area over the period. Initially, they were grown primarily on Java and Bali and in other intensified production areas. As a consequence, they were replaced by the higher yielding modern

varieties that were targeted through Bimas (government production program) for those areas. In contrast, much of the area still in traditional varieties in 1971-72 was probably in the less intensively cultivated areas such as high elevation, wetland rainfed, dryland and tidal-swamp environments, for which high yielding modern rices were not available.

Within the modern variety group, the distributional shift has been toward a rapid decline in modern nonresistant types, falling from 53% in 1974-75 to only 10% in 1979-80. The decline in the popularity of nonresistant varieties was largely the consequence of the increase in insect and disease problems especially BPH. From 1975-76 to 1976-77, the area in biotype 1- resistant varieties quadrupled (Table 7), but fell sharply as the increasing presence of BPH biotype 2 resulted in severe yield losses. By 1979-80 the adoption of modern BPH biotype 2-resistant varieties reached 76% of the modern variety area and had almost completely replaced all previously released modern varieties, except in areas where BPH had probably not been a significant problem.

It is important to note that in the 6 years from 1967-68, when modern rices were first released, until 1973-74, the area planted to those varieties increased to 2.1 million ha (Table 7). Over the next 6 wet seasons, the percentage of the area in modern rices rose by only 17 percentage points -- leaving about one-third of the planted wetland untouched by 15 years of varietal improvement. Contrary to what might be expected, most of the area still planted to traditional rices is not on the outer islands. During the 3 most recent wet seasons (1977-78 to 1979-80), about 63% of the traditional rice area was in Java.

Dry seasons. Almost all of the area planted in the dry season is irrigated. Given that about 72% of the irrigated area is on Java-Bali (Nyberg and Prabowo 1979, Table A-3) where extension services are strongest, we would expect a more rapid and extensive adoption pattern in the dry season. Yet, the differences are not substantial (Table 8). In the 1972 dry season, modern rices covered about 31% of the area and rose to about 69% by 1979.

As in wet seasons, the dry season area in national improved varieties fell over the period -- from 25% in 1972 to 2.3% in 1979. During the same period, the area in traditional rices fell from about 44 to 29%.

Within modern varieties, the distributional shift occurred somewhat more rapidly in the dry season. Because most varieties were first released in the wet seasons, apparently farmers who adopted BPH biotype 1-resistant varieties in the wet season planted them the following dry season. This is indicated by the data showing that in both the 1976 and 1977 dry seasons, about a 10% greater proportion of the area was planted than in the preceding wet seasons. Again, farmers who planted biotype 2-resistant varieties in the wet season appeared to have also planted them during the following dry season. This is reflected by the data showing an average of 13% greater use of biotype 2-resistant rices in the 1978 and 1979 dry seasons than in the preceding wet seasons. Furthermore, by the 1979 dry season, 70% of the modern rice area was planted to biotype 2-resistant rices compared to only 50% in the preceding wet season, as illustrated in Figure 4.

Table 8. Area planted (1,000 ha) to major types of wetland rice varieties in Indonesia, 1972 through 1979 dry seasons. Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production; 1975-76 through 1979 Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Year[a]	Local			Modern				All varieties
	Traditional[b]	Improved[c]	Total	Non-resistant[d]	Resistant to biotype 1[e]	Resistant to biotypes 1 & 2[f]	Total	
1972	966	552	1,518	687			687	2,205
1973	1,084	343	1,427	1,052			1,052	2,479
1974	1,059	348	1,407	1,144			1,144	2,551
1976	943	170	1,113	953	409	0.7	1,362	2,475
1977	779	167	946	629	770	64	1,463	2,409
1978	936	120	1,056	529	542	740	1,811	2,867
1979	833	80	913	392	222	1,400	2,014	2,927

[a] 1975 data not available. [b] Traditional varieties indigenous to Indonesia. [c] Improved - national improved varieties selected prior to 1968. Includes Bengawan, Sigadis, Syntha, Remaja, Jelita, Dewi Tara, and others. [d] Susceptible to brown planthopper (BPH) biotypes 1 and 2. Includes Pelita I-1, Pelita I-2, C4-63, PB5, PB8, PB20, Gemar, Adil, Makmur, Gata, Gati, and other lines. [e] Resistant to BPH biotype 1 but susceptible to biotype 2. Includes PB26, PB28, PB29, PB30, PB34, Brantas, Serayu, Citarum, and Asahan. Released in 1976. [f] Resistant to BPH biotypes 1 and 2. Includes PB32, PB36, PB38, Semeru, and Cisadane. Released in 1976.

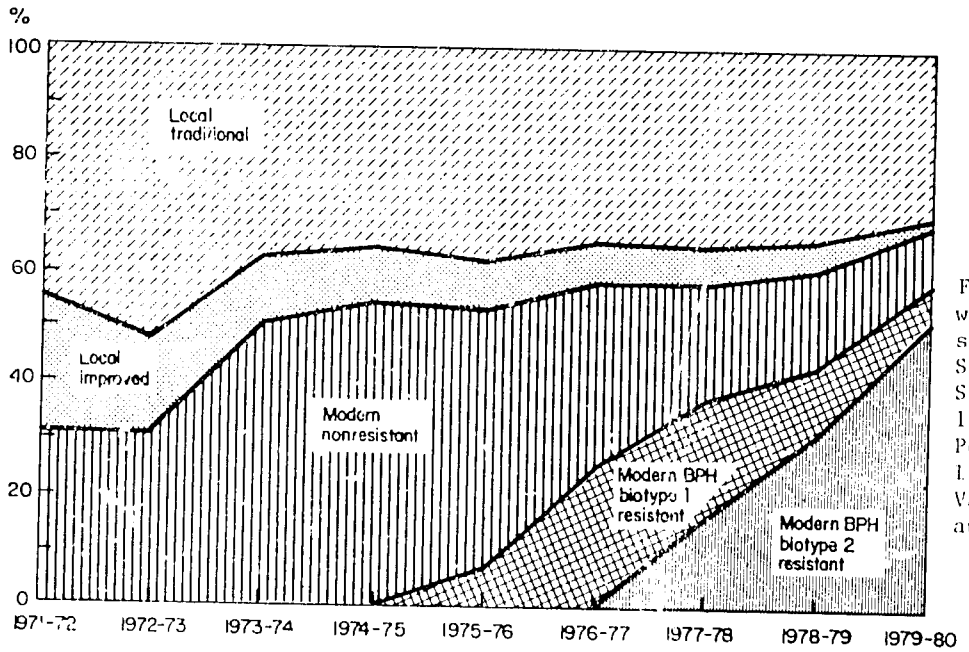

Fig. 4. Percentage of reported area in wetland rice varieties grown in Indonesia, 1972 through 1979 dry seasons. Source: 1971-72 through 1975, Bimas and Sub-Directorate for Seed Production; 1975-76 through 1979-80, Sub-Direktorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

PROVINCIAL TRENDS: 1975-76 THROUGH 1980

The differential adoption of modern varieties due to insects and diseases and cultural and environmental factors can be observed in data documenting varietal adoption in the leading rice production provinces.

Inner islands

West, Central, and East Java, Yogyakarta, and Bali produced about 60% of the rice crop in the 1979-80 wet and dry seasons. In that region, the overall adoption of modern varieties was highly associated with the distribution of irrigation. Although a map of the irrigated area is not available, Figure 5 shows the distribution of lowland areas, which includes all technical, semitechnical, and simple irrigation systems, but probably excludes village systems and rainfed rice in less-intensively cultivated areas. By comparing the relative concentration of modern variety planting (Fig. 6) to the distribution of lowland it is seen that throughout Java these two phenomena coincide. In addition to irrigation, elevation is also an important macrofactor explaining low adoption of modern rice varieties. Figure 7 shows that in areas with an elevation of 100-700 m, and especially in areas with an elevation of more than 700 m, traditional varieties tend to prevail. In terms of pests, BPH has been the major factor determining the succession of varieties adopted by farmers in Java and Bali.

West Java. By the 1975-76 wet season, the Pelitas had become the preferred varieties, planted to about 40% of West Java. In 1974-75 about 60,000 ha were infested with BPH. In response, BPH biotype 1-resistant PB26 was widely introduced in 1975-76 and PB30 in 1976-77. Those varieties were soon replaced because by 1977, BPH biotype 2 had developed and a new set of biotype 2-resistant varieties was required. To meet that need, PB36 and PB32 were introduced in 1977-78 and covered almost 17% of West Java. In the following 2 wet seasons the area in biotype 2-resistant varieties increased to nearly 40% of the planted area.

Although the pattern of adoption was similar during the dry seasons, there was a tendency for a larger share of the area to be planted to BPH biotype 1- and biotype-2 resistant varieties more rapidly tha in the wet seasons, probably because older nonresistant varieties continued to be planted during the wet seasons in rainfed and high-elevation environments where BPH damage was not as intensive.

Central Java. Adoption of modern varieties in Central Java followed a pattern similar to West Java's. Yet, by 1975-76 the Pelitas had been adopted on only 22.5% of the area, suggesting a persistent preference for local varieties (Table 9). As a result of BPH damage in 1974-75 and a greater area heavily damaged in 1975-76, the government widely introduced PB26 (1975-76) and PB30 (1976-77) to replace the popular Pelitas. As biotype 2 developed, the resistant varieties PB36 and PB38 were distributed to replace previous introductions and covered 78% of the province's area by 1979-80.

East Java. In East Java, the Pelitas, which covered 31% of the wetland area in 1975-76, were targeted for replacement by PB26 (1975-76) and PB30 (1976-77), following the damage of 62,500 ha in 1974-75 and 70,000 ha in 1975-76 (Mochida 1978). In the 1977 dry season, PB32 was widely introduced to counter the development of BPH biotype 2 (Table 10). The area in biotype 2-resistant varieties (PB32, PB36, and PB38) increased rapidly during the following three wet seasons. At the same time, it is significant to note that in 1979-80, 75% of the area was planted to a single variety -- PB36. PB32 persisted in East Java because it performed well in early demonstrations and was promoted locally. Many observers credit the high adoption rate of modern varieties in East Java to the strong interest and support given by the governor and provincial administration.

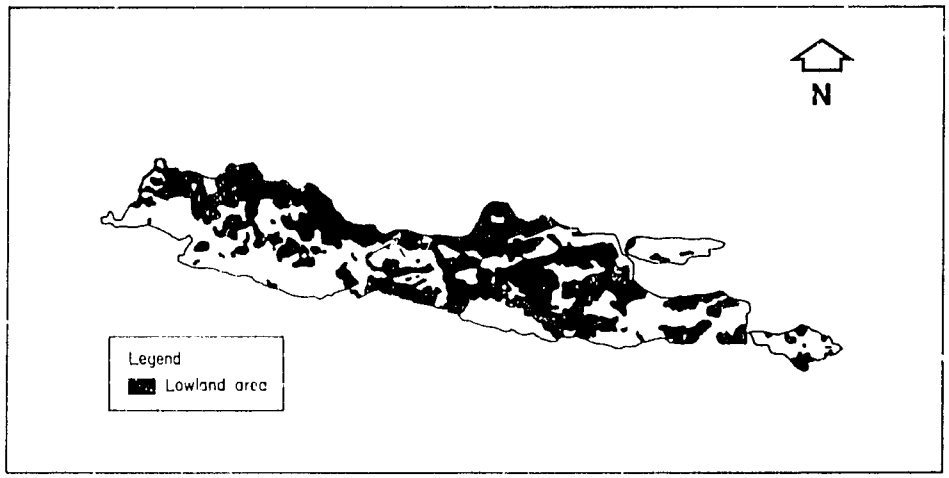

Fig. 5. Distribution of lowland area in Java-Bali, Indonesia.

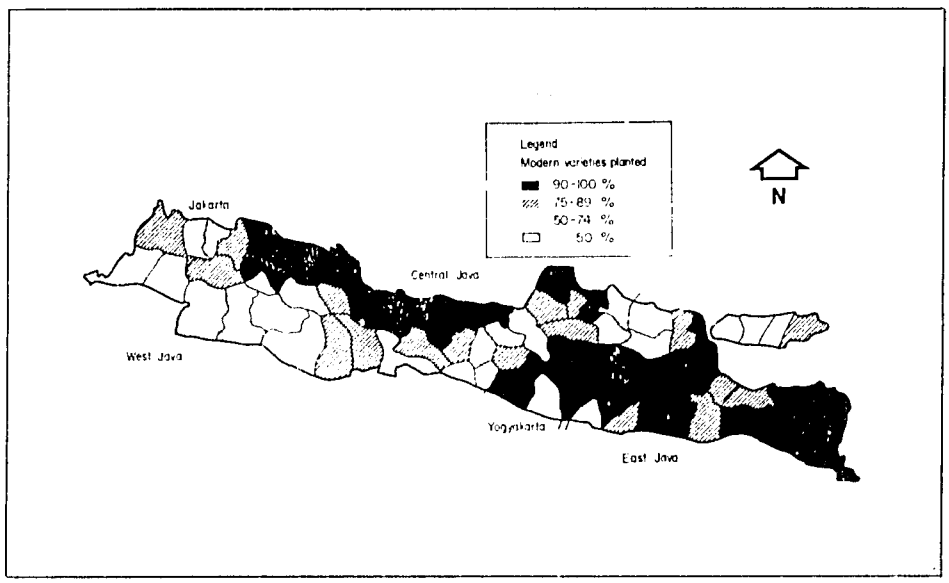

Fig. 6. Concentration of modern rice varieties in Java, Indonesia, by district, 1979-80 wet season.

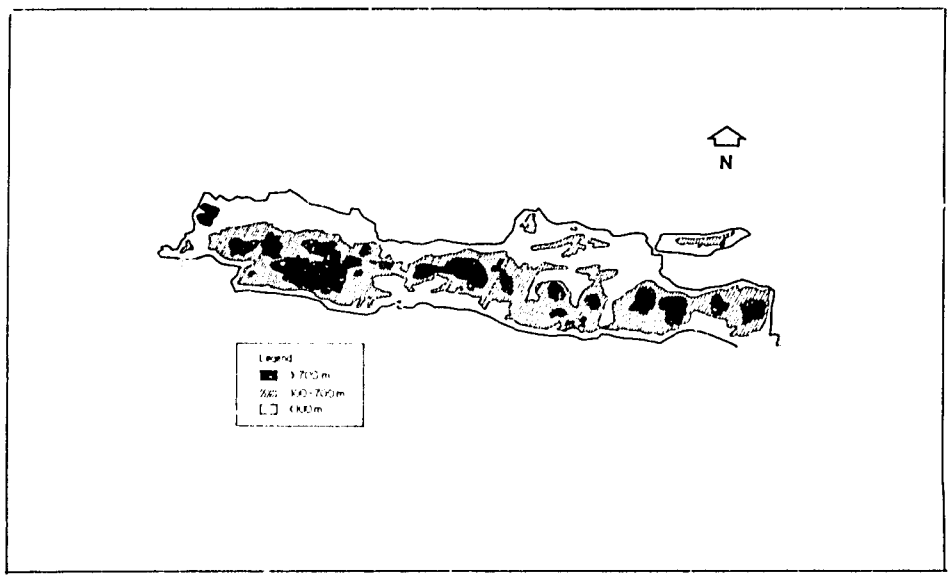

Fig. 7. Elevation of Java, Indonesia.

Table 9. Five most widely planted modern rice varieties on Indonesia's inner islands and percentage of total planted area, by province, 1975-76 through 1979-80 wet seasons. Source: Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.[a]

Year	West Java	Central Java	East Java	DKI Yogyakarta	Bali
1975-76	21.4[a]	19.2	21.3	1.4	2.1
	P.I-1 (31.7)	P.I-1 (14.3)	P.I-1 (28.1)	PB5 (38.8)	PB26 (23.7)
	P.I-2 (8.1)	PB26 (11.0)	PB5 (16.6)	P.I-1 (26.4)	P.I-1 (12.7)
	C4-63 (8.1)	PB5 (9.1)	C4-63 (9.7)	C4-63 (13.1)	C4-63 (10.3)
	PB26 (5.3)	P.I-2 (8.2)	PB26 (8.6)	P.I-2 (12.6)	PB5 (8.0)
	PB5 (3.2)	C4-63 (7.3)	P.I-2 (3.1)	PB26 (2.1)	P.I-2 (2.3)
1976-77	20.3	20.1	20.5	1.3	1.9
	P.I-1 (29.6)	PB26 (19.3)	PB26 (27.1)	PB26 (33.5)	PB30 (32.5)
	PB30 (6.9)	P.I-1 (12.2)	P.I-1 (16.1)	PB34 (18.7)	PB26 (18.9)
	PB34 (6.2)	PB30 (5.3)	PB30 (8.8)	P.I-1 (13.0)	PB28 (6.0)
	C4-63 (5.6)	P.I-2 (5.2)	C4-63 (7.6)	PB30 (6.0)	C4-63 (3.7)
	PB26 (4.8)	C4-63 (4.4)	PB5 (5.7)	PB5 (5.2)	P.I-1 (3.6)
1977-78	19.6	16.8	19.8	1.1	1.8
	PB30 (17.2)	PB36 (18.4)	PB32 (22.4)	PB26 (24.6)	PB36 (21.1)
	PB36 (10.2)	PB30 (15.1)	PB36 (10.8)	PB36 (19.5)	PB32 (17.4)
	P.I-1 (9.2)	PB26 (9.8)	PB26 (10.1)	PB32 (10.0)	C4-63 (10.2)
	PB32 (6.5)	PB28 (5.9)	PB30 (10.1)	PB30 (9.1)	PB26 (7.9)
	PB34 (4.4)	P.I-1 (5.8)	P.I-1 (7.0)	PB38 (4.8)	P.I-1 (6.4)
1978-79	21.2	16.9	19.8	2.1	3.5
	PB36 (13.1)	PB36 (34.4)	PB36 (36.8)	PB36 (27.4)	PB36 (46.2)
	P.I-1 (11.4)	PB38 (9.3)	PB32 (6.9)	PB38 (16.0)	PB38 (12.7)
	PB38 (8.0)	P.I-1 (7.4)	PB38 (6.3)	PB26 (3.6)	PB32 (8.1)
	PB30 (7.9)	PB30 (6.1)	P.I-1 (5.7)	PB30 (1.2)	P.I-1 (2.3)
	C4-63 (4.3)	C4-63 (4.4)	PB28 (1.0)	P.I-1 (0.7)	C4-63 (1.1)
1979-80	19.6	14.4	20.0	1.9	1.8
	PB36 (20.5)	PB36 (67.4)	PB36 (75.1)	PB36 (57.1)	PB36 (73.7)
	PB38 (19.2)	PB38 (10.9)	PB38 (7.4)	PB38 (11.1)	PB38 (4.7)
	P.I-1 (7.8)	P.I-1 (1.2)	PB32 (4.4)	P.I-1 (0.3)	PB32 (2.2)
	PB20 (2.4)	P.I-2 (0.8)	C4-63 (0.6)	PB32 (0.2)	P.I-1 (0.8)
	Citarum (2.1)	C4-63 (0.6)	P.I-1 (0.3)	PB29 (0.1)	C4-63 (0.4)

[a] Numbers underlined indicate the wetland rice area planted in the province, as a percentage of the total area in Indonesia planted in the respective wet seasons. P.I-1 = Pelita I-1, P.I-2 = Pelita I-2. Numbers in parenthesis are percentages of total.

Yogyakarta. The adoption pattern in Yogyakarta is particularly interesting because of its variability. In 1975-76 the Pelitas covered 39% of the province's area. By the following wet season, biotype 1-resistant varieties PB26, PB34, and PB30 dominated (Table 9). In the 1977 dry season, biotype 1-resistant varieties covered 76.8% of the wetland rice area (Table 10). With the development of BPH biotype 2, PB32, PB36, and PB38 were widely introduced in 1977-78, increasing from 34 to 68% of the area in the next 2 years. Although the adoption of resistant varieties was dramatic over the period, it is interesting to note that by 1979-80, only 69% of the area was planted to the top 5 varieties, compared to 93% in 1975-76 (Table 9). This was due to farmers' strong preference for their traditional varieties -- especially Rojolele -- which commanded a higher price than modern cultivars. After several years when BPH damage was not significant, farmers have tended to revert to planting the traditional varieties.

Bali. In Bali heavy BPH infestation occurred in 1974-75. In response, BPH biotype 1-resistant PB26 was widely planted by the 1975-76 wet season (Table 9). In the following wet season, 57% of the area was planted to BPH biotype 1-resistant varieties (Table 10). As biotype 2 appeared, resistant varieties were rapidly introduced. By 1979-80, about 74% of Bali was planted to PB36 alone.

Many observers attribute the rapid adoption of modern varieties in Bali to the existence of an indigenous water users' association (subak), which constitues a highly organized social system that was mobilized for the introduction of new technology.

Outer islands

The major rice-producing provinces of the outer islands -- South Sulawesi, North Sumatra, South

Table 10. Five most widely planted modern varieties on Indonesia's inner islands and percentage of total planted area, by province, 1976 through 1979 dry seasons. Source: Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Year	West Java	Central Java	East Java	DKI Yogyakarta	Bali
1976	26.1[a]	13.9	13.9	1.2	2.2
	P.I-1 (34.8)	PB26 (27.4)	PB26 (30.3)	PB26 (24.0)	PB30 (26.3)
	P.I-2 (9.2)	P.I-1 (12.9)	P.I-1 (18.8)	PB5 (22.5)	PB26 (24.7)
	C4-63 (8.2)	P.I-2 (4.9)	PB5 (12.3)	P.I-1 (18.9)	PB28 (4.7)
	PB26 (7.0)	PB5 (4.6)	C4-63 (6.1)	P.I-2 (10.5)	P.I-1 (3.1)
	PB5 (3.0)	C4-63 (2.9)	PB30 (3.8)	C4-63 (6.8)	C4-63 (2.5)
1977	27.3	12.7	14.4	1.4	2.6
	PB30 (18.0)	PB26 (15.3)	PB26 (33.7)	PB26 (43.7)	PB26 (20.9)
	P.I-1 (15.5)	P.I-1 (14.6)	PB30 (17.1)	PB30 (16.1)	PB32 (18.2)
	PB26 (6.0)	PB30 (11.5)	P.I-1 (9.6)	PB34 (10.3)	PB30 (13.8)
	PB34 (5.5)	PB28 (7.9)	PB28 (8.3)	PB28 (6.7)	P.I-1 (6.2)
	C4-63 (5.5)	PB34 (4.6)	PB32 (5.6)	PB29 (5.0)	C4-63 (4.7)
1978	26.0	13.1	13.1	2.1	2.6
	PB36 (24.4)	PB36 (20.6)	PB36 (38.1)	PB36 (16.3)	PB36 (35.6)
	PB30 (14.9)	PB30 (10.3)	PB30 (11.4)	PB26 (15.4)	PB38 (14.3)
	P.I-1 (5.3)	PB26 (7.9)	PB32 (10.0)	PB38 (8.6)	PB32 (11.6)
	PB38 (4.8)	P.I-1 (5.9)	PB26 (7.5)	C4-63 (7.4)	P.I-1 (3.7)
	C4-63 (3.3)	PB28 (5.8)	PB38 (5.9)	P.I-1 (7.1)	PB26 (3.1)
1979	25.5	15.4	13.8	1.4	2.7
	PB36 (18.4)	PB36 (54.5)	PB36 (74.6)	PB36 (70.2)	PB36 (73.9)
	PB38 (17.7)	PB38 (19.0)	PB38 (10.5)	PB38 (26.7)	PB38 (5.9)
	PB30 (6.6)	P.I-1 (4.0)	PB32 (4.9)	PB26 (0.4)	PB32 (2.6)
	Citarum(4.8)	PB30 (1.4)	PB30 (1.1)	PB29 (0.3)	P.I-1 (1.2)
	P.I-1 (4.8)	PB32 (1.2)	PB28 (0.6)	PB32 (0.1)	P.I-2 (0.6)

[a] Numbers underlined indicate the wetland rice area planted in the province, as a percentage of the total area in Indonesia planted in the respective dry seasons. P.I-1 = Pelita I-1, P.I-2 = Pelita I-2.

Kalimantan, and West Sumatra -- produced about 20% of Indonesia's rice crop in the 1979-80 wet and dry seasons. The outer islands have a great deal more ecological and cultural diversity than the inner islands. Consequently, single rice varieties have generally never predominated to the same degree.

South Sulawesi. In South Sulawesi, the main factors influencing the adoption pattern have been the spread of tungro disease and BPH, localized flooding problems, and farmers' desire to reduce risk in double-cropped areas. The available varieties have been widely accepted by farmers. In the wet season, the area covered by the top five varieties has remained relatively constant (Table 11). In the dry seasons, the proportion of the area in the leading 5 modern varieties declined from 61% in 1976 to 55% in 1979 due to the greater number of varieties from which farmers could choose (Table 12). Areas still planting traditional and national improved varieties are primarily those in higher elevations, areas under tidal influence, and those with toxic soils.

In the 1975-76 wet season C4-63 was the preferred variety due to its good eating quality. Yet, as tungro disease became more widespread, C4-63 was gradually replaced in the mid-1970s by PB20 and PB26, which gave high yields and had tungro resistance. Even though PB5 and Pelita I-1 were also susceptible to tungro, the percentage of the area planted to them remained high. These were grown in areas without major tungro problems because farmers preferred the leafy plant type, intermediate height, and superior eating quality.

PB20 was popular through 1977-78 because of its tungro resistance, but as BPH infestation spread, it was gradually replaced by PB26. Yet PB26 eventually became susceptible to tungro and declined in importance. PB32 was widely grown in 1978-79 because of its tungro resistance, intermediate height, and high yield. Also, its relatively late maturity (140 days) made it particularly appropriate for areas susceptible to flooding, where harvesting early varieties was difficult in the wet season. PB30, although never planted to a major proportion of the area, found its niche in double-cropped areas because its short duration (112 days) enabled farmers to reduce the probability of drought damage to the second crop. The rapid adoption of Citarum in 1979-80 (23%) was the consequence of a visit by President Soeharto who provided this Indonesian release to local officials (Table 11). Citarum is resistant to BPH biotype 1, but has poor eating quality and is likely to be replaced by future introductions.

Table 11. Five most widely planted modern varieties in selected provinces on Indonesia's outer islands, by province, 1975-76 through 1979-80 wet seasons. Source: Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Year	S. Sulawesi	N. Sumatra	S. Kalimantan	W. Sumatra
1975-76	5.2[a]	5.7	2.5	3.1
	C4-63 (17.0)	PB26 (6.6)	PB5 (24.0)	PB5 (24.4)
	PB20 (14.5)	C4-63 (4.7)	C4-63 (3.2)	PB20 (12.0)
	PB5 (8.6)	PB5 (4.5)	P.I-1 (3.0)	P.I-1 (4.8)
	P.I-1 (3.6)	P.I-1 (3.4)	P.I-2 (1.8)	PB8 (3.8)
	PB26 (3.2)	P.I-2 (1.8)	PB20 (1.2)	PB26 (3.2)
1976-77	6.2	6.3	3.1	1.0[b]
	C4-63 (13.7)	PB26 (8.5)	PB5 (25.0)	PB5 (44.2)
	PB20 (13.5)	PB34 (4.8)	C4-63 (3.4)	PB26 (19.8)
	PB5 (8.1)	C4-63 (2.7)	P.I-1 (2.9)	PB20 (8.8)
	PB26 (6.0)	PB5 (2.2)	P.I-2 (1.4)	P.I-1 (5.7)
	P.I-1 (2.5)	P.I-1 (1.7)	PB26 (0.8)	P.I-2 (3.4)
1977-78	5.6	5.7	4.1	1.6[b]
	PB20 (12.1)	PB32 (11.7)	PB5 (18.1)	PB5 (31.5)
	PB26 (10.9)	PB36 (3.5)	C4-63 (6.8)	PB26 (24.7)
	C4-63 (10.3)	PB34 (2.7)	P.I-1 (2.8)	PB20 (10.4)
	PB5 (7.4)	C4-63 (1.8)	PB26 (1.6)	P.I-1 (8.1)
	P.I-1 (3.1)	PB5 (1.6)	P.I-2 (1.3)	PB28 (5.3)
1978-79	5.8	4.8	3.4	3.0
	PB32 (20.6)	PB36 (18.5)	PB5 (15.9)	PB5 (18.1)
	C4-63 (9.0)	PB32 (17.3)	C4-63 (3.0)	PB26 (11.5)
	PB26 (8.2)	PB34 (2.0)	P.I-1 (1.6)	PB20 (4.1)
	PB5 (6.1)	C4-63 (1.4)	PB8 (1.6)	P.I-1 (3.9)
	PB30 (4.7)	P.I-2 (1.0)	PB32 (1.4)	PB28 (3.8)
1979-80	7.3	5.8	2.7	2.9
	Citarum (22.9)	PB36 (19.4)	PB5 (23.2)	PB5 (13.5)
	PB32 (16.1)	PB32 (11.4)	C4-63 (2.7)	PB32 (12.3)
	PB5 (4.2)	C4-63 (0.8)	PB32 (2.4)	PB36 (12.0)
	C4-63 (2.9)	PB26 (0.2)	PB8 (1.9)	PB26 (10.9)
	PB26 (2.8)	PB38 (0.2)	P.I-1 (1.7)	PB38 (6.4)

[a] Numbers underlined indicate the wetland rice area planted in the province, as a percentage of the total area in Indonesia planted in the respective wet seasons. b/Extensive underreporting of planted area. P.I-1 = Pelita I-1, P.I-2 = Pelita I-2.

Because PB36 was introduced only in 1979-80 in anticipation of the development of BPH biotype 2, it is not among the top five varieties planted. Yet, it is similar in duration as PB30, has better eating quality than PB32, and is tungro resistant. Consequently, the area planted to PB36 will probably increase. PB42 was not officially released and consequently not reported by farmers but it was known to be widely grown because of its high yielding ability and adaptability to a wide variety of environments. In addition, its resistance to tungro and BPH biotype 2 is sought by local farmers.

The general pattern of adoption in the dry seasons is similar to that in the wet season. Almost all of the areas planted to a second crop are irrigated and are where extension (Bimas) support is concentrated. Consequently, in each dry season the percentage of areas planted to the five most widely grown varieties was greater in the dry season. The difference appears, however, to be declining -- falling from a 23% differential in 1975-76 vs 1976 to a 7% differential in 1978-79 vs 1979 (Tables 11 and 12).

North Sumatra. In North Sumatra, heavy BPH infestation first occurred in 1972-73 (Mochida 1978). BPH-resistant PB26 was introduced and covered about 7% of the area in 1975-76 (Table 11). By the end of 1976, this variety became susceptible to BPH biotype 1, requiring the introduction of biotype 2-resistant varieties in the 1977 dry season (Table 12). The area planted to biotype 2-resistant PB32, PB36, and PB38 rose steadily -- from 15% in 1977-78 to 31% in 1979-80.

Although modern varieties have been adopted widely, BPH-susceptible C4-63, PB5, and traditional varieties still cover as much as 65% of the wet

season and 50% of the dry season area. These have persisted because of local farmers' taste preference and the existence of environmental niches where the BPH is not a major problem.

South Kalimantan. In South Kalimantan the major factors explaining the adoption pattern have been an absence of serious disease problems because of extensive rather than intensive rice production, and absence of water control which made it risky to plant modern varieties.

Throughout the 5-year period considered, PB5 has remained the most widely adopted cultivar. It has persisted because BPH has never been a significant problem in South Kalimantan. Also, PB5's height makes it suitable for deepwater areas that characterize much of the province. In addition, farmers have observed that this variety has a particularly strong ability to recover from initial damage -- such as rat attack -- and still give good yield.

C4-63 remained the second most popular cultivar throughout the period. It is grown particularly in rainfed areas where its leafy characteristics provide good weed control. In addition, the eating quality of C4-63 is compatible with local taste preferences.

The Pelitas are grown in deepwater areas where their intermediate height reduces damage from periodic flooding. Although the Pelita's taste is considered good, they have spread to only a small part of the area because they have less ability to recover from early damage, compared to PB5. PB20 and PB26 have never become important because of their poor eating quality and short stature, which made them vulnerable to fluctuations in the water level. Yet, PB26 has been grown in limited areas affected by tungro virus.

The dry season pattern of adoption was similar to that observed in the wet seasons. It is noted, however, that a much smaller percentage of the areas is planted to modern varieties in the dry season, compared to the previous wet season.

In general, available modern varieties have not been widely adopted in South Kalimantan, claiming only about 30% of the area in the wet seasons and less than 20% in the dry seasons. This suggests that modern varieties presently available perform poorly, relative to local varieties, in most of the existing environments.

West Sumatra. In West Sumatra, modern varieties have been widely adopted, in both growing seasons. As in South Kalimantan, the absence of serious

Table 12. Five most widely planted modern varieties in selected provinces of Indonesia's outer islands, 1976 through 1979 dry seasons. Source: Subdirektorat Pembinaan Mutu Benih, Direktorat Perlindungan Tanaman Pangan, Penyebaran Varietas Padi. Raw data summarized by authors.

Year	S. Sulawesi	N. Sumatra	S. Kalimantan	W. Sumatra
1976	12.9[a]	7.4	2.5[b]	0.9[b]
	C4-63 (19.2)	PB26 (14.8)	PB5 (12.5)	PB5 (34.1)
	PB20 (18.9)	C4-63 (4.0)	C4-63 (5.2)	PB20 (18.9)
	PB5 (13.4)	PB5 (3.4)	P.I-1 (2.4)	PB26 (16.0)
	PB26 (7.3)	P.I-1 (2.3)	P.I-2 (2.4)	PB8 (7.4)
	P.I-1 (1.8)	PB34 (1.1)	PB26 (1.2)	P.I-1(1.5)
1977	9.6	7.4	0.9	4.6
	C4-63 (16.4)	PB26 (7.4)	PB5 (47.4)	PB5 (18.9)
	PB26 (15.4)	PB32 (7.0)	C4-63(10.7)	PB26 (15.5)
	PB5 (14.0)	PB34 (6.6)	PB8 (8.0)	PB20 (7.5)
	PB20 (12.2)	C4-63 (2.8)	P.I-1 (3.9)	P.I-1 (5.8)
	PB34 (1.0)	P.I-1 (2.4)	PB26 (1.0)	PB28 (3.8)
1978	10.4	5.9	4.6	4.4
	PB26 (18.5)	PB32 (25.1)	PB5 (4.3)	PB5 (14.5)
	C4-63 (12.0)	PB36 (15.6)	C4-63 (2.6)	PB26 (12.3)
	PB20 (9.4)	PB34 (3.9)	PB36 (0.9)	P.I-1(3.9)
	PB5 (8.9)	C4-63 (2.2)	PB8 (0.8)	PB20 (3.7)
	PB30 (4.2)	P.I-1 (1.6)	P.I-1 (0.4)	PB28 (3.1)
1979	10.9	6.4	4.6	3.3
	PB32 (26.4)	PB26 (23.4)	PB5 (4.4)	PB36 (15.4)
	PB26 (10.3)	PB32 (21.5)	C4-63 (2.0)	[illegible]
	C4-63 (8.0)	P.I-1 (0.8)	PB36 (1.4)	[illegible]
	PB5 (5.4)	P.I-2 (0.3)	PB32 (1.1)	PB26 (7.0)
	PB30 (5.0)	PB38 (0.3)	PB8 (0.7)	PB5 (6.5)

[a] Numbers underlined indicate the wetland rice area planted in the province, as a percentage of the total area in Indonesia planted in the respective dry seasons. [b] Extensive underreporting of planted area. P.I-1 = Pelita I-1, P.I-2 = Pelita 1-2.

insect and disease problems enabled farmers to continue to widely plant such varieties as Pelita, PB5, and PB20 in many areas through the 1979-80 wet season (Table 11). Although there has been no serious BPH problem in West Sumatra, biotype 2 varieties were introduced in 1979-80 as a precautionary measure because of serious outbreaks in nearby provinces.

DELIVERING NEW TECHNOLOGY TO FARMERS

In the early 1960s, Indonesia's population grew rapidly but rice production remained relatively constant. Consequently, the government sought ways to stimulate rice output. Agricultural intensification played an important role.

The foundation of the existing program is the 1963-64 Action Research project developed by the Bogor Institute of Agriculture and tested at Karawang. In this experiment, university students lived in the villages and provided technical advice, credit, and inputs to cooperating farmers. During the following year, this effort was expanded to include about 440 students from 9 agricultural colleges working in 220 villages (Birowo 1975). In 1965-66 the program was implemented nationwide and renamed Bimas, meaning mass guidance.

The basic program has been modified several times in response to a variety of circumstances. To accommodate farmer participants who no longer needed credit because yields and income had increased, Inmas was initiated in 1967-68. When the first modern varieties (IR5, IR8) became available in 1968, the program was renamed Bimas Baru (new Bimas).

At the same time as farmer participation in Bimas increased, Indonesia suffered from a shortage of foreign exchange which made it difficult to import inputs. Consequently, Bimas Gotong-Royong (mutual cooperative Bimas) was introduced in 1968-69. Foreign private enterprises were recruited to provide technical guidance and required inputs to the Government on 1-year credit. By the 1970 wet season, however, this assistance was no longer needed.

In 1969-70 improved Bimas was started and the unit village concept was introduced. This represents the current model. The agricultural area was divided into blocks of 600-1,000 ha each, which became the organizational unit for activities to support intensification -- including credit, input retailers, extension officers, and product marketing. In 1972-73 the improved Bimas program was expanded to include food crops other than rice.

The Bimas program is built around three principles.

- First, participating farmers are encouraged to use modern production practices, including good land preparation, seeds, efficient irrigation practices, fertilizer, and insecticide.
- Second, noncollateral credit is made available to obtain a package of inputs that presently includes a recommended modern variety, 100-250 kg urea/ha and 35-75 kg triple superphosphate/ha (depending on area), 2 liters of insecticide, 100 g of rodenticide, and a nominal cost-of-living allowance. Inputs are provided in kind and the living allowance in cash, with an interest rate of 1%/month charged on the outstanding balance.
- Third, technical assistance is provided by extension agents (PPL) through a three-tier system. Each PPL works with 16 master farmers, who in turn are assigned 20 farmers, each of whom has 5 farmers to whom he should communicate new information that is passed down the chain. Ideally, 1 PPL reaches 1,600 farmers through the tier structure.

Farmers accepted the Bimas program rapidly. Four years after the program was initiated (1968) more than 750,000 ha were enrolled. That increased to 3,086,000 ha by 1975. Bimas participation has declined since but, the total program area (Bimas plus Inmas) has increased steadily and covered 5.9 of the slightly more than 7 million ha of the wetland rice cropped during the late 1970s (Table 13).

The two most important inputs in the production package are fertilizer and modern varieties. As the program expanded, adoption of fertilizer and modern varieties grew. From 1970 to 1979, urea consumption tripled and the area planted to modern varieties increased fivefold (Table 13).

As input use increased, yields also rose steadily. Over the 10-year period considered, wetland rice yields climbed from 2.6 to 3.2 t/ha or by 22% (Table 13). The actual magnitude of the yield increase in the production program area was probably even greater. While wetland is defined as both rainfed and irrigated areas, the production program was largely confined to irrigated farms.

During the first year of the program, repayment stood at 90% or more. In the 1975 dry season, defaults on loans increased steadily. As of January 1980, only 47% of the 1978-79 wet season loans had been repaid (Bank Rakyat Indonesia 1980). It would appear that even though farmers with outstanding loans cannot obtain additional credit, this has not had a noticeable impact on urea consumption or modern variety adoption because inputs can still be obtained for cash through Inmas.

The rice pricing policy of the government has also stimulated the application of high levels of inputs. Since 1968 government has supported the price of rice and subsidized the cost of inputs. Over the period 1968-69 to 1979-80 wet season, the rice-urea price ratio increased from 0.80 to 1.50 (i.e. in 1979-80 1 kg of rice pays for 1.5 kg of urea). At current world market prices for urea

(US$200/t, CIF), the existing farm-gate price (US$ 0.11/kg) implies a urea subsidy of $80/t, exclusive of delivery costs. Insecticides are also highly subsidized with farmers paying only 20% of the imported cost.

IMPACT OF NEW TECHNOLOGY ON YIELDS AND PRODUCTION

Until the mid-1960s, wetland rice yields fluctuated between 1.8 and 2.2t/ha in 1960-67 (Table 14).

With the introduction and widespread adoption of modern varieties in the late 1960s, wetland yields rose steadily. Despite serious BPH outbreaks in the mid-1970s, average wetland yield increased every year, except from 1974 to 1975. In 1980 total production reached 19.9 million t (milled rice) -- an 11% increase over 1979.

Although Indonesia's population has continued to grow rapidly, the per capita availability of rice

Table 13. Production program coverage and complementary input use, 1970-79. Source: Bimas Office, Pasar Minguu, and Biro Pusat Statistics.

Year[a]	Program area (1,000 ha)			Urea[b] (1,000 t)	Modern varieties[c] (1,000 ha)	Wetland yield[d] (t/ha)
	Bimas	Inmas	Total			
1970	1,235	849	2,084	342	1,072	2.6
1971	1,419	1,467	2,886	413	1,848	2.7
1972	1,243	2,020	3,263	485	2,279	2.7
1973	1,889	2,223	4,112	669	3,226	2.8
1974	2,996	1,094	4,090	604	3,244	2.9
1975	3,086	1,161	4,247	670	3,784	2.8
1976	2,974	1,500	4,474	666	4,151	3.0
1977	2,509	2,775	5,284	919	4,801	3.0
1978	2,235	3,348	5,583	975	5,216	3.2
1979	1,802	4,067	5,869	1,096	5,552	3.2

[a] Year includes wet and dry season data, i.e. 1970 includes data for 1969-70 wet season and 1970 dry season. [b] Program farmers only. [c] Wetland area including nonprogram hectares. [d] Rainfed and irrigated paddies.

Table 14. Rice yield, production, population, and per capita availability, Indonesia, 1960-80. Source: Biro Pusat Statistics; 1960-70 data adjusted by Lains (1978) to take into consideration changes in definitions.

Year	Rice yield (t/ha)		Production (1,000 t)		Population (1,000)	Per-capita availability[c] (kg/person per yr)
	Stalk paddy	Dry unhusked	Stalk paddy	Milled		
1960	2.3	1.8	18,132	9,401	95,552[a]	98.4
1961	2.8	2.2	17,111	8,872	97,387	91.1
1962	2.8	2.2	18,207	9,440	99,257	95.1
1963	2.8	2.1	16,348	8,476	101,221	83.7
1964	2.8	2.2	17,200	8,918	103,271	86.4
1965	2.9	2.1	18,269	9,472	105,414	89.9
1966	2.9	2.2	19,198	9,954	107,645	92.5
1967	2.8	2.2	18,557	9,622	109,964	87.5
1968	3.0	2.3	20,846	10,809	112,377	96.2
1969	3.1	2.4	21,816	11,312	114,880	98.5
1970	3.5	2.7	24,457	12,681	117,469	108.0
1971	3.5	2.7	26,392	13,684	120,149	113.9
1972	3.5	2.7	25,351	13,144	123,115	106.8
1973	3.7	2.8	28,091	14,565	126,088	115.5
1974	3.8	2.9	29,376	15,231	129,083	118.0
1975	3.7	2.8	29,202	15,141	132,110	114.6
1976	3.9	3.0	30,470	15,799	135,190	116.9
1977	4.0	3.0	30,472	15,829	138,342	114.4
1978	4.1	3.1	33,702	17,547	141,109[a]	124.4
1979	4.2	3.2	34,492	17,918	143,931[a]	124.5
1980	[b]	[b]	38,323	19,908	146,000[a]	136.4

[a] Trend estimation. [b] Data not available. [c] Milled-rice production divided by population.

has increased at a faster rate.[4/] In the period before modern varieties (1960-67), per capita availability averaged 90.6 kg compared to 136.4 kg in 1980. While these developments are the result of numerous contributing factors, the timely introduction of appropriate varieties has played a major role.

CONCLUSION

Over the past 15 years, modern rice technology has had a significant impact on the rice sector in Indonesia. Yields and production have increased steadily as a consequence of several interdependent factors. Improvements in expanding irrigation systems have created a physical environment conducive to high productivity. Modern rice varieties, with yield potential substantially above that of traditional varieties, have been introduced through the varietal improvement program. The national seed production program has rapidly multiplied these varieties to meet the demand for new cultivars. Through the Bimas program, improved varieties, fertilizer, insecticides, and production credit have been made available to a large portion of the nation's farmers. All of these developments resulted from governmental investment in irrigation, agricultural research, seed production, plant protection, extension, and policies that have supported the price of rice and subsidized the price of inputs.

Although modern varieties have been widely adopted throughout Indonesia, this has largely occurred in the wetland (irrigated and rainfed) environments. Consequently, substantially large portions of the rice growing area have not benefited from the new technology; including the dryland, high-elevation, and tidal environments. Presently, several candidate varieties are being screened for these areas and during the past few years two varieties have been released for the dryland area and four varieties for high-elevation areas. Yet, more effort must be made to develop modern varieties suitable for farmers in dryland and tidal environments because they represent the major share of the untapped agricultural potential in Indonesia and have been targeted for the transmigration of the landless and near-landless farmers of Java-Bali.

In the intensively cultivated irrigated areas where BPH has been a persistent problem, primary reliance on varietal resistance for control has led to the almost total planting of large contiguous areas to the single variety PB36. This has created a potentially dangerous situation in which an insect or disease outbreak could spread rapidly throughout the area. For example, in December 1980 in Bali -- where more than 75% of the wetland was planted to PB36 -- a serious tungro outbreak occurred on several hundred hectares. A potentially serious problem was averted because the Directorate of Plant Protection's pest and disease surveillance system provided an early warning and control measures were rapidly initiated.

Consequently, to reduce the likelihood of future outbreaks, measures must be taken to broaden the varietal diversity in contiguous areas and genetic sources of resistance to major pests and diseases. At the same time, greater emphasis must be placed on reducing the present heavy reliance on varietal resistance. It is anticipated that this can be achieved through implementation of integrated pest control, including cultural controls (synchronized planting, crop rotation), selective sanitation, manipulation of natural enemies, spraying of pesticides only when insect populations reach economic damage thresholds, and an aggressive pest surveillance program (Oka 1979).

Indonesia's attempt to increase rice production has faced numerous obstacles over the past two decades. Although setbacks have occurred, the achievements have been impressive. With the strong foundation that has been laid and the experiences of the past as a guide, Indonesia is well prepared to meet the challenge of self sufficiency in rice production.

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4/Per capita availability is calculated as production divided by population. This is not equivalent to per capita consumption because imports, seed requirements, and storage losses are not considered.

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