AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Food production and nutrition AF30-0150-G570

B. SECONDARY: Plant breeding--Rice--Asia

2. TITLE AND SUBTITLE

Genetic interrelationships of improved rice varieties in Asia

3. AUTHOR(S)

Hargrove, T. R.; Coffmann, W. R.; Cabanilla, V. L.

4. DOCUMENT DATE: 1979

5. NUMBER OF PAGES: 36p.

6. ARC NUMBER: ARC FEA633.18.H279

7. REFERENCE ORGANIZATION NAME AND ADDRESS

IRRI

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

(In IRRI res. paper ser. no. 23)

9. ABSTRACT

10. CONTROL NUMBER

PN-AAG-564

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Plant genetics
Rice
Varieties
Asia

13. PROJECT NUMBER

14. CONTRACT NUMBER

AID/ta-G-1074 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

IRRI RESEARCH PAPER SERIES
Number 23 January 1979

GENETIC INTERRELATIONSHIPS OF IMPROVED RICE VARIETIES IN ASIA

T. R. Hargrove, W. R. Coffman, and V. L. Cabanilla

The International Rice Research Institute
P.O. Box 933, Manila, Philippines

GENETIC INTERRELATIONSHIPS OF IMPROVED RICE VARIETIES IN ASIA[1]

ABSTRACT

Genetic uniformity has set the stage for crop-destructive insect and disease epidemics in the past. Therefore, the International Rice Research Institute (IRRI) has interest in the genetic diversity of improved rice varieties released in Asia.

The diffusion of rice genetic materials used as parents from 1965-67 to 1974-75 was traced by analyzing randomly selected crosses made in 7 Asian nations. Sixty-one percent of the 1965-67 crosses involved at least one semidwarf parent; 84% did in 1974-75. Over the 10-year period the percentage of semidwarf parents used in the *total gene pool* nearly doubled because breeders were increasingly crossing semidwarf parents with other semidwarfs.

Taichung Native 1 (TN1) and IR8 were the most extensively used gene sources in 1965-67, but their use had dropped nearly to zero 10 years later. Use of other IRRI semidwarfs increased significantly, but the strongest trend was the growing use of *locally developed* semidwarfs -- from 2% of the 1965-67 crosses to 49% in 1974-75. Seventy-six percent of those local semidwarfs were progeny of IR8 or other IRRI rices. IRRI semidwarf parents were generally used as donors of disease and insect resistance. Locally developed semidwarfs were used for grain quality and growth duration. Test nurseries and trials were the breeders' most common sources of introduced materials. About 70% of the 36 varieties most recently released by the stations were semidwarfs (mostly progeny of IR8 or TN1). About half of the 95 most widely grown varieties were semidwarfs, and 35% were tall. Jaya was the most popular, followed by IR8.

All IR varieties trace to the same maternal parent, Cina, implying that components of their cytoplasm are similar. Cina is the ultimate maternal parent of 62% of the new (post-IR8) varieties in Bangladesh; 74% in Indonesia; 60% in Korea; 75% in Sri Lanka; and 25% in Thailand. More than half of the rice land in the Philippines is planted to maternal derivatives of Cina.

Among 79 International Rice Yield Nursery (IRYN) entries from 10 nations and IRRI, 58% trace their maternal ancestry to Cina. From 36 to 92% of

---

[1] by T. R. Hargrove, associate editor, W. R. Coffman, plant breeder, and V. L. Cabanilla, research assistant, International Rice Research Institute, Los Baños, Philippines. Submitted to the IRRI Research Paper Series Committee in May 1978.

the elite materials in various other nurseries and IRRI screening trials derive from Cina. Forty-four percent of the female parents used in the first 20,000 crosses made at IRRI can be traced to Cina, but the trend is declining. About half of the female parents used in 1974-75 crosses made in 10 nations can be traced to Cina.

All named IR varieties, except IR5, and virtually all semidwarfs developed in national programs, carry the same dwarfing gene, from the dwarf Chinese variety, Dee-geo-woo-gen (DGWG).

The cytoplasmic similarity of the modern varieties, while posing no immediate practical problem, is of sufficient relevance to demand a prompt broadening of the maternal genetic base of modern rices. Recommendations include avoiding the use of maternal derivatives of Cina as females in crosses, the naming of varieties of diverse maternal origin, and the identification and use of alternative sources of dwarfism.

GENETIC INTERRELATIONSHIPS OF IMPROVED RICE VARIETIES IN ASIA

Improved crop varieties, developed by plant breeders and rapidly adopted by farmers, have spearheaded dramatic increases in world food production. But when farmers adopt the modern varieties intensively, they tend to discard their traditional cultivars. This loss of diverse germplasm has clearly eroded the genetic diversity of many of the world's cultivated crops, rendering large areas of genetically similar crops potentially vulnerable to insect and disease epidemics.

A recent and dramatic example of a genetic-based epidemic was that of southern corn leaf blight in the U.S. in 1970. But destructive epidemics also struck the potato crop in Ireland in the late 1840s, coffee in Ceylon (Sri Lanka) in the 1870s, grapes in France in the late 1800s, bananas throughout the Carribean, wheat in the U.S. in 1916, rice in Bengal, India in 1942, and oats in the U.S. in 1946 (National Academy of Sciences 1972).

It is not certain that all of those epidemics had a genetic component, but the spread of potato blight in Ireland was probably caused by genetic uniformity. Most of the Irish crop was planted to one variety. Genetic uniformity was certainly responsible for the spread of the Panama banana disease and for wheat rust epidemics of modern times (National Academy of Sciences 1972).

The development of modern semidwarf varieties has altered rice production dramatically since the mid-1960s. Today, vast areas of Asia's rice-growing land, particularly the irrigated regions, are planted to semidwarf varieties. They are also widely grown in Africa and Latin America.

More than a decade has passed since the first semidwarfs reached farmers' fields. Therefore, it seems an appropriate time to examine the genetic composition of the improved rice varieties coming from national rice improvement programs and from the International Rice Research Institute (IRRI), and to analyze their impact on the genetic diversity of the world's cultivated rices. Equally important is examination of the factors that have contributed to current trends in rice breeding.

BACKGROUND OF MODERN RICES

Taichung Native 1 (TN1) was the world's first semidwarf rice variety developed by hybridization and was the first tropical semidwarf to cross national boundaries for wide cultivation. TN1 was the prototype for development of IR8, the variety responsible for later use of terms such as *miracle rice* and *green revolution*. TN1 was released in 1956 in Taiwan from a 1949 cross of a dwarf Chinese variety, Dee-geo-woo-gen,

and a local Taiwanese variety, Tsai-yuan-chor. According to Huang et al (1972), TN1 was first introduced into India in 1960 through a University of Missouri cooperative project. In 1966, IRRI sent a ton of TN1 seed to India, and the Indian government later purchased more than 50 tons. Farmer production of TN1 in tropical Asia probably peaked in 1968-69, when it was planted on 810,000 ha in India.

In 1962, IRRI plant breeders used Dee-geo-woo-gen (DGWG) -- the same Chinese variety that had given TN1 its semidwarf plant structure -- as a male parent (pollinator) in a cross with Peta, a tall vigorous variety from Indonesia that was also popular in Malaysia and the Philippines. IR8, a short, stiff-strawed progeny of the cross, was released in late 1966 as IRRI's first variety.

Like TN1, IR8 responded bountifully to fertilizer without lodging, and was insensitive to day length. Farmers in irrigated regions across tropical Asia rapidly adopted IR8, and within a few years it was the world's most widely grown rice variety. In the decade following the release of IR8, IRRI named 10 other varieties. More than 50 IRRI experimental lines have been released as varieties in national programs, usually with local names (Khush and Coffman 1977). Many of the later IR varieties became popular because of their wide spectrums of insect and disease resistance.

Today, semidwarf varieties are grown on about 30% of the rice areas of the tropics (Dalrymple 1978). But not all of those varieties originated at IRRI. By the early 1970s, farmers in many regions had begun to replace IRRI rices with new *locally developed* varieties such as Jaya and Ratna in India, Tong-il in Korea, and BG11-11 in Sri Lanka.

Because most of the locally developed varieties are semidwarfs of the IR8 plant type, questions arise about their genetic composition. Are they progeny of IR8 and other early semidwarf varieties? To what extent have the original semidwarfs served as *genetic building blocks* for the newer, locally developed varieties? And, how has that affected the genetic diversity of the world's rice crop?

The spread of IR8, TN1, and other improved rice varieties onto farmers' fields is well documented, but little is known about their use as parent varieties in crossbreeding programs.

ADOPTION OF IMPROVED RICE VARIETIES AS PARENTS

In a 1975 study partially funded by The Rockefeller Foundation, IRRI scientists traced the diffusion of rice genetic materials into breeding programs through analysis of 819 parents used in 355 randomly selected hybridizations made in 27 rice improvement programs of 10 Asian nations: Bangladesh, India, Indonesia, Iran, Korea, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand. From national breeding records, crosses made during 3 time periods (1965-67, 1970-71, and 1974-75) were randomly selected and analyzed (Hargrove 1978).

Diffusion of semidwarf parent materials

The IRRI study showed that Asian plant breeders rapidly utilized the early semidwarf rice varieties as parents. In 1965-67, a semidwarf parent was involved in 61% of the crosses from 14 research centers in 7 Asian nations where breeding records for the total 10-year period were available (Bangladesh, India, Indonesia, Korea, Philippines, Sri Lanka, and Thailand) (Table 1).

But a more interesting trend was the increase in the *intensity* of use of semidwarfs as parents. In the total 1965-67 genetic pool, 28% of all parents were semidwarf, and 40% were tall. Ten years later, the percentage of semidwarf parents had almost doubled and that of tall and intermediate parents had dropped sharply -- because breeders were increasingly crossing semidwarf parents with other semidwarfs.

IR8 was a parent in 20% and TN1 a parent in 22% of the 1965-70 crosses analyzed, but by 1974-75, IR8 and TN1 were seldom used. The use of IRRI materials other than IR8 increased significantly between 1965 and 1975, with an interesting trend to increased use of *locally developed* semidwarfs as parents -- from almost no use in 1965-67 to use in half of the crosses made 10 years later (Hargrove 1978).

Indian plant breeders adopted the semidwarf plant concept as a breeding objective earlier, and more extensively, than breeders in the other nations. In 1965-66, Indian use of TN1 in crosses was 8 times that in the

Table 1. Percentages of rices of different plant height used as parents in crosses from 819 parents used in 355 randomly selected crosses at 14 agricultural experiment stations and universities in 7 Asian nations, 1965-75.

Plant height	Rices used (%) 1965-67[a]	1970-71[b]	1974-75[c]
		In crosses	
Tall	74	57	45
Intermediate	51	39	35
Semidwarf	61	86	84
Floating or deepwater	2	1	2
		As individual parents	
Tall	40	30	24
Intermediate	31	22	17
Semidwarf	28	48	58
Floating or deepwater	1	-	1

[a] 277 rice varieties and lines used in 119 crosses. [b] 351 rices used in 147 crosses. [c] 191 rices used in 89 crosses.

other nations (41 vs. 4-5%)(Hargrove 1978), probably because India was the first country outside Taiwan where TN1 was widely used for commercial production. Indian breeders also adopted IR8 more rapidly. It was used in 27% of the 1965-67 crosses compared with 16% in the other nations.

Ten years later, 75% of the Indian crosses involved a locally developed semidwarf; 21% involved an IRRI parent other than IR8. In the six other countries, IRRI was the major source of semidwarf parents (more than half of their crosses involved an IRRI semidwarf), but the trend was the same -- toward the use of locally developed semidwarfs. Eighty-three separate semidwarf varieties or breeding lines were used as parents 111 times in 89 crosses during 1974-75 (Hargrove 1978).

Dwarf gene source

Among the locally developed semidwarf parents used in 1974-75 crosses, about 75% were progeny of IR8 or other IRRI parents. (For example, the variety K35, used as a parent in Indian crosses, is a progeny of the cross IR8/HR19.) About 25% of the local semidwarfs were progeny of TN1, such as Jaya (from the cross TN1/T141), probably the most widely grown variety in India (see Table 5) or Sona (TN1/GEB24). Twenty-five percent of the local semidwarfs had at least two different semidwarf parents (for example, Tong-il, often used in Korean crosses, is from IR8//Yukara/TN1). But 25% of the locally developed parents were themselves progeny of local semidwarfs that had been developed earlier. Eighty percent of those second-generation semidwarfs were progeny of TN1, and 33% had both IR8 and TN1 in their ancestry. Most of those locally developed *parent* semidwarfs were progeny of crosses made during the mid- to late-1960s (Hargrove 1978).

Rice types used for specific objectives

The breeders at 27 research centers were asked the objectives (yield potential, grain quality, etc.) for which they made their 1974-75 crosses (Hargrove 1978). These data were gathered from all 10 nations -- the 7 mentioned previously, plus Iran, Nepal, and Pakistan.

With few exceptions the breeders used *semidwarf rices* as parents for the most common objectives -- *high yield, fertilizer response,* and *lodging resistance*. But 65% of the times that breeders used *tall varieties,* they hoped to transfer a *preferred grain type* from the donor.

To determine if Asian breeders differed in their reasons for use of locally developed and IRRI semidwarfs, we analyzed the sources of semidwarf parents used for some major traits. Of 201 semidwarfs used as parents in 1974-75, about half were from IRRI and 45% were locally developed. But 60% of the semidwarfs used for preferred grain quality and for a specific growth duration were locally developed. On the other hand, 60% to 70% of the semidwarfs used as sources of disease or insect resistance were from IRRI. Thus, IRRI material often fails to meet local grain-quality and growth preferences (which helps explain the trend toward use of locally developed materials). But pest resistance is a strong reason for its use.

Changes in races

The infusion of semidwarf indica varieties largely pushed the japonica, ponlai, and other races out of the Asian breeding programs over the decade (Table 2).

Sources of introduced material

The breeders were asked how they acquired the parents used in 1974-75 crosses. They already had access to half of the parents through their local germplasm collections, but 79 parents were introduced from outside the experiment stations. The major source from which breeders acquired new parents was from test nurseries and trials (Table 3). A typical breeder's comment was "I grew it in the blast nursery. I liked the way it looked at our station, so I made some crosses with it."

Table 2. Races of 819 parents used in 355 randomly selected crosses at 14 agricultural experiment stations and universities in 7 Asian nations, 1965-75.

Type of parents	Parents analyzed					
	1965-67		1970-71		1974-75	
	(no.)	(%)	(no.)	(%)	(no.)	(%)
Indica	219	79	303	86	175	91
Japonica	30	11	35	10	7	4
Javanica	4	1	2	1	0	0
Indica-japonica	2	1	6	2	7	4
Indica-javanica	6	2	1	a/	0	0
Ponlai	16	6	2	1	1	a/

a/ Less than 1%.

Table 3. How rice breeders acquired 79 rice varieties introduced from outside their experiment stations for use as parents in crosses. Twenty-seven agricultural experiment stations and universities in 10 Asian nations, 1974-75.

Source	Parents	
	(No.)	(%)
Sent in trials or test nurseries (national or IRRI)	48	61
Requested from IRRI	15	19
Requested from other source	6	8
Other	10	12

Genetic composition of newest varieties

The flow of rice genes into new varieties subsequently fed into seed production channels to farmers was traced. First, breeders at 27 experiment stations in the 10 countries named the newest varieties released at each station. A standardized *genetic data sheet* was then completed on the ancestry and the traits of each rice named.

Of the 36 newest varieties cited, 69% were semidwarfs, 25% were intermediate, and 6% were tall. IR8 was an immediate parent of 13 of the 25 semidwarfs and TN1, of 2 (Table 4) (Hargrove 1978). By tracing the ancestry of the locally developed parents, we found that IR8 and TN1 appeared 33 times in the genetic backgrounds of the 25 semidwarf varieties.

Genetic composition of widely grown varieties

The Asian breeders named 95 rices, comprising 73 different varieties, as most widely grown by farmers within 31 areas served by their experiment stations. Almost half of the rices cited were semidwarfs, 35% were tall, and 17% had intermediate stature. Only 10 of the 95 rices were cited in 2 or more regions, and 8 of those were semidwarfs. Jaya (TN1/T141) was cited as widely grown in 8 of the 15 regions surveyed in India (see Table 6). IR8 was the second most-often cited variety in the 10 countries (Hargrove 1978).

ORIGIN OF IR VARIETIES

We traced the genetic ancestry of the 15 named IR varieties, including 4 named as IR varieties by the Philippines. All are from crosses made at IRRI involving 11 parents that trace to 18 original land races from 8 countries (Fig. 1).

It is difficult to judge whether 18 original varieties serving as the gene pool for 15 released varieties is relatively narrow or diverse. For comparison, we extrapolated similar data on Australian wheat varieties from a genealogic chart initiated by McMillan in 1933 and updated by Moss and Wrigley (1974). Eighty-three improved Australian wheat varieties were developed from a pool of 96 separate parents, many of which were themselves developed by hybridization.

A careful examination of Figure 1 shows that all IR varieties trace to the same maternal parent *Cina* (formerly called Tjina), from China via Indonesia. Thus, components of the cytoplasm of all IR varieties are similar. This is more easily seen in Figure 2, where the female progenitors of the IR varieties are emphasized.

The finding is not altogether new. The 1976 IRRI Annual Report (IRRI 1977) included a statement that there has been concern that a high proportion of IRRI's improved breeding material is derived from cytoplasm of the variety Peta (Cina is the maternal parent of Peta). The report also noted that since 1972 IRRI has made a concerted effort to overcome that problem and

Table 4. The 36 newest rice varieties released by 27 agricultural experiment stations in 10 Asian nations, 1975.

Variety	Station where named[a]	Genetic composition
	Semidwarf	
CNM25	West Bengal (India)	IR8 mutant
Jyothi	Kerala (India)	PTB10/IR8
Bharathi	Kerala (India)	PTB10/IR8
Sabari	Kerala (India)	IR8/Annapoorna[b]
OR34-16	Orissa (India)	TN1/TKM6
Vani	CRRI (India)	IR8/CR1014
IET1039	Bihar (India)	T90/IR8
Kalinga 1	CRRI (India)	Dunghanshali/IR8
Kalinga 2	CRRI (India)	Dunghanshali/IR8
Palman 579[c]	Punjab (India)	IR579 (IR8/Tadukan)
HM95	Punjab (India)	Jhona 349/TN1 (hybrid mutant)
RP4-14	AICRIP (India)	T90/IR8
Pusa 2-21	IARI (India)	IR8/TKM6
CO39	Tamil Nadu (India)	Culture 340/Kannagi[d]
IR24[e]	Uttar Pradesh (India)	IR8///CP231/SLO17//Sigadis
IR24[e]	Nepal	IR8///CP231/SLO17//Sigadis
BP-Ri2	Maligaya (Philippines)	BE3-37-5/IR20
IR841	Dokri, Sind (Pakistan)	IR262-43-8-11/Khao Dawk Mali
IR6	Kala Shah Kaku (Pakistan)	Siam 29/Dee-geo-woo-gen
BG90-2	Batalagoda (Sri Lanka)	IR262/Remadja
PD106-1	Peradeniya (Sri Lanka)	Warangal 1263/IR8
Glutinous Tong-il	Seoul National University(Korea)	Tong-il[e]/IR1317-31
Milyang 21	ORD (Korea)	IR1317-316-3-2/IR24
Mulyang 23	ORD (Korea)	IR1317-316-5-2/IR24
Gati (B9c)	CRIA (Indonesia)	Short Sigadis[f]/Basmati
	Intermediate-statured	
K78-13	Kashmir (India)	Sihi-ei/China 971
K84	Kashmir (India)	Mutant of T65
Karjat 14-7	Maharashtra (India)	IR8/Ziniya 149
BG11-11	Batalagoda (Sri Lanka)	H7/H8
LD125	Bombuwela (Sri Lanka)	IR262/H7
BR4	BRRI (Bangladesh)	IR20/IR5
RD7	Bangkhen (Thailand)	C4-63G/GR88//Sigadis
RD9	Bangkhen (Thailand)	LY34-/TN1//W1256///RD2[g]
Pelita I-2	CRIA (Indonesia)	IR5/Syntha
	Tall-statured	
RD5	Bangkhen (Thailand)	Puang Nahk/Sigadis
Mehre	Amol (Iran)	Pureline selection

[a]CRRI = Central Rice Research Institute; AICRIP = All India Coordinated Rice Improvement Project; IARI = Indian Agricultural Research Institute; ORD = Office of Rural Development; CRIA = Central Research Institute for Agriculture; BRRI = Bangladesh Rice Research Institute. [b]Annapoorna is a semidwarf variety developed in Kerala from the cross PTB10/TN1. [c]IRRI variety or line named locally as a variety. [d]Kannagi, from the cross IR8/TKM6, is the varietal name in Tamil Nadu state for Pusa 2-21. [e]IR8//Yukara/TN1. [f]Sigadis/TN1. [g]TN1/GP15.

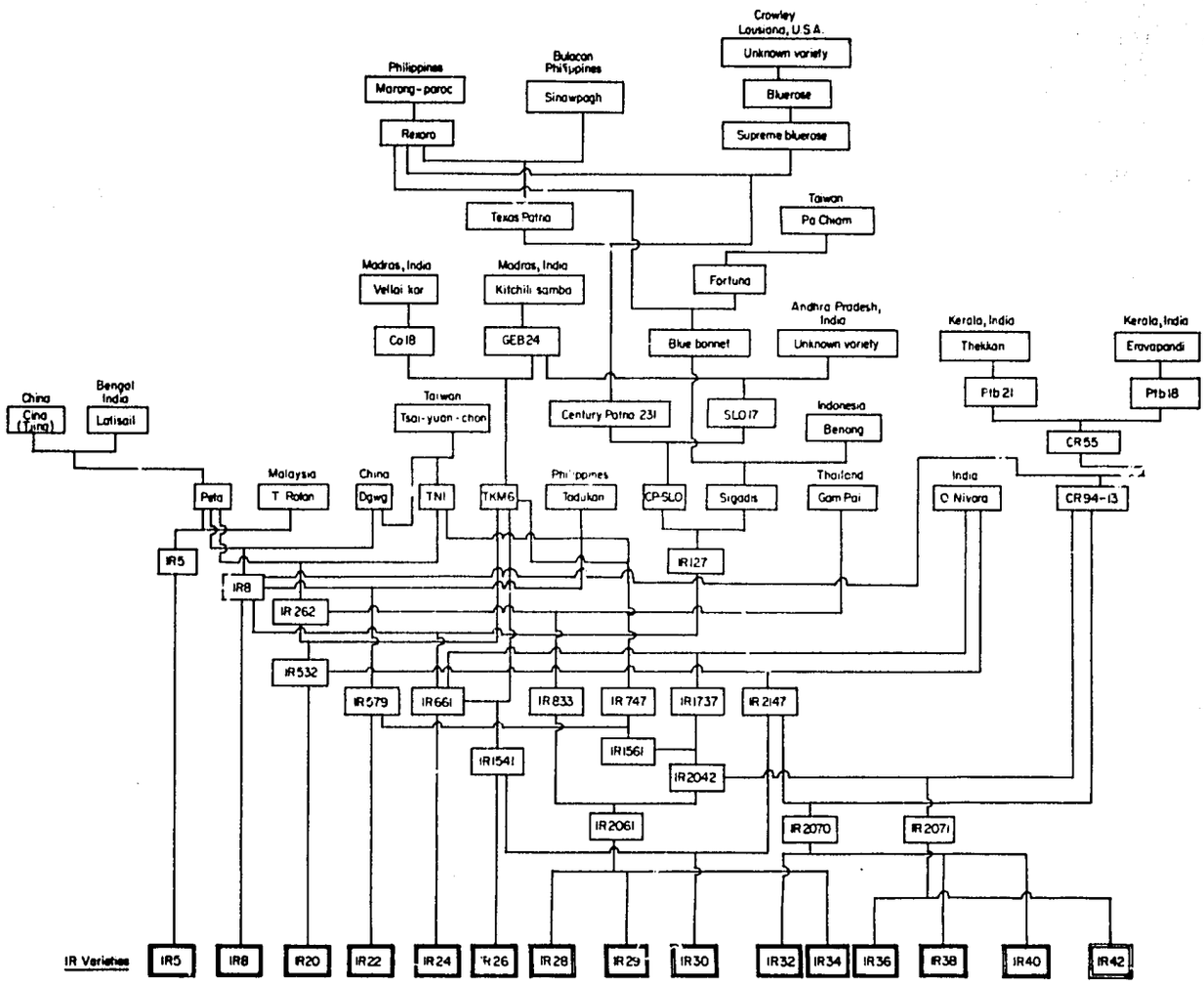

Fig. 1. The derivation of IR varieties. Female parents are on the left, male parents on the right.

a steadily increasing proportion of the advanced breeding lines has cytoplasm other than Peta.

All of the semidwarf IR varieties derive their dwarfing gene from the Chinese variety Dee-geo-woo-gen (DGWG). Only IR5, which is not a true semidwarf, does not carry this gene. We know that virtually all other semidwarf varieties in major rice-growing countries, except the People's Republic of China, carry the DGWG gene. Furthermore, there is some evidence that the Chinese varieties may also have the same gene.

MATERNAL ORIGIN OF NATIONAL RICE VARIETIES

To identify the maternal origin of improved varieties released by national programs during the post-IR8 era we analyzed the newest and most widely grown varieties identified through the 1975 rice breeding survey, as well as other varieties and advanced breeding lines announced through experiment station reports, newsletters, and other publications.

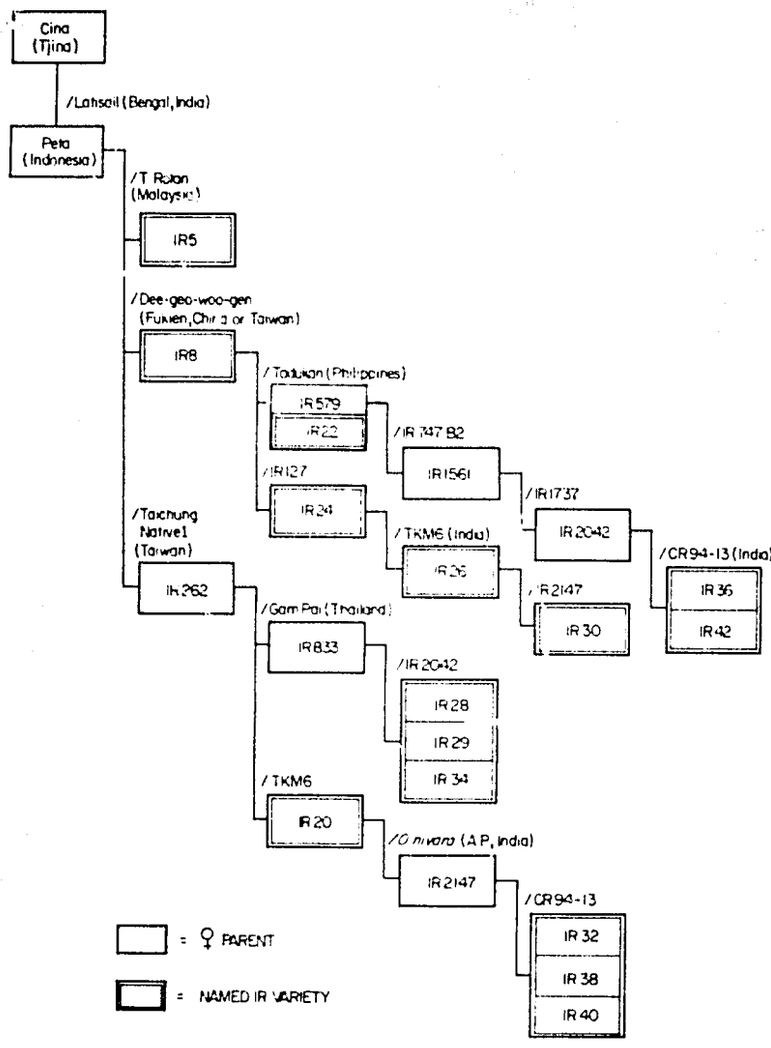

Fig. 2. Maternal derivation of IR varieties. Female parents are in boxes on the left; male parents are on the right.

Bangladesh

Eight of 13 new varieties released in Bangladesh since 1968 derive from the female progenitor Cina (Fig. 3). Those 13 new varieties are estimated to be planted on about 20% of the total rice land cultivated in Bangladesh (BRRI 1977).

India

A sample 73 improved rice varieties released in India since the late 1960s was compiled. Fifty-four ultimate parents were used in their development. Cina is the ultimate maternal ancestor of 22% of the improved varieties, and DGWG, of 25% (Table 5). Figure 4 shows only those varieties in the sample that derive maternally from Cina and DGWG. A much higher proportion of India's improved varieties carry

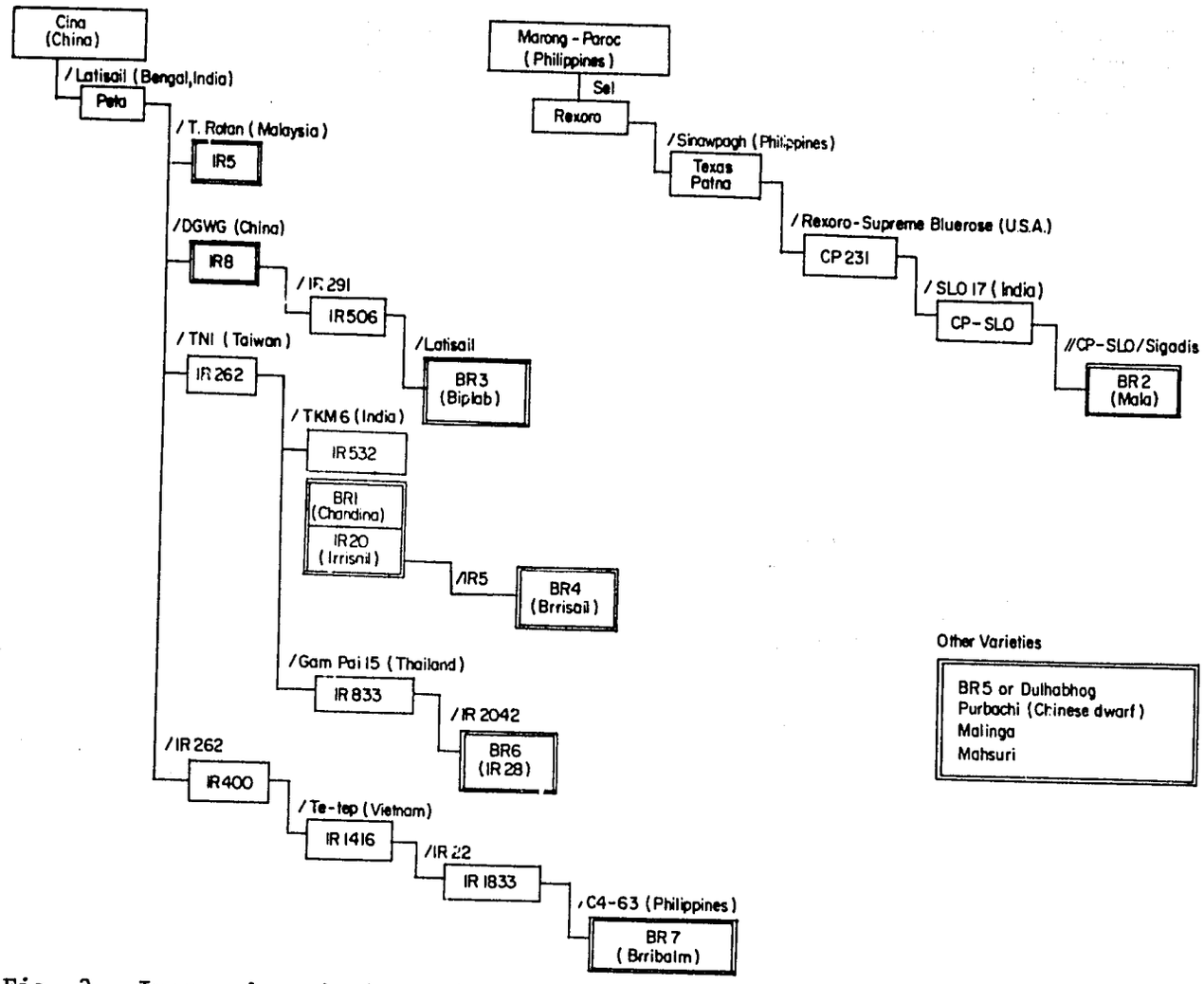

Fig. 3. Improved varieties released in Bangladesh during the post-IR8 era.

DGWG cytoplasm than in other countries because of the heavy late-1960s crossing with TN1, of which DGWG was the female parent.

Indian rice breeders cited 46 rices, which comprised 32 individual varieties, as most widely grown by farmers in 15 regions of India in 1975. Twenty-four percent of the 46 cited rices have Cina as their ultimate female parent (Table 6). DGWG is the maternal progenitor of 21% (mostly through Jaya, from the cross TN1/T141).

Indonesia

In 1975, more than half of the rice land in Indonesia was estimated to be planted to six varieties. All of them trace maternally to Cina (Table 7). Virtually all of the older improved Indonesian varieties are progeny of the same cross -- Cina/Latisail (Fig. 5). Of 27 varieties released in Indonesia from 1965 to 1975, 20 are female derivatives of Cina. Figures 5 and 6 show the series of crosses from which those 27 varieties were selected.

Table 5. The 22 maternal parents from which 73 improved semidwarf varieties have been released in India over the past 10 years.

Female progenitor	Origin	Progeny and where released[a]
Cina	China	IR8, IR20, Pankaj (CVRC); Bhavani, CO36, Karuna, Kannagi (T.N.); Sabari, Pusa 2-21 (Kerala); Vani (CRRI); Palman 579 (Punjab); IR24, Surekha (U.P.); CNM25 (W. Bengal); Kakatiya (A.P.); Kanchan (Bihar).
DGWG	Fukien, China	IET849, Kiran (Bihar); Rasi (AICRIP); Cauvery, Jamuna, Kanchi, Jaya (CVRC); OR34, Parijata (Orissa); Sabarmati, Improved Sabarmati (IARI); Vaigai, Karikalan, Pennai (T.N.); Suma, Madhu, MR118 (Mysore); Karjat 184 (Maharashtra).
Machakanta	Orissa	IET1039 (Bihar); RP4-14 (AICRIP); Vijaya, Jayanti, Prakash (CVRC); Rajeswari, Kumar (Orissa).
Thekkan Cheera	Kerala	Jhothi, Bharathi, Rohini, Annapoorna, Triveni, Aswathi (Kerala).
Soruchinna-mali	Orissa	Padma, Jagannath (CVRC); Hema, (Orissa).
Z31	Gujurat	GAU-R-1, GAU-R-10, GAU-R-100 (Gujurat).
Kameji	Japan	Ponni (T.N.); Sarju 49 (U.P.).
Raja Hamsalu	Andhra Pradesh	Hamsa, Tella Hamsa (A.P.).
Vellai Kar	Madras	Ratna (CVRC); Saket 4 (U.P.).
Dunghanshali	Hungary	Kalinga 1, Kalinga 2, (CRRI).
Kitchili Samba	Madras	Sona (CVRC).
Jhona 349	Punjab	HM95 (Punjab).
O-luan-chu	Taiwan	CO39 (T.N.).
Raj Bhog	Uttar Pradesh	Bala (CVRC).
Zinya 63	Maharashtra	Ratnagiri 24 (Maharashtra).
Basmati	Punjab	Kusuma (Mysore).
Chaul	Uttar Pradesh	Sarju 50 (U. P.)
Bhondu	Raipur	Kranti (CRRI).
"4"	Madhya Pradesh	Garima (Jabalpur).
NSJ200	Orissa	CRM1-3241 (CRRI).
China 1039	China	China dwarf (China).
Thekkan	Kerala	Sakti (CRRI).

[a] Places released are in parentheses. CVRC = Central Varietal Release Committee, for national production.

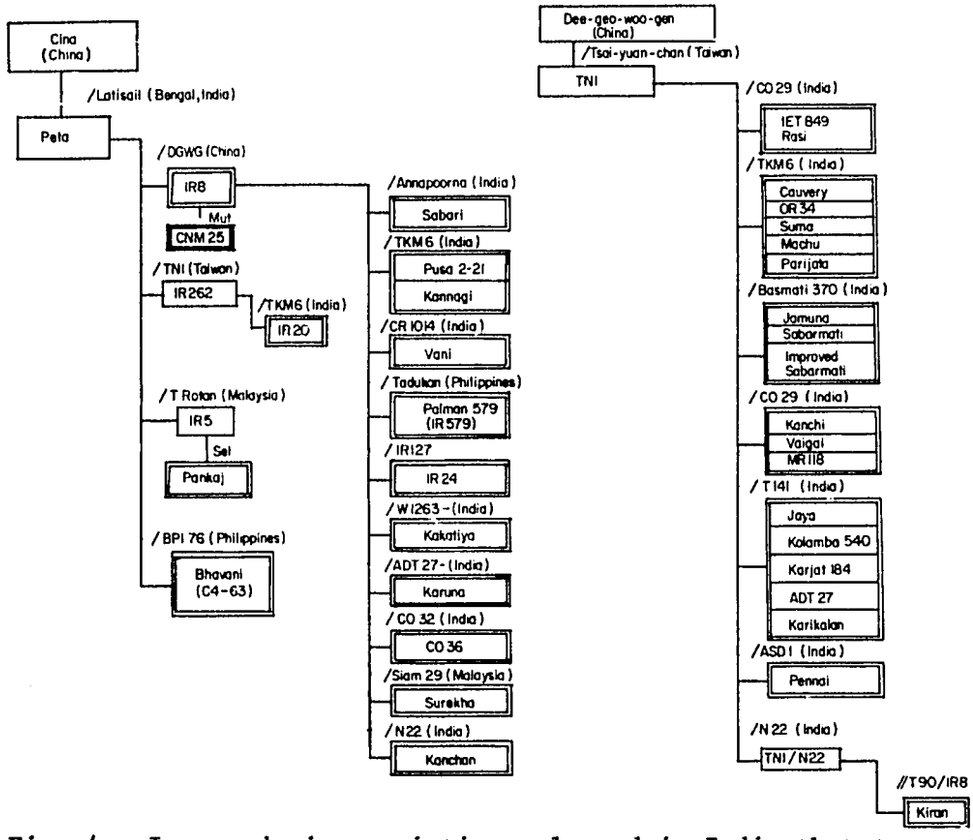

Fig. 4. Improved rice varieties released in India that trace to Cina and Dee-geo-woo-gen as the ultimate female progenitor.

Republic of Korea

Improved varieties of indica/japonica origin are grown on about 55% pf Korea's rice land; they are mixtures of 22 ultimate land races (Fig. 7). Tong-il and selections of it are the most widely grown; Cina is the ultimate maternal parent of Tong-il and of a new popular variety, Yushin (Fig. 8). But 5 other new varieties that are increasingly popular in Korea such as Milyang 21 and 23 trace back to another ultimate female progenitor, the japonica variety Norin 13 (Fig. 9).

Philippines

In 1968, about a year after IR8 was released, about 20% of the Philippines' rice land was planted to improved varieties, which comprised the IR series, the BPI series (developed by the Philippine Bureau of Plant Industry), and the C series (developed at the University of the Philippines at Los Baños). Within a year, the land planted to improved varieties had almost doubled. By 1977, 68% of the Philippines' 3.5 million hectares of rice land was planted to improved varieties, mostly the IR varieties (all Cina derivatives) (Bureau of Agricultural Economics *ca* 1978) (Fig. 10).

Table 8 shows the BPI- and C-series varieties named in the Philippines during the post-IR8 era, along with some of the best experimental lines. Thirty percent have Cina as their ultimate maternal ancestor. The most

Table 6. The 32 rice varieties cited by 16 Indian rice breeders as among 3 most widely grown by farmers in 15 regions of India, 1975. (Hargrove 1977)

Variety	Locations[a]	Genetic makeup	Origin	Regions where widely grown (%)	Ultimate female progenitor[b]
		Semidwarf varieties			
Jaya	Ker., Bih., Pun., W.B., U.P., I., NWI, I-irrig.	TN1/T141	Local	53	DGWG
IR8	I-irrig., NWI., Bih., Pun.	Peta/DGWG	IRRI	27	Cina
Ratna	U.P., NWI.	TKM6/IR8	Local	13	Vellai Kar
IR20	T.N., W.B.	Peta*3/TN1//TKM6	IRRI	13	Cina
IR24	U.P.	IR8///CP231/SL017// Sigadis	IRRI	6	Cina
Jyothi	Ker.	PTB10/IR8	Local	6	Thekkan Cheera
Palman 579	Pun.	IR579 (IR8/Tadukan)	IRRI	6	Cina
Pusa 2-21	W.B.	IR8/TKM6	Local	6	DGWG
Triveni	Ker.	Annapoorna[b]/PTB15	Local	6	Thekkan Cheera
Vaigai	T.N.	TN1/CO29	Local	6	DGWG
Jagannath	Or.	Mutant from T141	Local	6	Soruchinnamali
		Intermediate-statured varieties			
Pankaj	W.B., I-irrig.	IR5 (Peta/T. Rotan)	IRRI	13	Cina
Mahsuri	Or., I	Taichung 65/Mayang Ebos	Int. Rice Comm.	13	Kameji
Bhavani	T.N.	C4-63 (Peta/BP176)	Phil.	6	Cina
China 972	Kas.	---[d]	China	6	---[d]
China 988	Kas.	---	China	6	---
China 1039	Kas.	---	China	6	---
		Tall varieties			
BR34	Bih	Pureline selection	Local	6	Dolangi
CO25	T.N.	CO4/ADT10	Local	6	Anaikomban
CR10	Or.	T90/W113	Local	6	Machakanta
EB17	Mah.	Pureline selection	Local	6	---[d]
Kolamba 42	Mah.	Pureline selection	Local	6	Kolamba
Larbeoul	Kas.	Traditional	Local	6	Larbeoul
Madew 3	Kas.	Unimproved	Local	6	Madew
Niver	Kas.	Unimproved	Local	6	Niver
NC1281	Or.	Pureline selection	Local	6	---[d]
Patni	Mah.	Pureline selection	Local	6	Patni
Siga	Kas.	Unimproved	Local	6	---[d]
T141	Or.	Pureline selection	Local	6	Soruchinnamali
T1242	Or.	Pureline selection	Local	6	Magura
White Luchai	Mah.	Pureline selection	Local	6	Luchai
Ziniya 149	Mah.	Pureline selection	Local	6	Zuriya

[a] I = grown across all India; I - Irrig. = irrigated regions of India; NWI = Northeast India; Ker.= Kerala state; Kas.= Kashmir (2 regions); Mah.= Maharashtra (2 regions); T.N. = Tamil Nadu; Or. = Orissa (2 regions); Pun.= Punjab; Bih.= Bihar; U.P. = Uttar Pradesh; W. B. = West Bengal.

[b] When the variety or its female parent is a pureline selection, its original progenitor is listed, if available.

[c] Annapoorna is from the cross PTB10/TN1.

[d] Genetic ancestry could not be determined.

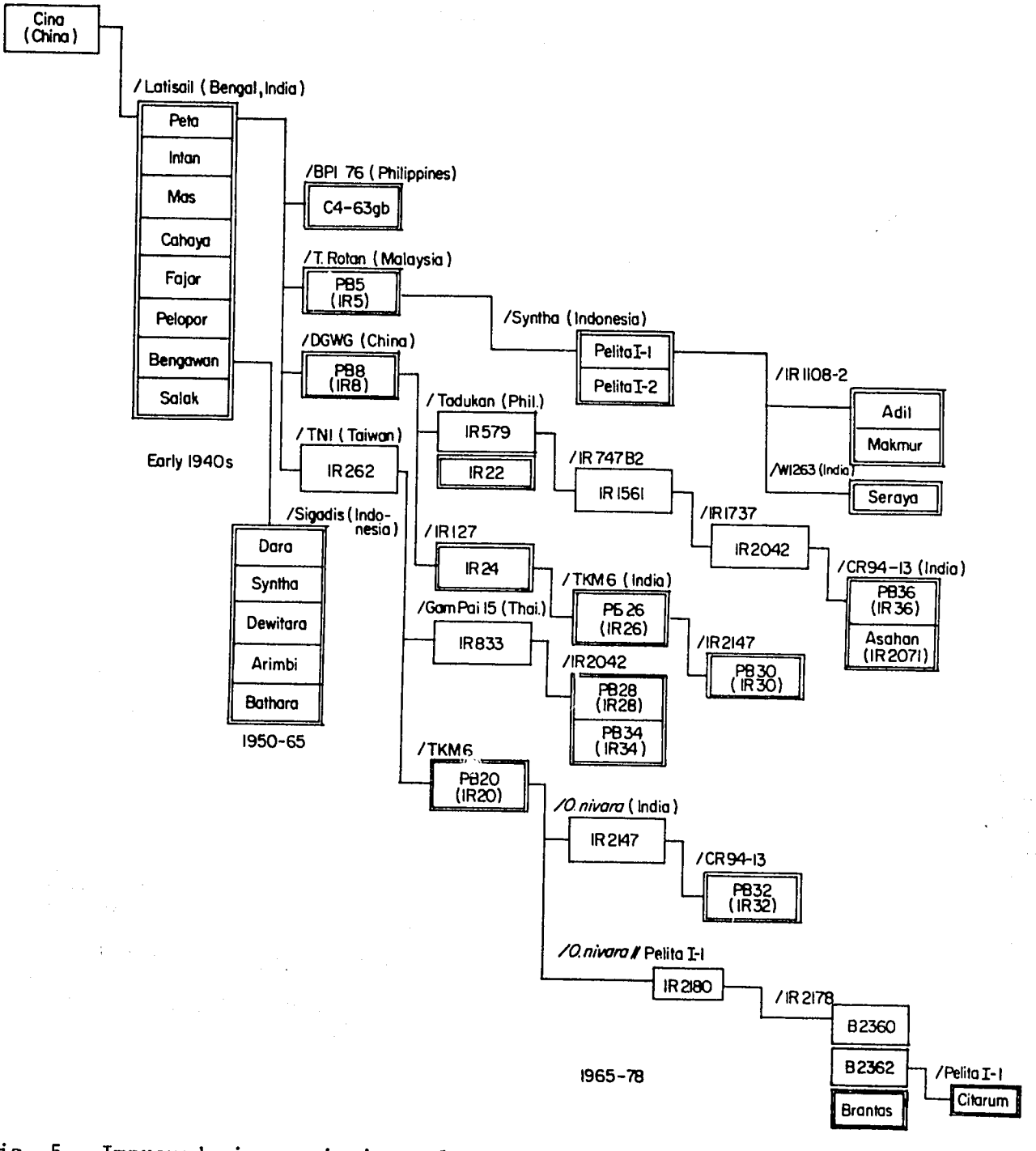

Fig. 5. Improved rice varieties released in Indonesia since the early 1940s that trace maternally to Cina.

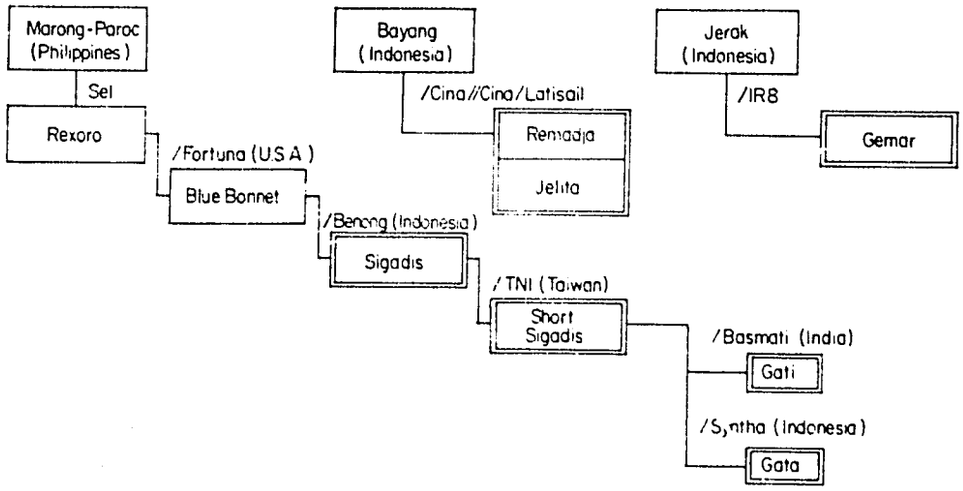

Fig. 6. Improved rice varieties released in Indonesia that do not trace maternally to Cina, 1978.

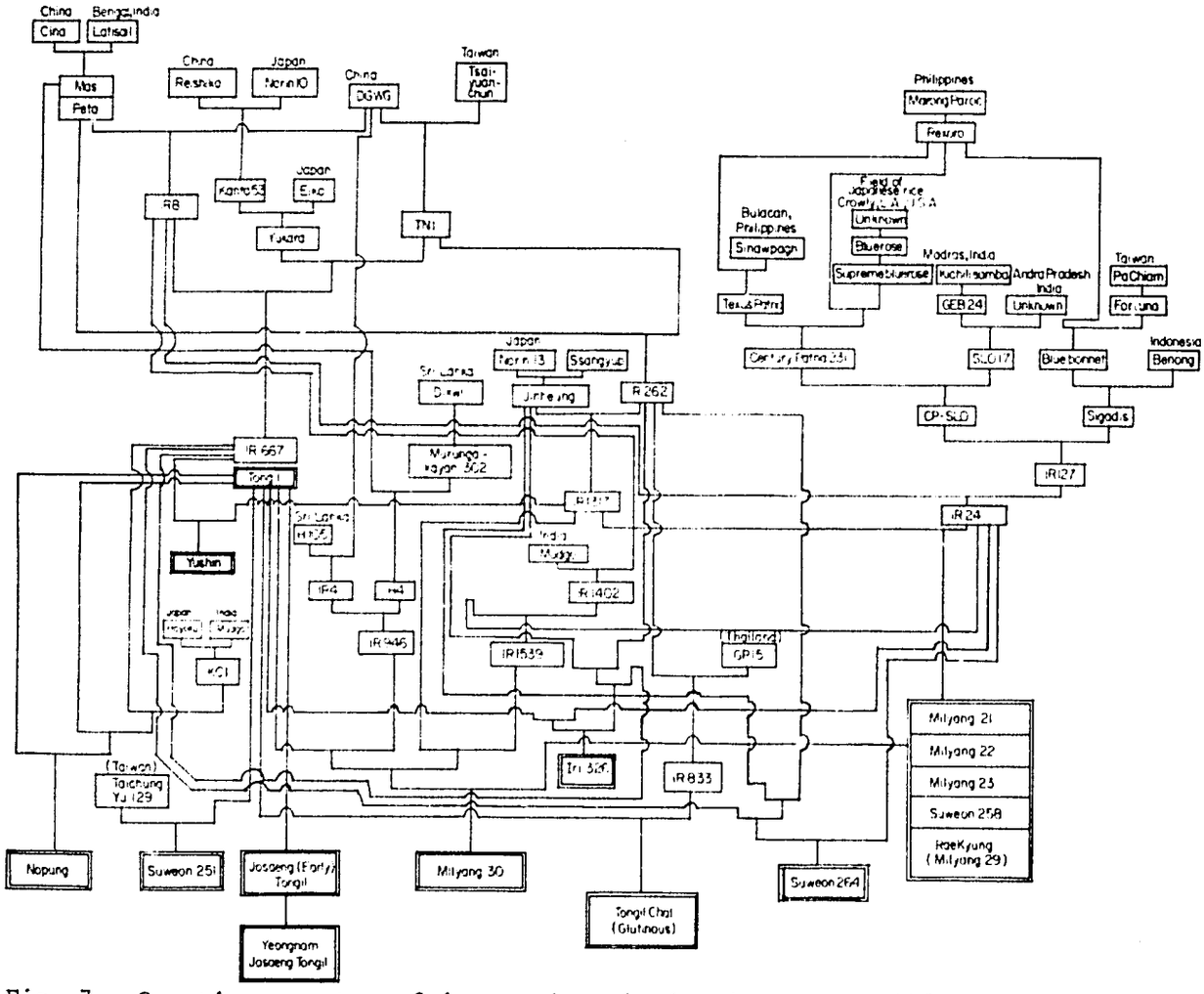

Fig. 7. Genetic ancestry of improved varieties in Korea, 1978.

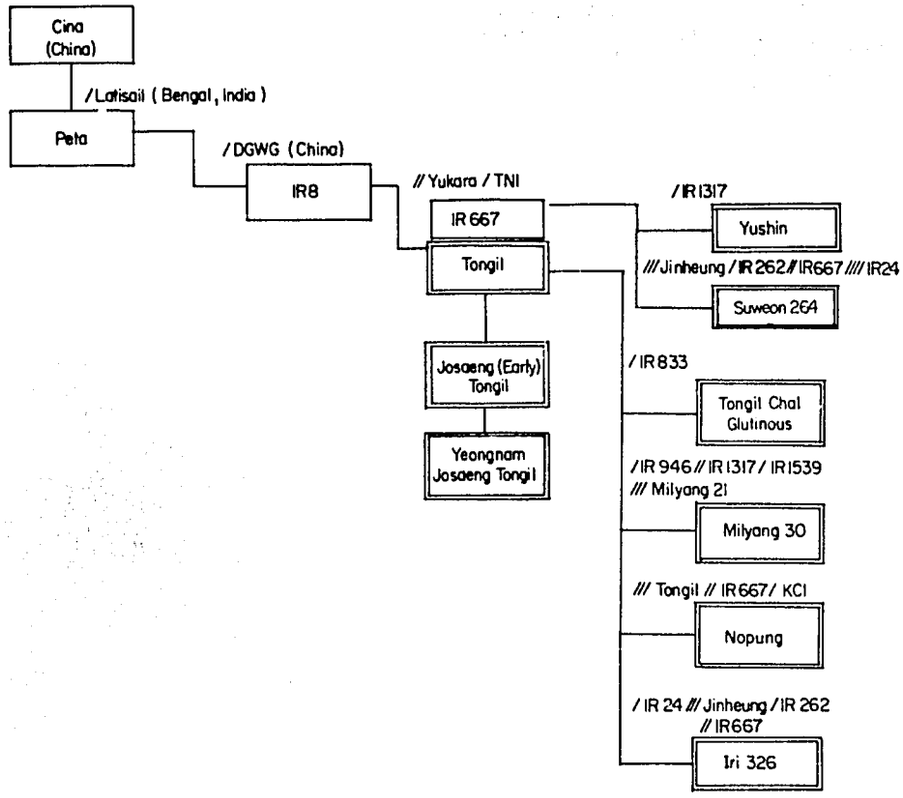

Fig. 8. Improved rice varieties released in Korea that trace maternally to Cina, 1978.

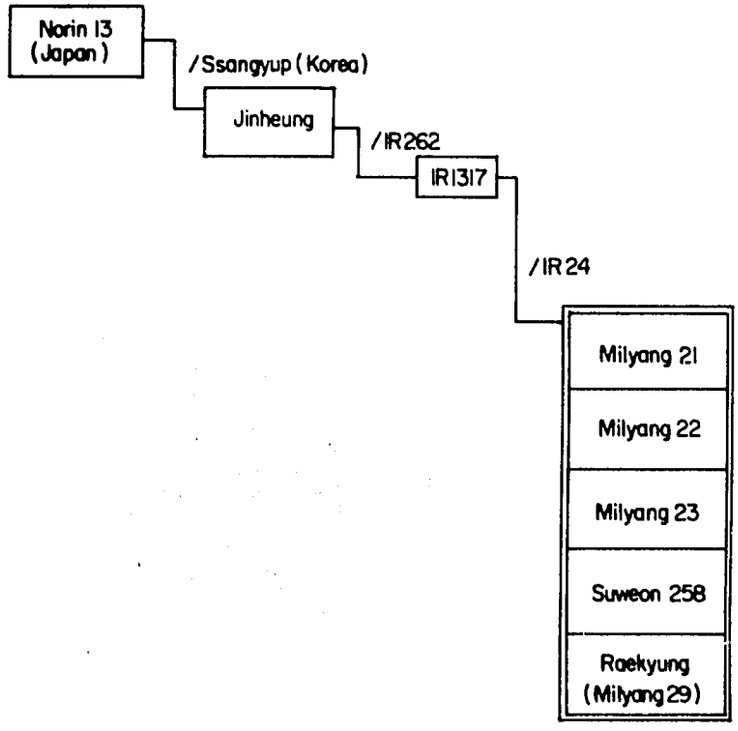

Fig. 9. Improved rice varieties released in Korea during the post-IR8 era that trace maternally to Norin 13, 1978.

Table 7. Estimated area planted to improved varieties in Indonesia, 1972-1975.

Variety	Area (1000 ha)			
	1972	1973	1974	1975[a]
PB5 (IR5)	1318	1076	1068	527
PB8 (IR8)	84	95	97	39
C4-63gb	428	459	573	389
Pelita I/1	26	418	1027	868
Pelita I/2	7	199	422	211
PB20 (IR20)	-	7	39	31
% of total ha	31.0	34.5	47.7	51.3

[a] 1974-75 wet season only.

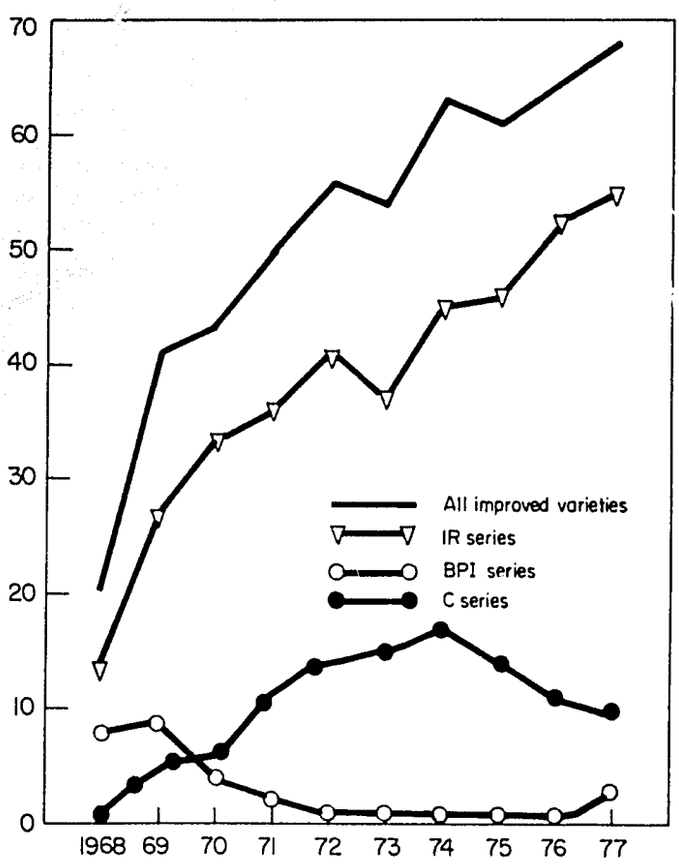

Fig. 10. Percent of area planted to improved rice varieties, Philippines, 1968-77.

Table 8. Improved rice varieties and breeding lines developed in the Philippines and released under the BPI(Bureau of Plant Industry)series and C (University of the Philippines at Los Baños) series.

Variety	Cross	Ultimate maternal parent
BPI76	Fortuna/Seraup Besar 15	Pa Chiam
BPI121-407	Mutant selection from BPI121	Pa Chiam
BPI3-2	Fortuna//Milfor 6*2/Azucena	Pa Chiam
BP-Ri-2	BE3-37-5/IR20	BE3
BPI1-48	Rexoro/Zenith//Dinalaga/Fortuna 6-7-63A	Marong Paroc
BPI9-33B	Rexoro/Zenith//Dinalaga/Fortuna 3-1-47B	Marong Paroc
C4-63	Peta/BPI76	Cina
C4-137	Peta/BPI76	Cina
C12	Peta/BPI76//Tjeremas/BPI76	Cina
C21	Tjeremas/BPI76//Dinalaga/Palawan	Tjeremas
C22	Tjeremas/BPI76//Palawan/Azucena	Tjeremas
C22-51	Tjeremas/BPI76//Palawan/Azucena	Tjeremas
C121-95	RP42 x B5580-A_1-15/2	DGWG
C166-135	Intan/5580-A_1-15	Cina
C168	Intan/BPI76-1	Cina
C168-134	Intan/BPI76-1	Cina
C171-136	Sigadis/BPI76-1	Marong Paroc
C424-2	Malagkit Sungsong/IR532E576	Malagkit Sungsong
C732-14	Azucena/IR5-47-2//PB76 TB934	Azucena
C894-21	C4-63(G)/Carreon	Cina
C924-9	Palawan/Carreon//Dinalaga/Dalwa Sannam MUT-15	Palawan
C46	C74/Dee-geo-woo-gen	C74

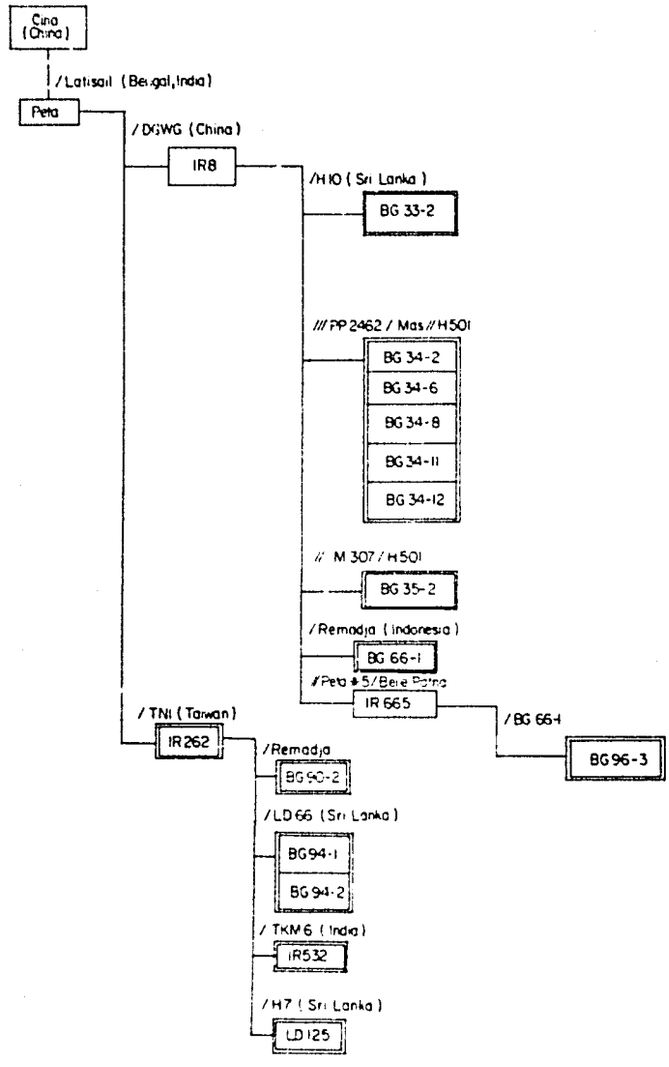

Fig. 11. Improved rice varieties released in Sri Lanka that trace maternally to Cina, 1978.

popular C-series variety is C4-63, which derives maternally from Cina through the cross Peta/BPI76. C4-63 is also widely grown in Indonesia, Malaysia (under the local name Padi Jaya), and in Tamil Nadu, India (as Bhavani) (Table 6).

Sri Lanka

Sixty-seven percent of the rice land in Sri Lanka is planted to improved rice varieties (Palacpac 1977). We compiled a list of 20 of those varieties; 15 of them derive maternally from Cina (Fig. 11).

Thailand

Of 12 improved varieties released in Thailand since 1969, 3 have Cina as their ultimate female progenitor (underlined in Table 9).

Table 9. Improved rice varieties developed in Thailand from 1969 to 1975. (Maternal derivatives of Cina are underlined.)

Variety	Cross
RD1	Leuang Tawng/IR8
RD2	TN1/Gam Pai 15
RD3	Leuang Tawng/IR8 (sel. 17-1)
RD4	Leuang Tawng/IR8//W1252///RD2
RD5	PN16/Sigadis
RD6	Khao Dawk Mali 105 Glutinous Mutant[a]
RD7	C4-63/GR88//Sigadis
RD8	IR262/2*Niaw San Patong
RD9	Luang Yai 34/TN1//W1256///RD2
RD11	IR661/KDM105
RD13	Nahng Payah/Pak Sian 39
RD15	Khao Dawk Mali 105[a]

[a] Radiation-induced mutant.

MATERNAL ORIGIN OF POTENTIAL IMPROVED VARIETIES

To determine what maternal base might be expected in varieties released during the next few years, we traced the female parentage of elite breeding lines and of female parents used in recent crosses -- from which varieties of the future will be selected.

Seventy-nine elite varieties and breeding lines from 10 nations and IRRI are included in the 1978 early, medium-, and late-maturing International Rice Yield Nurseries (IRYN). Those nursery sets are grown at about 45 sites in about 20 nations. Fifty-nine percent of the IRYN entries trace back to Cina. Those 47 Cina progeny are underlined in Table 10. We know that national program breeders acquire much of their introduced genetic materials through such trials (Table 3).

Table 10. Elite varieties and breeding lines entered in the 1978 International Rice Yield Nursery (IRYN). Cina is the ultimate female progenitor of the varieties underlined.

Designation	Cross	Origin
	IRYN-Early Maturing	
B459-Pn-32-3-5	C4-63/IR127///Latisail//IR5/Syntha	Indonesia
B541b-Pn-58-5-3-1	Pelita I-1/IR1108-2	Indonesia
B1014b-Pn-18-1-4	Pelita I-1/EK1263	Indonesia
B1991b-Pn-43-4-1	Pelita I-1/CPA6805-7	Indonesia
B2360-6-7-1-4	IR2180-2/IR2178-1	Indonesia
BKN7033-3-3-2-2-3	Iratom 20/SPT 6624-113-2-3	Thailand
BP-Ri-2	BE3-37-5/IR20	Philippines
BR51-54-2	IR20/IR5-114-3-1	Bangladesh
BR169-1-1	Mala/IR8	Bangladesh
G28b-Si-11-2	Aria//IR12-178/Pelita I-1	Indonesia
IET2361 (RP79-5)	IR8/N22	India
IET2473 (RP79-9)	IR8/N22	India
IET4094 (CR156-5021-207)	BU1/CR115	India
IET5850 (RP1158-72-1)	RPA5824/RP79-9	India
IR3941-25-1	CR126-42-5/IR2061-213	IRRI
IR5853-118-5	Nam Sagui/IR2071-88//IR2061-214	IRRI
IR9093-216-3	73-1196/IR30//IR2071-625-1	IRRI
IR9129-136-2	IR28/IR2053-521//2071-625-1	IRRI
IR9129-192-2	IR28/IR2053-521//2071-625-1	IRRI
IR9209-181-2	IR2061-465/IR2053-521//IR2070-625	IRRI
Kaohsiung 139	Tainan 5/Kokumasari//Chianung 242	Taiwan
Mala/J 15	Mala/J 15	Bangladesh
MRC505	BPI121-3-1/TKM6	Philippines
MRC603-303	C12//Sigadis/TN1///IR24	Philippines
MTU3419	Jaya/GEB24	India
RNR7306	HR19/TN1	India
IR36 (check)	IR1561-228/IR1737//CR94-13	IRRI
	IRYN-Medium Maturing	
BR51-46-5	IR20/IR5-114-3-1	Bangladesh
BR51-282-8	IR20/IR5-114-3-1	Bangladesh
BR167-28-9	IR272-4-1-2 (J)/IR305-3-17-1-3	Bangladesh
RP919-24-7-1	Sona/RP8-8	India
CR261-7039-236	Jayanti/IET3144	India
UPR96-38-1-1-1	IR24/IR22	India
IET2877 (BK 284)	IR8/T3	India
IET6073 (RP825-24-7-1)	Vijaya/PTB21	India
IET5905 (RP1015-29-7-2)	Sona/Manoharsali	India
IET3363 (RP9-10-3-2-1-2)	IR8/W1251	India
B441b-126-3-2-1	C4-63gb/B531b-Tk-39	Indonesia
B541b-Kn-22-7-2	Pelita I-1/IR1108-2	Indonesia
B541b-Kn-58-5-3	Pelita I-1/IR1108-2	Indonesia
B2360-6-5-1-10	IR2180-2/IR2178-1	Indonesia
IR2058-78-1-3-2-3	IR1416-131/IR1364-37//IR1366/IR1539	IRRI

Table 10. Elite varieties and breeding lines (cont'd.)

Designation	Cross	Origin
	IRYN-Medium Maturing	
IR2863-38-1-2	IR1529-680-3/CR94-13//IR480-5-9-3	IRRI
IR4422-98-3-6-1	IR2049-134-2/IR2061-125-37	IRRI
IR4432-52-6-4	IR2061-125-37/CR94-13	IRRI
IR4750-83-3-3-2	IR2072-74/IR1721-11//IR2055-481	IRRI
IR5853-162-1-2-3	Nam Sagui/IR2071-88//IR2061-214	IRRI
MR10	IR8//Eng/Sac///Ria 163	Malaysia
BG374-1 (75-311)	BG66-1/IR20	Sri Lanka
CICA 8	IR665/Tetep	Colombia
Taichung sen yu 195	Bin-tang-chieh/IR661-1-149-3-54	Taiwan
SPR7824-57-5	RD3/IR648	Thailand
IR42	IR1561-228/IR1737//CR94-13	IRRI
IR8	Peta/Dgwg	IRRI
	IRYN-Late Maturing	
CR1002	CR70-80-2/Pankaj	India
CR1009	Pankaj/Jagannath	India
CR1012	Jagannath natural cross 118	India
CR1016	Waikoku T90	India
IET3235 (MTU-8089)	IR8/SL013	India
IET3257 (CR149-3244-198)	CR63/Pankaj	India
IET4888 (TNAU 13493)	IR8/CO25	India
IET5656 (RP975-109-2)	RPW6-13/Sona	India
IET5863 (CR1010)	Pankaj/Jagannath	India
RP1015-7-1	Sona/Manoharsali	India
IET5854 (RP1017-76-1-4-3)	Sona/Mahsuri	India
RP1045-23-2-1	RP31-49-2/LMN	India
RP1064-14-2-2	RP31-49-2/Patnai 23	India
TNAU 13508	IR8/CO25	India
TNAU 13493/2	IR8/CO25	India
TNAU 15875	ASD5/TN1	India
TNAU 17596	Ponni/CO36	India
BKN6819-36-3-1	PN16/PKR//C4-63	Thailand
BKN6986-147-2	IR262/PG56	Thailand
IR3351-38-3-1	IR841-85/IR1917-3//CR94-3	IRRI
IR3454-80-2-1	IR1539-823/IR1416-131//IR2061-213	IRRI
IR3464-4-3-2	IR1628-68/IR841-67//IR2061-213	IRRI
IR3464-75-1-1	IR1628-68/IR841-67//IR2061-213	IRRI
IR4219-35-3-3	IR2061-213/IR480-5-9-3	IRRI
IR4625-132-1-2	IR2049/IR2061//IR2055/IR2061	IRRI

We also analyzed the elite breeding lines included in nurseries and in IRRI screening trials for tolerance for salinity, alkalinity, iron toxicity, phosphorus deficiency, and zinc deficiency and found the same trend -- from 36 to 92% of the lines in each trial were maternal progeny

of Cina. Similarly, Cina is the ultimate female progenitor of more than half of the most promising IRRI lines developed for intermediate amylose content, for high protein content, and for resistance to the striped stem borer.

Finally, we traced the female parentage of the first 20,000 crosses (1962-1977) made at IRRI; 44% of the females are derived maternally from Cina. The trend, however, is declining. Although 53% of the crosses made in 1974 had Cina cytoplasm, only 37% of those crosses made in 1977 traced maternally to Cina (Fig. 12). Appendix 1 lists those crosses for which Cina is the ultimate female progenitor.

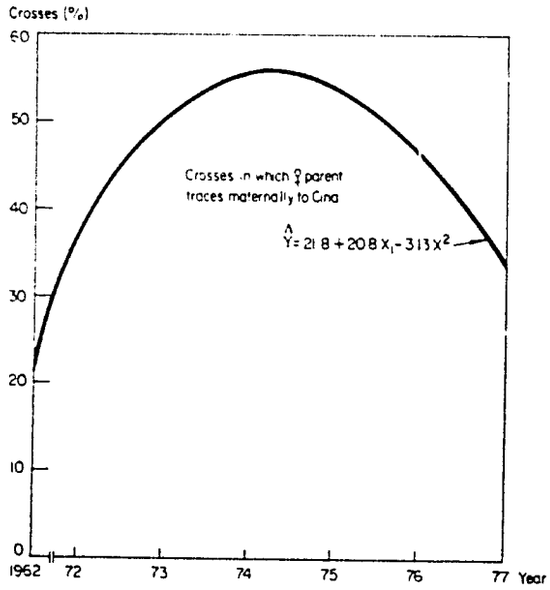

Fig. 12. IRRI crosses in which female parent traces maternally to Cina. Crosses No. 1-19853, 1962-77.

FACTORS THAT LED TO MATERNAL SIMILARITY

A series of events during the past several decades led to the apparent cytoplasmic similarity of many of today's improved rice varieties.

In the late 1930s, Indonesian plant breeders made the cross Cina/Latisail[2], using Cina as the female parent. From that cross, eight varieties were selected and released in the early 1940s that were later grown widely in Indonesia: Peta, Intan, Mas, Bengawan, Cahaja, Fadjar, Pelopor, and Salak (Fig. 5). These were distributed to the Philippines, Malaysia, and other areas.

---

[2] The name *Cina*, formerly *Tjina*, is synonymous with *China* in Bahasa and Malay. *Latisail* is a tall, vigorous variety from the former Indian state of Bengal. It is sensitive to photoperiod and has relatively strong straw (in Bengal, *lati* means *stick* and *sail* means *aman*, or the long monsoon season).

Peta was subsequently used as the female parent in the IRRI cross Peta/DGWG, from which IR8 was selected, as well as in many other crosses. Plant breeders at IRRI and in national programs subsequently crossed IR8 and other Peta derivatives, such as IR5, IR262, and C4-63, usually as the female parents. Semidwarf progeny of those crosses were subsequently crossed with other varieties -- again, often as the females.

Breeders tended to use the semidwarfs as the females in crosses for several reasons. First, when crossing a tall variety with a semidwarf, it is physically more convenient for a breeder to use the semidwarf as the female. If the tall variety is the female, it usually must be staked to prevent lodging. Also, because tallness is dominant to dwarfism, use of the semidwarf as the female makes it possible to be certain that the breeders had made a true cross. If the semidwarf self-pollinates, the F_1 progeny are short, but all of the F_1 of a true cross are tall.

IMPLICATIONS

The implications of this maternal similarity should be drawn with caution. A cytoplasmically conditioned susceptibility to a new strain of *Helminthosporium maydis*, first reported by Mercado and Lantican (1961), set the stage for the 1970 southern corn leaf blight epidemic in the U.S. corn crop. That is probably the only cytoplasm-induced pest epidemic recorded in food crops. But several researchers have found that the cytoplasm conditions both resistance and susceptibility to pests in various crops.

Harland and King (1957) found cytoplasmic effects on mildew manifestation in *Fragaria*. Nagaich et al (1968) reported that the cytoplasm of the female parent in potato controls the inheritance of the expression of virus infection symptoms. Kazas et al (1975) reported that *Phylloxera* resistance in muscat belyi, sereksiya, and chaush grapes was associated with cytoplasmic inheritance.

Washington and Maan (1974) found that certain alien cytoplasms influence the expression of genes for resistance to specific races of wheat leaf rust. In 1972, Rath and Padmanabhan reported that parental cytoplasm influenced the expression of leaf blast reaction in rice.

Mahill and Davis (1978) found that *Gossypium harknessii* cytoplasm in F_1 cotton hybrids slightly enhanced bacterial blight resistance, accounting for about 12% of the total resistance, and emphasized the need for cytoplasmic as well as overall genetic diversity with respect to host plant resistance.

We should note that numerous varieties with Cina cytoplasm have been intensively grown under varied environmental and pest pressures in many rice-growing regions for at least 10 years. No weakness in Cina cytoplasm has been detected. We should also note that only about 30% of tropical Asia's rice land is planted to improved rice varieties (Dalrymple 1978) and that they have not been as uniformly adopted in huge contiguous areas as F_1 hybrid corn in the U.S.

This rice cytoplasm situation, while posing no immediate practical problem, should be of sufficient concern to demand a prompt broadening of the maternal genetic base of modern rices. Even though it is difficult to draw an analogy between improved rice technology in Asia and hybrid corn technology in the U.S., the lesson of the southern corn leaf blight epidemic seems worth noting. Almost six decades of technology set the stage for that epidemic.[3]

In 1917, Donald Jones exploited heterosis or "hybrid vigor" in corn by crossing inbred corn line A with inbred line B, then crossing inbred C with inbred D. He then crossed AB with CD. The progeny ABCD lines (F_1 hybrids) yielded 25% higher than standard corn. Seedsmen soon learned that they could plant six rows of the AB pair, then two rows of the CD pair to pollinate the AB rows. In the late 1920s, commercial seed companies began to market F_1 hybrid corn varieties. Thousands of high school students were hired to detassel the ABCD rows so that they would not self-pollinate.

The discovery of a corn plant with sterile tassels in the 1930s eventually made detasseling unnecessary. The sterility was inherited through the cytoplasm of the female line -- not through the nuclear genes; therefore it became known as *cytoplasmic male sterility*. Because this particular source of cytoplasm was identified by two Texans, Mangesdorf and Rogers, in a Texas corn variety, it was designated by a capital *T* -- the *Texas* strain. A restorer gene was identified and put into the CD rows, which carry the fertile pollen. That enabled breeders to plant male-sterile plants with *T* cytoplasm in the AB rows. Pollen from the CD rows would fertilize the AB rows, restoring fertility to the sterile parents.

Breeders knew that the incorporation of cytoplasmic male sterility might influence traits other than pollen, so hundreds of thousands of dollars were invested in research to compare hybrids with male-sterile cytoplasm with those with normal cytoplasm. Included in the studies was the response to numerous disease organisms, including *Helminthosporium maydis*. Little difference was found in lines with the two types of cytoplasm. Furthermore, past experience had generally shown that a particular genotype's cytoplasm had little or no influence on economically important traits of field crops. As a result, seed companies rapidly and widely adopted this new form of genetic technology, both in the U.S. and abroad.

In 1961, Mercado and Lantican, of the University of the Philippines College of Agriculture (now U.P. at Los Baños), published an article in *The Philippine Agriculturist* pointing out that *Helminthosporium maydis* was particularly virulent on several lines and hybrids carrying *T* cytoplasm in the Philippines. They wrote:

> Unfortunately, if susceptibility to the *Helminthosporium* disease is controlled by the same cytoplasm causing male sterility, the hybrid seed that will be produced with this system will be of limited use.

---

[3] Most of the following information on southern corn leaf blight was adapted from *Genetic Vulnerability of Major Crops* (National Academy of Sciences 1972).

The Philippine work was subsequently reported in the *Maize Genetics Cooperative Newsletter*. Several U.S. breeders, including Arthur Hooker of the University of Illinois, tested whether U.S. corn hybrids that carried the *T* cytoplasm were more susceptible to *H. maydis* than those that carried normal cytoplasm. They found no evidence of it.

By 1970 almost every corn farmer in the U.S. was planting varieties with *T* cytoplasm. Early that spring *H. maydis* struck as southern corn leaf blight disease in Florida and rapidly spread northward through the U.S. cornbelt. Only those hybrids that carried the *T* cytoplasm were infected, but they comprised virtually the entire U.S. crop. About 15% of the U.S. corn crop was wiped out that year -- but if weather conditions had been more favorable to the blight, the repercussions could have been far more serious.

An interesting question is whether the *H. maydis* strain reported in the Philippines in 1961 spread to the U.S. to re-emerge as southern corn leaf blight almost a decade later, or if *H. maydis* mutated twice -- 9 years apart -- to attack the *T* cytoplasm in two different regions separated by about 9,000 miles. Many scientists tend to think that a mutation caused the U.S. epidemic. In a post-epidemic evaluation sponsored by the U.S. National Academy of Sciences, scientists wrote:

> *Helminthosporium maydis* had been present in American corn ever since, and probably before, the days when Squanto showed the Pilgrims how to plant the crop....Before 1970 *Helminthosporium* sometimes blighted a few leaves and rotted a few ears, but it was not considered very important. It doubtless mutated from time to time...and it probably produced more virulent strains from time to time. These strains, if they arose, tended to die out, however, because American corn was too variable to give the new strain a very good foothold.
>
> The introduction of Texas cytoplasm changed all this. Corn was now nearly uniform throughout the country so far as its cytoplasm was concerned. While...*T* cytoplasm was being developed and spread across the nation, *H. maydis* continued to mutate. In due time, one of its mutant forms proved ideal for *T* cytoplasm and spread like wildfire across the cornfields.

RECOMMENDATIONS

More complete information and a careful analysis is desirable before drawing firm conclusions about potential dangers. The seemingly narrow genetic base of the IR varieties and other varieties being developed and grown in the various countries is not necessarily a cause for alarm. Analysis of any breeding program in other crops in a developed country such as the U.S. or Japan might reveal a similar situation. Diversification is difficult because of combining ability and other considerations beyond the control of breeders.

But developed countries can absorb losses from epidemics such as southern

corn leaf blight and recover relatively easily. For example, within 2 years of that epidemic, almost all U.S. farmers were planting new F_1 corn varieties with different cytoplasmic bases. The resources and ability to respond to such an emergency in most of rice-growing Asia are far more limited.

We offer some suggestions for consideration.

1. Strong and autonomous local breeding programs should be encouraged.

2. When possible, breeders should avoid the use of rice varieties that trace maternally to Cina as female parents in crosses. (This would not preclude their use as male parents.) Appendix I lists IRRI crosses that derive maternally to Cina.

3. The naming of varieties of diverse maternal origin should be encouraged.

4. Where possible, varieties of diverse maternal origin should be substituted for those with Cina cytoplasm in nursery sets of the International Rice Testing Program and in national testing nurseries, particularly because such screening nurseries serve plant breeders as major sources of new parents to use in crosses (Table 3). The cytoplasmic sources of IRTP entries should be identified and included in the entry booklets so that scientists will be able to diversify the material they release and use in crosses.

5. Scientists should mount a major effort to identify and utilize alternative sources of dwarfism.

6. Tests might be conducted to determine whether varieties that carry Cina cytoplasm differ from varieties with other cytoplasms in resistance or susceptibility to pests.

7. Scientists should communicate findings through international publications, workshops, and conferences.

In 1978, IRRI initiated an *International Rice Genetic Survey* to continuously monitor the genetic composition of the world's rice crop (IRRI 1978). The complete genetic ancestry of older varieties, and of varieties and elite lines developed during the post-IR8 period, is being determined and put on computer file. Lists of hybridizations made in national programs are also being collected and preserved. Scientists can use such information to identify sources of resistance and to measure genetic diversity of the world's rice crop. Rice scientists everywhere may request information on the background of specific varieties from the survey.

In conclusion, although the concern we express in this paper may ultimately prove to be invalid, rice scientists should at least realize that modern efforts in rice improvement and associated technology clearly have the potential to carry the world into unintended and unforeseen problems. To the best of their ability, scientists should scan the horizon and prepare alternatives.

LITERATURE CITED

Bangladesh Rice Research Institute. 1977. Workshop on ten years of modern rice and wheat cultivation in Bangladesh. Publication No. 27, Bangladesh Rice Research Institute, Joydebpur, Dacca, Bangladesh.

Bureau of Agricultural Economics, Statistics Division, (*ca* 1978), Department of Agriculture, Quezon City, Philippines.

Dalrymple, D. G. 1978. Development and spread of high-yielding varieties of wheat and rice in the less developed nations. Foreign Agricultural Economic Report No. 95 (sixth edition). U. S. Department of Agriculture, Office of International Cooperation and Development *in cooperation with* U. S. Agency for International Development, Washington, D. C. 20250 U. S. A. p. xi.

Hargrove, T. R. 1977. Genetic and sociologic aspects of rice breeding in India. IRRI Research Paper Series No. 10. International Rice Research Institute, Los Baños, Laguna, Philippines.

Hargrove, T. R. 1978. The diffusion and adoption of genetic materials among rice breeding programs in Asia. IRRI Research Paper Series No. 18. International Rice Research Institute, Los Baños. Laguna, Philippines.

Harland, S. C. and E. King. 1957. Inheritance of mildew resistance in *Fragaria* with special reference to cytoplasmic effects. Heredity 11:287 (abstract).

Huang, C. H., W. L. Chang, and T. T. Chang. 1972. Ponlai varieties and Taichung Native 1. Pages 31-46 *in* International Rice Research Institute, Rice Breeding. Los Baños, Philippines.

International Rice Research Institute. 1977. Annual Report for 1976. Los Baños, Laguna, Philippines.

International Rice Research Institute. 1978. Invitation to participate in an international rice genetic survey. International Rice Research Newsletter (IRRN)3:3. Page 6.

Kazas, I. A., T. I. Sokolovska, and V. V. Zotov. 1975. Segregation in the vegetative progeny for the character of *Phylloxera* resistance in the varieties Muskat belyi, Sereksiya, and Chaush. Plant Breeding Abstracts, 1975. 45:312.

Khush, G. S. and W. R. Coffman. 1977. Genetic Evaluation and Utilization (GEU) program: the rice improvement program of the International Rice Research Institute. Theoretical and Applied Genetics 51:97-110.

Mahill, J. F. and D. D. Davis. 1978. Influence of male sterile and normal cytoplasms on the expression of bacterial blight in cotton hybrids. Crop Science 18:440-442.

Moss, H. J. and C. W. Wrigley. 1974. Interrelationships between the pedigrees of Australian wheats. The Journal of the Australian Institute of Agricultural Sciences, September 1974. pp. 207-211.

Mercado, A. C. and R. M. Lantican. 1961. The susceptibility of cytoplasmic male sterile lines of corn to *Helminthosporium maydis* Nish & Miy. Philippine Agriculturist, Vol. XLV, No. 5, pp. 235-243.

Nagaich, B. B., M. D. Upadhya, O. Prakash, and S. J. Singh. 1968. Cytoplasmically determined expression of symptoms of potato virus X crosses between species of Capsicum. Nature 220-1341-1342.

National Academy of Sciences. 1972. Genetic Vulnerability of Food Crops. Washington D. C., U. S. A. ISBN No. 0-309-02030-1.

Palacpac, A. 1977. World Rices Statistics, International Rice Research Institute, Los Baños, Laguna, Philippines. 140 pp.

Rath, G. G. and S. U. Padmanabhan. 1972. Cytoplasmic effects on the leaf blast reaction in rice. Current Science 41:338-339.

Washington, W. J. and S. S. Maan. 1974. Disease reaction of wheat with alien cytoplasms. Crop Science 14:903-905.

Appendix 1. IRRI crosses that trace maternally to Cina. Crosses 1-20,000 (1962-1977).

IR5
IR8-IR9
IR39
IR84
IR86
IR95
IR283-IR284
IR286
IR300
IR314
IR400-IR403
IR407-IR408
IR436-IR437
IR442
IR447
IR460
IR4[illegible]
IR482
IR485-IR486
IR503
IR506-IR508
IR528
IR532
IR539
IR542-IR545
IR564
IR570-IR594
IR596
IR598
IR625-IR636
IR643-IR646
IR649-IR650
IR658
IR660-IR669
IR672
IR704-IR705
IR709-IR710
IR714
IR743
IR748-IR761
IR765-IR766
IR769
IR771-IR775
IR777
IR781-IR792
IR795
IR801-IR807
IR809-IR812
IR822-IR854
IR874-IR880
IR882-IR890
IR902
IR906
IR910
IR914
IR930-IR940
IR964-IR966
IR972
IR983
IR987-IR988
IR1001
IR1005-IR1018
IR1042
IR1061-IR1067
IR1092-IR1119
IR1130-IR1139
IR1147
IR1149
IR1154-IR1159
IR1160-IR1177
IR1180-IR1186
IR1190-IR1191
IR1200
IR1207
IR1224-IR1227
IR1229-IR1233
IR1236-IR1239
IR1241
IR1244-IR1245
IR1249-IR1254
IR1257
IR1259-IR1270
IR1285-IR1287
IR1289
IR1296
IR1311-IR1315
IR1337-IR1339
IR1343-IR1344
IR1355-IR1365
IR1367
IR1371
IR1382-IR1384
IR1391
IR1408-IR1412
IR1415-IR1416
IR1420-IR1425
IR1432-IR1433
IR1446-IR1449
IR1471-IR1476
IR1479-IR1486
IR1495-IR1500
IR1507-IR1511
IR1513
IR1522-IR1524
IR1528
IR1532
IR1538-IR1549
IR1559-IR1570
IR1573-IR1603
IR1614-IR1616
IR1618-IR1636
IR1641
IR1644
IR1649-IR1653
IR1683-IR1689
IR1694
IR1696-IR1711
IR1713-IR1721
IR1723-IR1726
IR1729
IR1734
IR1737
IR1742-IR1745
IR1751
IR1755-IR1794
IR1813-IR1828
IR1831-IR1833
IR1835-IR1837
IR1844-IR1845
IR1847-IR1862
IR1867-IR1873
IR1875-IR1884
IR1894-IR1901
IR1903-IR1905
IR1908-IR1909
IR1911-IR1914
IR1916-IR1923
IR1926-IR1927
IR1932
IR1934-IR1935
IR1966
IR1968-IR1981
IR1986-IR2008
IR2012-IR2038
IR2040-IR2043
IR2046-IR2053
IR2057-IR2067
IR2069-IR2071
IR2073-IR2077
IR2079-IR2089
IR2099-IR2101
IR2146-IR2149
IR2151-IR2153
IR2158-IR2166
IR2171
IR2178-IR2181
IR2183-IR2199
IR2201-IR2202
IR2206-IR2220
IR2222-IR2234
IR2236-IR2241
IR2243-IR2247
IR2294-IR2298
IR2321-IR2336
IR2341-IR2350
IR2374-IR2378
IR2384-IR2425
IR2447-IR2498
IR2506-IR2515
IR2539-IR2548
IR2571-IR2620
IR2687-IR2692
IR2695-IR2696
IR2698-IR2700
IR2706-IR2708
IR2710-IR2712
IR2714-IR2722
IR2728
IR2743-IR2746
IR2750-IR2761
IR2766-IR2767
IR2769-IR2776
IR2778-IR2785
IR2789
IR2791-IR2795
IR2799-IR2805
IR2811-IR2813
IR2816
IR2818-IR2822
IR2824-IR2825
IR2827-IR2828
IR2830-IR2831
IR2833
IR2838-IR2842
IR2855-IR2861
IR2866
IR2872
IR2874-IR2880
IR2887-IR2888
IR2894
IR2898-IR2906
IR2984-IR3015
IR3020-IR3036
IR3040-IR3061
IR3067-IR3076
IR3124-IR3214
IR3229-IR3240
IR3255-IR3262

IR3265-IR3266
IR3268-IR3274
IR3292-IR3297
IR3302-IR3310
IR3314-IR3321
IR3324-IR3351
IR3353-IR3368
IR3379-IR3389
IR3395-IR3404
IR3406
IR3429-IR3434
IR3436-IR3437
IR3440-IR3443
IR3453-IR3483
IR3501-IR3511
IR3526-IR3549
IR3558-IR3570
IR3587-IR3593
IR3633-IR3644
IR3649-IR3678
IR3803-IR3841
IR3848-IR3882
IR3954-IR3997
IR4031-IR4040
IR4043-IR4056
IR4062-IR4204
IR4210-IR4243
IR4344-IR4351
IR4366-IR4371
IR4378
IR4382-IR4399
IR4403-IR4411
IR4417-IR4423
IR4432-IR4454
IR4466
IR4468-IR4518
IR4520-IR4549
IR4556-IR4557
IR4563-IR4582
IR4585-IR4591
IR4601-IR4605
IR4608-IR4620
IR4624-IR4630
IR4661-IR4706
IR4708-IR4724
IR4727-IR4733
IR4755-IR4763
IR4787-IR4891
IR4900-IR4929
IR4934-IR4944
IR4955-IR4976
IR5074-IR5080
IR5104-IR5107
IR5130
IR5141-IR5177
IR5181-IR5366
IR5480-IR5482
IR5488
IR5496-IR5497
IR5533-IR5534
IR5536-IR5619
IR5624
IR5628-IR5677
IR5693-IR5694
IR5699-IR5703
IR5706-IR5736
IR5739-IR5743
IR5752-IR5766
IR5777-IR5779
IR5782-IR5828
IR5838-IR5845
IR5869
IR5871
IR5895
IR5915-IR5925
IR5927-IR5928
IR5936
IR5938-IR5953
IR5956-IR5965
IR5968-IR5969
IR5973-IR5974
IR6047-IR6080
IR6127-IR6149
IR6188-IR6253
IR6359
IR6443-IR6468
IR6471-IR6475
IR6483-IR6492
IR6498-IR6534
IR6545-IR6552
IR6558-IR6803
IR6822-IR6863
IR6892-IR6918
IR6936-IR6945
IR6956-IR6990
IR6998-IR7007
IR7070-IR7072
IR7108
IR7111-IR7113
IR7119-IR7120
IR7193-IR7194
IR7196-IR7519
IR7529-IR7602
IR7617-IR7626
IR7632-IR7654
IR7739-IR7743
IR7789-IR7819
IR7841-IR7850
IR7893-IR7913
IR7958
IR7960-IR7961
IR7964
IR7967-IR8013
IR8018-IR8024
IR8076-IR8078
IR8080
IR8083-IR8089
IR8097-IR8165
IR8174-IR8192
IR8203-IR8204
IR8207-IR8217
IR8237-IR8239
IR8257-IR8270
IR8272-IR8273
IR8275-IR8276
IR8278
IR8288-IR8330
IR8454-IR8469
IR8496-IR8505
IR8533-IR8633
IR8637-IR8782
IR8791-IR8799
IR8810
IR8838-IR8840
IR8923
IR8930-IR8936
IR9009-IR9014
IR9018-IR9045
IR9074-IR9076
IR9083-IR9085
IR9128-IR9149
IR9155-IR9242
IR9248-IR9251
IR9294-IR9395
IR9408-IR9437
IR9458-IR9471
IR9491-IR9504
IR9510
IR9517-IR9519
IR9541
IR9549-IR9574
IR9577-IR9619
IR9624-IR9663
IR9665-IR9696
IR9743-IR9770
IR9780-IR9842
IR9844-IR9851
IR9854-IR9855
IR9887-IR9888
IR9900-IR9905
IR9919-IR9961
IR9967-IR9978
IR9988-IR9997
IR10000
IR10124-IR10137
IR10164-IR10175
IR10191-IR10206
IR10235
IR10246-IR10250
IR10254-IR10255
IR10767-IR10770
IR10772-IR10790
IR10856-IR11005
IR11016-IR11047
IR11105-IR11113
IR11116-IR11134
IR11136-IR11306
IR11361-IR11369
IR11371-IR11372
IR11435-IR11440
IR11443-IR11458
IR11561-IR11564
IR11572-IR11585
IR11748-IR11759
IR11823-IR11902
IR11912-IR11921
IR11923
IR11925-IR11934
IR11960-IR12004
IR12070-IR12160
IR12162-IR12234
IR12346-IR12365
IR12404-IR12421
IR12458-IR12469
IR12473-IR12474
IR12484-IR12491
IR12497-IR12500
IR12504-IR12551
IR12706-IR12714
IR12771-IR12789
IR12822-IR12825
IR12902-IR12904
IR12941-IR12945
IR12977-IR12984
IR12987-12990
IR13015-IR13041
IR13043-IR13044
IR13047
IR13136 IR13137
IR13142-IR13157
IR13195-IR13274
IR13277-IR13386

IR13403-IR13404
IR13406-IR13407
IR13410
IR13427-IR13429
IR13511-IR13512
IR13517-IR13518
IR13597-IR13599
IR13601-IR13604
IR13612-IR13614
IR13617-IR13618
IR13624-IR13641
IR13643-IR13646
IR13675-IR13678
IR13693-IR13710
IR13715-IR13718
IR13723-IR13726
IR13732-IR13763
IR13770-IR13774
IR13945-IR13963
IR13973-IR14009
IR14042-IR14044
IR14125-IR14126
IR14137-IR14138
IR14141-IR14150
IR14156
IR14169-IR14171
IR14176
IR14187-IR14188
IR14195-IR14196
IR14203-IR14210
IR14218-IR14221
IR14232-IR14235
IR14255-IR14266
IR14284-IR14286
IR14298-IR14299
IR14317
IR14322
IR14329-IR14332
IR14334-IR14337
IR14344-IR14352
IR14365-IR14371
IR14374-IR14462
UR14509-IR14581
IR14638-IR14656
IR14664-IR14666
IR14692-IR14724
IR14733-IR14889
IR14892-IR14896
IR15084
IR15088-IR15090
IR15123
IR15203-IR15205
IR15207-IR15214
IR15216-IR15218
IR15238-IR15244
IR15257-IR15271
IR15284-IR15292
IR15316
IR15327
IR15329-IR15331
IR15335-IR15337
IR15341-IR15343
IR15357-IR15359
IR15366-IR15368
IR15374-IR15395
IR15412-IR15415
IR15456-IR15466
IR15493
IR15510
IR15519-IR15530
IR15532-IR15539
IR15544-IR15546
IR15559-IR15565
IR15619-IR15620
IR15680-IR15702
IR15705
IR15734-IR15737
IR15743
IR15751
IR15756-IR15763
IR15767-IR15769
IR15776-IR15807
IR15824-IR15849
IR15877-IR15882
IR15899-IR15905
IR15908-IR15919
IR15971-IR15976
IR15987
IR15991
IR16289-16290
IR16315-IR16347
IR16458-IR16465
IR16475-IR16477
IR16582-IR16593
IR16602-IR16606
IR16628-IR16648
IR16655-IR16686
IR16695-IR16713
IR16718-IR16721
IR16724-IR16728
IR16734-IR16738
IR16743-IR16771
IR16776-IR16780
IR16786-IR16876
IR16889-IR16990
IR17005-IR17127
IR17171-IR17173
IR17263
IR17270-IR17316
IR17336-IR17340
IR17354
IR17357-IR17366
IR17371-IR17391
IR17409-IR17418
IR17448-IR17465
IR17477-IR17487
IR17501-IR17514
IR17588-IR17589
IR17779-IR17782
IR17791-IR17793
IR17800-IR17803
IR17933-IR17958
IR17971-IR17979
IR17986-IR17987
IR17990-IR17994
IR18002-IR18027
IR18034-IR18055
IR18072-IR18118
IR18127-IR18138
IR18140-IR18159
IR18184-IR18185
IR18189-IR18310
IR18321-IR18370
IR18554-IR18566
IR18581-IR18583
IR18739-IR18740
IR18835
IR18838-IR18864
IR18892
IR18914
IR18916-IR18918
IR18955
IR19066-IR19070
IR19091-IR19[illegible]
IR19138-IR19169
IR19175-IR19182
IR19205-IR19226
IR19236-IR19287
IR19300-IR19315
IR19320-IR19321
IR19324-IR19330
IR19332-IR19333
IR19341-IR19389
IR19396-IR19436
IR19441-IR19458
IR19468-IR19502
IR19506-IR19510
IR19606-IR19610
IR19621-IR19629
IR19633-IR19637
IR19645-IR19656
IR19664-IR19669
IR19676-IR19685
IR19714-IR19772
IR19832-IR19846

Other papers in this series

No. 1 Recent studies on the rice tungro disease at IRRI

No. 2 Specific soil chemical characteristics for rice production in Asia

No. 3 Biological nitrogen fixation in paddy field studies by in situ acetylene-reduction assays

No. 4 Transmission of rice tungro virus at various temperatures: A transitory virus-vector interaction

No. 5 Physicochemical properties of submerged soils in relation to fertility

No. 6 Screening rice for tolerance to mineral stresses

No. 7 Multi-site tests environments and breeding strategies for new rice technology

No. 8 Behavior of minor elements in paddy soils

No. 9 Zinc deficiency in rice: A review of research at the International Rice Research Institute

No. 10 Genetic and sociologic aspects of rice breeding in India

No. 11 Utilization of the Azolla-Anabaena complex as a nitrogen fertilizer for rice

No. 12 Scientific communication among rice breeders in 10 Asian nations

No. 13 Rice breeders in Asia: A 10-country survey of their backgrounds, attitudes, and use of genetic materials

No. 14 Drought and rice improvement in perspective

No. 15 Risk and uncertainty as factors in crop improvement research

No. 16 Rice ragged stunt disease in the Philippines

No. 17 Residues of carbofuran applied as a systemic insecticide in irrigated wetland rice: Implications for insect control

No. 18 Diffusion and adoption of genetic materials among rice breeding programs in Asia

No. 19 Methods of screening rices for varietal resistance to *Cercospora* leaf spot

No. 20 Tropical climate and its influence on rice

No. 21 Sulfur nutrition of wetland rice

No. 22 Land preparation and crop establishment for rainfed and lowland rice

The International Rice Research Institute
P.O. Box 933, Manila, Philippines

Stamp

ISSN 0115-3862