IRRI RESEARCH PAPER SERIES
NUMBER 111 OCTOBER 1985

CHANGES IN RICE BREEDING IN 10 ASIAN COUNTRIES: 1965-84

DIFFUSION OF GENETIC MATERIALS, BREEDING OBJECTIVES, AND CYTOPLASM

T. R. HARGROVE, V. L. CABANILLA, and W. R. COFFMAN

...ul Development
...05.23
RECEIVED

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

CHANGES IN RICE BREEDING IN 10 ASIAN COUNTRIES: 1965-84 Diffusion of Genetic Materials, Breeding Objectives, and Cytoplasm

ABSTRACT

In 1975 IRRI measured the diffusion of semidwarf rice varieties into breeding programs in 10 Asian countries over the previous decade. In 1980 the effect of extensive semidwarf adoption on the cytoplasmic base of modern varieties was studied. In 1984 the studies were extended to cover almost 20 yr of rice breeding.

Semidwarf parents were used in 61% of the crosses made in Asian rice breeding programs in 1965-67, and in about 85% of the crosses from 1975 through 1984. The adoption of IRRI varieties as parents peaked — 62% of the crosses — in 1970. The strongest trend was the adoption of locally developed semidwarf varieties within about 5 yr of the development of TN1 and IR8. Most local semidwarfs were progeny of earlier crosses with IRRI varieties or TN1.

Yield, grain quality, and growth duration remained the top breeding objectives from 1975 to 1984. The intensity of crossing for pest resistance and environmental adaptation increased from 1975 to 1984, and semidwarfs were used more often as genetic sources of those traits.

Breeders were releasing more tall and intermediate-statured varieties, and fewer semidwarfs, in 1984 than in 1975. However, the same breeders indicated that a higher proportion of popular farm varieties were semidwarfs in 1984.

Breeders acquired 70% of the introduced parents used in 1984 crosses from International Rice Testing Program nurseries.

In 1975, 42% of the newest varieties were maternal progeny of Cina and thus probably carried Cina cytoplasm; in 1984, 46% were Cina progeny. For widely grown varieties, 45% in 1975 vs 34% in 1984 could be traced maternally to Cina. Maternal progeny of Cina comprised 38% of the female parents used in 1984 crosses.

Suggestions for broadening the maternal (and overall genetic) base of future rice varieties are included.

[1] By T. R. Hargrove, editor and head, V. L. Cabanilla, senior research assistant, Communication and Publications Department, International Rice Research Institute; and W. R. Coffman, professor of plant breeding and international agriculture, Cornell University, USA. Submitted to the IRRI Research Paper Series June 1985.

CHANGES IN RICE BREEDING IN 10 ASIAN COUNTRIES: 1965-84
Diffusion of Genetic Materials, Breeding Objectives, and Cytoplasm

The dramatic farmer adoption of high-yielding semidwarf varieties of rice and wheat, and the subsequent *Green Revolution* in Third World agriculture, have been well documented (2, 3, 6, 14, 16).

Less obvious has been how *plant breeders* have adopted such varieties as parents — genetic building blocks — in their crossbreeding, or hybridization, programs to develop subsequent generations of improved varieties suited to specific needs of local farmers.

In 1975 IRRI and The Rockefeller Foundation (RF) studied the diffusion of improved rice varieties into crossbreeding programs from 1965 to 1975 at 14 agricultural research centers in Bangladesh, India, Indonesia, Korea, Philippines, Sri Lanka, and Thailand (9). We also measured plant breeders' objectives — reasons for adopting specific varieties as parents in crosses — at 27 centers in those countries plus Iran, Nepal, and Pakistan (10).

In 1984, IRRI and RF initiated a followup study to monitor changes in rice breeding during the decade, and to extend the earlier study to cover almost 20 yr of rice improvement.

Data on 1975 parents and breeding objectives should be kept in mind when analyzing similar data for 1984 because, using conventional breeding, it takes 4-7 yr from the initial hybridization through selection and release of a rice variety. Many of the 1984 varieties and parents are progeny of crosses made in the 1970s. Projecting into the future, varieties of the late 1980s will be progeny of 1984 crosses.

We had noticed through the 1975 diffusion study that breeders tended to use the semidwarfs as females in their crosses. Components of plant cytoplasm are inherited through the female parents. We became interested in the cytoplasm of rice varieties because cytoplasmic uniformity (23) led to the most serious pest epidemic based on genetic uniformity in recent times — the 1970 epidemic of southern corn leaf blight (*Helminthosporium maydis*, Nish and Miy.) in the U.S. maize crop. Therefore, we also traced the maternal ancestry of varieties in 1975, 1980 (12), and 1984.

BACKGROUND

The Third World food situation was desperate in the mid-1960s; in 1967, Paddock and Paddock (24) predicted a *Time of Famines* in the 1970s and classified India and Egypt as countries that were beyond saving.

The semidwarf variety IR8 was released to Asian rice farmers in late 1966. IR8 was selected from IRRI's 8th hybridization, made in 1962. (By 1984 IRRI had made more than 50,000 crosses.) IR8's female parent was Peta, a tall but vigorous Indonesian variety derived from the 1934 cross Cina/Latisail and released to Indonesian farmers in the late 1930s. Its male parent was Dee-geo-woo-gen (DGWG), a stiff-strawed Chinese rice whose genes gave semidwarf stature not only to IR8 but to almost all subsequent semidwarf varieties in tropical Asia.

IR8 had high yield potential, mainly because its short, stiff straws allowed it to produce heavy panicles of grain without falling over; it tillered profusely; and its insensitivity to photoperiod, or day length, allowed farmers in many latitudes to grow it any time of the year.

Farmers, particularly in Asia's irrigated areas, adopted IR8 so rapidly that it became widely, if inaccurately, known as the *Miracle Rice*. IR8 and similar semidwarf varieties of rice and wheat probably spread faster and more extensively than any other innovation in the history of Third World agriculture (7). By the late 1960s, about 25% of Asia's rice land was planted to IR8 or similar semidwarf varieties and by 1984, about 40%.

The improved rice and wheat varieties and accompanying technology averted the *Time of Famines*. Average rice yields in Asia for 1971-80 were 42% higher than in 1951-60 and total production rose 77%. Asia's land area planted to rice increased only 25% during that period (3), while Asia's population rose 53% (34).

It is often forgotten that IR8 was not the first semidwarf rice variety in tropical Asia. Taichung Native 1 (TN1) had been released in 1956 from DGWG/Tsai-yuan-chon, a 1949 hybridization made in Taiwan, China. In 1960, 1 kg of TN1 seed was introduced into India through a University of Missouri cooperative project, and in 1966 IRRI sent 1 t of TN1 to India. The Indian Government later bought 50 t of TN1 (2). In 1968-69, Indian farmers grew 800,000 ha of TN1, but IR8 soon replaced the Taiwanese semidwarf.

In the 1970s and 1980s, hundreds of new semidwarfs were released to Asian farmers; most were bred by scientists in national rice improvement programs. For example RD 7, RD 9, and RD 25 were released in Thailand; Jyothi, TKM 9, Pusa 44, and Sabari in India; Tong-il then Milyang 30 and Dae Seang Byeo in Korea; Pelita and Cisadane in Indonesia.

Other new varieties were bred at IRRI but were tested

then released to farmers, usually under local names, by national programs. IR20, released in 1969, replaced IR8 in many areas because of its genetic resistance to pests, particularly tungro virus and bacterial blight diseases, stem borers, and green leafhoppers (26). IR26, released in 1973, had a much broader spectrum of resistance and soon replaced IR20. By 1982 a newer variety, IR36, was grown under a dozen names on 11 million ha of rice land and was probably the most widely grown variety — of any crop — the world has ever known (16).

REVIEW OF LITERATURE

The diffusion and adoption of agricultural technology has been widely researched since the classic 1950 Ryan and Gross study on the diffusion of hybrid seed corn among Iowa farmers (28). But our 1975, 1980, and 1984 studies are the only ones we know that focus on the diffusion of genetic materials among plant breeding programs.

In this paper we stress the implications of a cytoplasmic similarity (or, perhaps, uniformity), and thus the possibility of a cytoplasmically based pest epidemic in rice.

A plant cell is divided into two major parts: the nucleus and the cytoplasm. In addition to the genes in the nucleus, evidence now confirms the existence of genes outside the nucleus in certain types of organisms, including higher plants. The role of extranuclear genes in the control of plant phenotypes has become increasingly clear in the past decade (29).

Plant cytoplasm is well organized and contains a heterogeneous array of organelles and membranes. Extranuclear genes are found in two organelles of green plants — the chloroplasts and the mitochondria — which are responsible for photosynthesis and the synthesis of ATP. Each organelle contains its own set of unique and autonomous genes, linked together in an organellar chromosome. Much is now known about the genetics and biochemistry of organelle genes in some organisms but studies were only recently initiated for rice (15, 33). Reports of cytoplasmic inheritance in rice, however, date back at least 25 yr (4).

In 1961, Mercado and Lantican (21) first warned of the importance of cytoplasm in conditioning disease resistance in maize. In 1970 cytoplasmic uniformity of maize in the USA led to the most dramatic disease epidemic in recent history (23). Hargrove et al (12) identified several other crops where the cytoplasm is known to condition both resistance and susceptibility (13): potato (22), grape (17), wheat (32), cotton (20), and rice (27); barley (1) was subsequently added to the list. Cytoplasm is also implicated in the control of herbicide tolerance in Brassica (19).

METHODS

In 1975, the senior author worked with IRRI and national plant breeders to develop the initial methodology, based on *cross analysis*. During personal interviews, hybridizations were randomly selected and analyzed from the cross-breeding records of 27 rice improvement programs in 10 nations. For 7 countries we had records of crosses made in 1965-67, 1970-71, and 1974-75. For the 1984 study we returned to as many of the same stations as possible; political problems during the interview period (Jul-Sep) meant we had to drop 1 station in Iran and 3 in India. We used similar methods to analyze the 1980 and 1983-84 crosses. We analyzed 1,233 parents used in 540 crosses from 1965 to 1984. We then plotted the diffusion of varieties, and the objectives for their use, over the 20-yr period.

Breeding objectives in 1975 and 1984 were determined by asking each breeder to describe in detail exactly why he or she made each cross and the reasons for the use of each parent (e.g., because of its yield potential, early maturity, insect resistance). Information was also gathered on plant type (semidwarf, tall, etc.) and the origin of parents used for each objective.

RESULTS

Diffusion of varieties as parents

Asian plant breeders rapidly adopted the early semidwarf varieties as parents to develop their own range of semidwarfs. In 1965-67, 61% of all crosses analyzed involved a semidwarf parent (Table 1). By 1975, semidwarfs were used in 84% of the crosses; that trend continued through 1984. The percentage of crosses that involved a tall variety dropped from 74% in 1965 to 45% in 1975, then increased slightly in 1984.

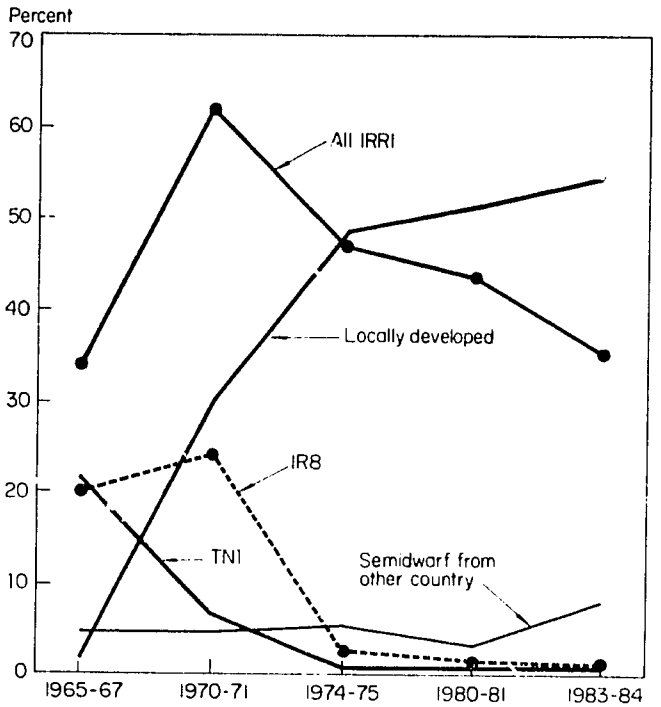
Breeders increasingly crossed semidwarfs with other semidwarfs over the first 10 yr, then maintained that level (Table 1). In 1965, 28% of all parents in the total genetic pool were semidwarfs and 40% were tall. By 1975, the intensity of semidwarf use in crosses had increased to 58%; it remained at that level through 1984.

Direct use of IRRI semidwarfs peaked in 1970, when 62% of the Asian crosses involved an IRRI parent (Fig. 1). Use of

Table 1. Percentages of 1,233 rices of different plant height used as parents in 540 randomly selected crosses at 14 agricultural experiment stations and universities in 7 Asian nations, 1965-84.

Plant height	Rices used (%)				
	1965-67[a]	1970-71[b]	1974-75[c]	1980-81[d]	1983-84[e]
		In crosses			
Semidwarf	61	86	84	89	84
Intermediate	51	39	35	37	31
Tall	74	57	45	41	49
Floating or deep water	2	1	2	8	2
		As individual parents			
Semidwarf	28	48	58	58	58
Intermediate	31	22	17	18	16
Tall	40	30	24	21	25
Floating or deep water	1	—	1	3	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. [d]177 rices used in 79 crosses. [e]237 rices used in 106 crosses.



1. Sources of semidwarf parents used in hybridizations from 1965 to 1984: 1,233 parents used in randomly selected crosses at 14 research stations in 7 Asian nations. Note: The crossing of IR8 (● - - - ●) is also reflected in the line that indicates crosses involving all IRRI parents (● ● ●). Thus, in 1965-67, 35% of all crosses involved an IRRI variety; IR8 was the IRRI parent in 20% of 1965-67 crosses and other IRRI varieties in 15%.

IRRI materials leveled off from 1975 to 1984, the reflection of a strong trend toward the use of *locally developed semidwarfs*. About half of the crosses made from 1975 to 1984 involved at least one local semidwarf.

TNI was used in 22% of the mid-1960 crosses in the 7 countries.

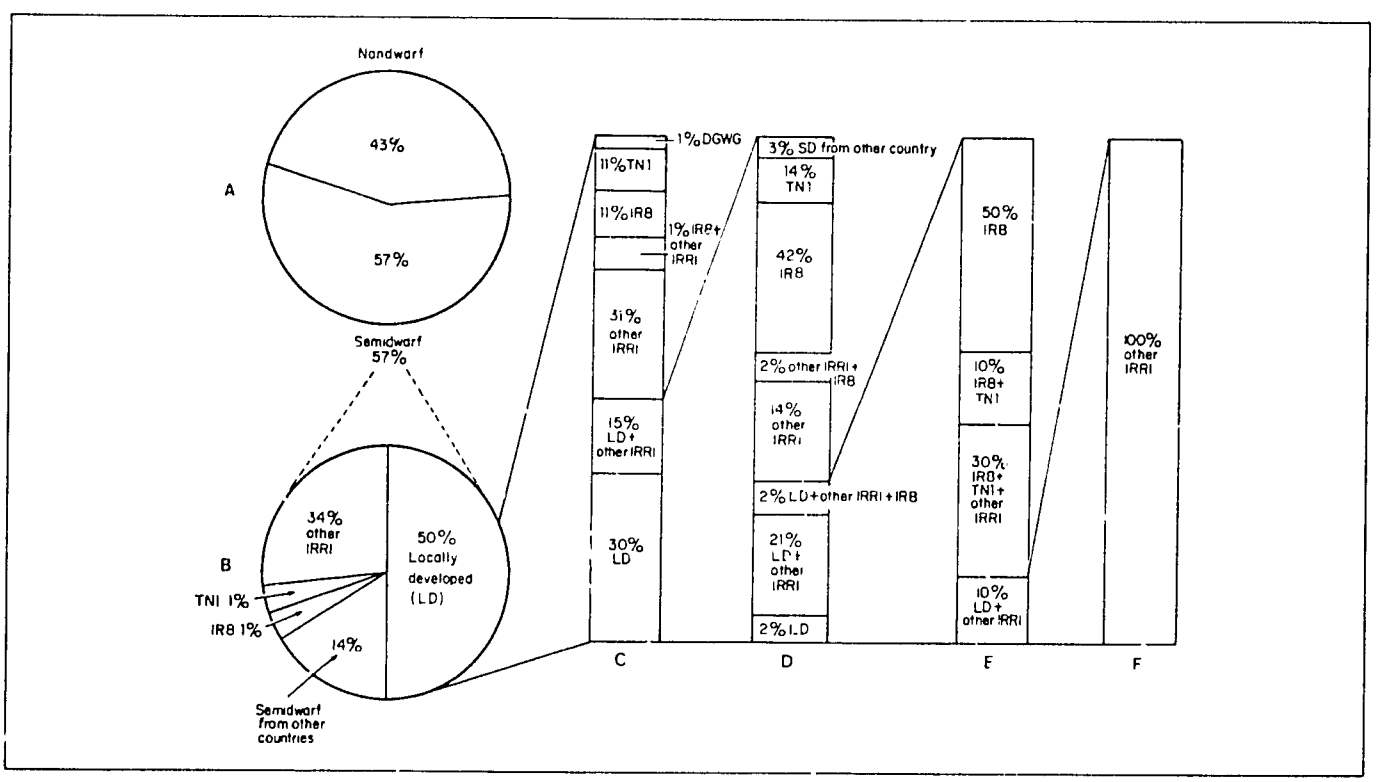
The adoption of IR8 as a parent was surprisingly rapid – IR8 was used in 20% of the 1965-67 crosses, even though it was officially released late in 1966. Breeders apparently acquired IR8 seed and began to cross it with local varieties even before it was released to farmers.

Five percent of the non-IRRI semidwarfs (other than TNI) used in 1965-67 were developed by Asian programs. Taichung 65, a pre-World War II dwarf ponlai variety developed in Taiwan, China, was used in three crosses and DGWG was used once.

By 1970, IR8 and other IRRI cultivars had largely replaced TNI. But by 1975 IR8, like its predecessor, had virtually disappeared from the Asian breeding scene. In 1984, IR50 was the most popular IRRI parent, used in 10% of the crosses. IR36 was used in 9%.

The Indian cultivars OR59-6 and Rasi (or IET 1444) were often used, particularly in India, as parents in 1984.

We traced the pedigrees of all local semidwarfs used in the 1983-84 crosses back four generations and found that IRRI varieties formed a strong genetic base (Fig. 2). An IRRI variety or experimental line was a *direct* parent of 58%



2. A. Plant height of 294 parents used in 134 crosses made in 1983-84. B. Origin of 167 semidwarf parents used in 134 crosses (1983-84). C. Sources of dwarfing genes in the direct ancestry of 84 locally developed (LD) semidwarf rices used as parents in 1983-84 crosses. D. Sources of the dwarf genes in the ancestors of 37 locally developed semidwarf rices. E. Sources of the dwarfing genes in 10 locally developed semidwarf rices. F. Sources of the dwarfing genes in the ancestors of local semidwarfs that were used in crosses in 1983-84.

(Fig. 2C). But 45% were progeny of still earlier crosses involving a local semidwarf. By tracing the ancestry of those local semidwarfs back a second generation, we found that 81% were progeny of IRRI varieties (Fig. 2D).

Thirty-eight percent of the female parents used in 1983-84 crosses traced maternally to Cina (Table 2). We do not have comparable data for 1975.

Breeding objectives

The *relative breeding objectives* remained about the same from 1975 to 1984. But the *intensity of crosses* for resistance to pests and environmental stresses, and for suitability to local conditions, changed considerably; so did the types of varieties that breeders used as parental sources of the needed characters.

After high yield potential, grain quality remained the primary breeding objective and increased from 73% of the 1975 crosses to 78% in 1984 (Fig. 3). Growth duration (usually early) as an objective increased from 61 to 72%.

Breeding for disease resistance increased from 53 to 60% of the crosses, and insect resistance from 41 to 46%.

Drought resistance breeding went from 6 to 19%. This large increase could partly reflect the omission of 1984 data from three breeding stations (in Iran, and in Kashmir and Punjab, India). Those stations serve mostly irrigated regions; inclusion of their crosses might have diluted the apparent increase in drought-tolerant crosses.

On the other hand, low temperature is a problem in Iran and Kashmir. Yet even without their data, cold-tolerance breeding increased from 11% in 1975 to 14% in 1984.

To determine *why* breeders use specific parents, we classified each parent used for each objective (yield potential, grain quality, pest resistance, etc.) by plant type (semidwarf, intermediate-statured, tall, deep water).

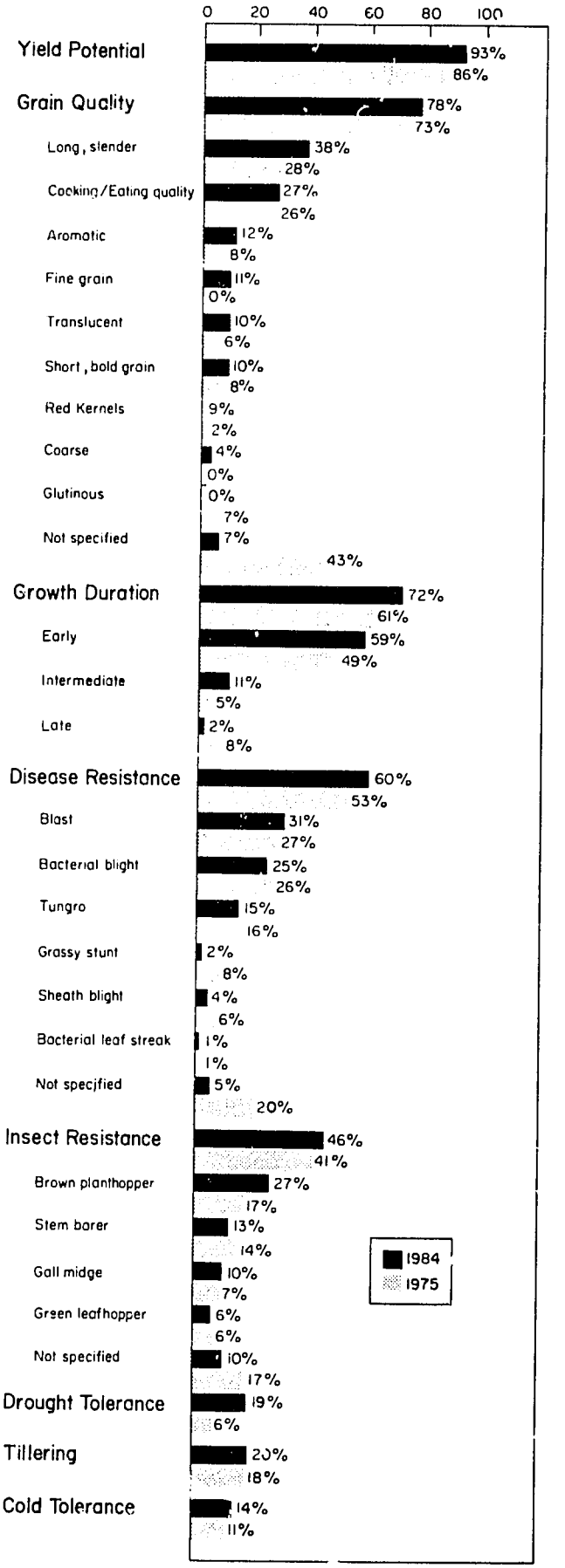
Eighty-five percent of the time that a breeder crossed a semidwarf parent in 1975, he hoped to transfer its yield potential into a progeny variety; in 1984 breeders used semidwarfs less for yield potential and more for other traits (Table 3).

For example, in 1975 grain quality was an objective 65% of the time that a breeder used a tall variety and 40% of the time he used a semidwarf. Data in 1984 showed a marked shift to semidwarfs as parental sources of locally preferred grain, growth duration, and resistance to diseases and insects.

Table 2. Ultimate maternal ancestry of rice cultivars in 10 Asian nations, 1975 and 1984.

Cultivars	Rice cultivars (%) that traced maternally[a] to			
	Cina		Others	
	1975	1984	1975	1984
Female parents used in crosses		38		62
Newest varieties	42	46	58	54
Widely grown varieties	45	34	55	66

[a]Refers to the original female progenitor.

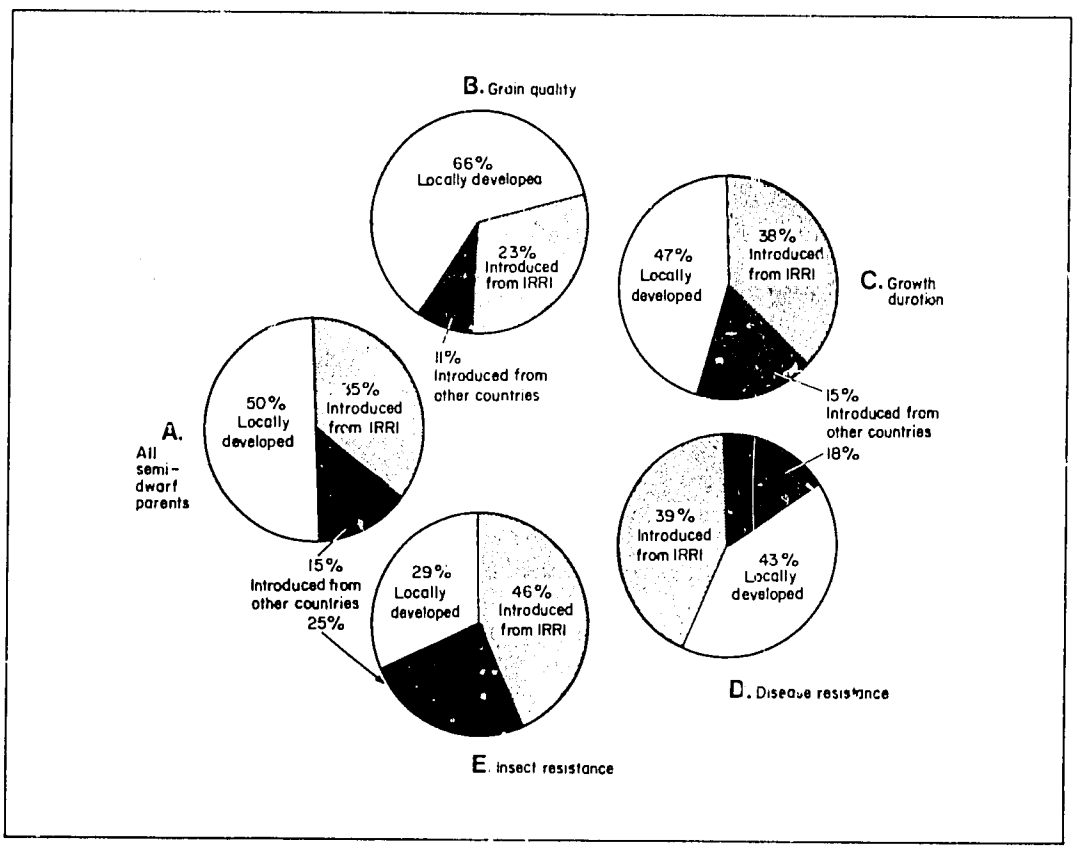


3. Comparison of breeding objectives, 1984 and 1975.

Table 3. The frequency with which rice breeders in 10 Asian nations sought major desired genetic traits from different types of varieties. Source of data = 201 semidwarf, 47 intermediate, 85 tall, and 10 floating parents in 161 randomly selected crosses made in 1974-75 at 27 agricultural experiment stations, 10 Asian nations; and 167 semidwarf, 46 intermediate, 79 tall, and 2 floating parents in 134 randomly selected crosses made in 1983-84 at 24 agricultural experiment stations.

Breeding objectives	Use (%) as parents							
	Semidwarf		Intermediate		Tall		Floating or deep water	
	1975	1984	1975	1984	1975	1984	1975	1984
Yield potential	85	51	51	42	5	16	10	0
Grain quality	40	54	60	72	65	49	20	0
Growth duration	34	44	36	33	31	9	80	100
Disease resistance	36	49	64	56	25	25	20	0
Insect resistance	30	42	15	28	19	16	0	0
Drought tolerance	2	5	4	13	5	11	0	100
Cold tolerance	1	7	17	11	11	3	0	0
Local adaptability	2	9	13	2	2	6	0	0
Adverse soils tolerance	3	3	19	11	9	3	0	0
Photoperiod sensitivity/insensitivity	4	1	2	6	5	5	90	100
Panicle weight	2	2	4	0	0	11	0	0
Straw yield	0	0	0	2	0	5	0	0
Genetic diversity	0	2	0	0	0	0	0	0
Deep water tolerance	0	1	4	—	16	11	100	100
Others	3	1	11	11	8	12	—	0

Similarly, we analyzed *why* breeders used locally developed and IRRI semidwarfs. Half of the semidwarf parents used in the 1984 sample were locally developed, 35% were from IRRI, and 15% were introduced from other national programs. But 66% of the time that a breeder crossed a *local* semidwarf, he hoped to transmit a preferred type of grain into the progeny vs 23% for IRRI semidwarfs (Fig. 4B). However, disease resistance was an objective 39% of the time that an IRRI semidwarf was used, and insect resistance 46% (Fig. 4D, 4E).



4. Sources of semidwarf parents used for different breeding objectives. A. Origin of 167 semidwarf parents. B. Origin of 71 semidwarf parents used for grain quality. C. Origin of 73 semidwarf parents used for growth duration. D. Origin of 56 semidwarf parents used for disease resistance. E. Origin of 48 semidwarf parents used for insect resistance.

Seed sources

Breeders were asked where they got seeds of parents that were introduced from outside their countries. In 1975, the International Rice Testing Program (IRTP) was the source of 61% of all introduced parents; in 1984 IRTP provided 70%. For example, breeders in Pakistan crossed an Indian line, RP1057; the seeds came from International Irrigated Rice Nursery trials.

New varieties

In both 1975 and 1984 rice breeders in the 10 countries were asked to list new varieties they had released to farmers over the previous 3 yr. We filled out *genetic data sheets* on each new variety. We then compared the newest varieties released in 1975 with those of a decade later at the same stations.

There was a shift toward release of taller varieties over the decade. In 1975, 69% of new varieties were semidwarf and 25% intermediate-statured (130-160 cm). In 1984, 54% of new varieties were semidwarfs, and 31% were of intermediate stature (Table 4). In 1975, 6% of the new varieties were tall vs 15% in 1985.

Several breeders — particularly in India, Bangladesh, and Sri Lanka — attributed the shift to higher yield of straw, which is used for cattle fodder and fuel and has a high cash value. Breeders also mentioned that crop management — particularly weed control — was easier with taller varieties.

Eighty-six percent of the new varieties released in 1975 were developed locally, and the others at IRRI. In 1984, 10% of the new varieties released in the 10 countries were introduced from other countries.

Forty-two percent of the newest rice varieties released in 1975, and 46% in 1984, were maternal progeny of Cina (Table 2). In the 1980 survey (12) we found that Cina was the ultimate maternal parent of 62% of the post-IR8 rice varieties released in Bangladesh, 22% in India, 74% in Indonesia, 60% in Korea, 75% in Sri Lanka, and 25% in Thailand.

Widely grown varieties

We asked breeders in 1975 and in 1984 to name the three varieties most widely grown by farmers within the regions served by their research centers. Genetic data sheets similar to those for new varieties, were completed on the varieties.

The 95 widely grown rices in 1975 comprised 73 distinct varieties. Forty-five percent were semidwarfs, 17% were of intermediate stature, and 35% were tall. Of the 71 similar varieties in 1984, however, 66% were semidwarf, 11% were intermediate, and 21% were tall (Table 5).

Table 4. Characteristics of 36 newest varieties released by 1975 at 27 agricultural research stations in 10 Asian nations, and of 68 newest varieties released by 1984 at 22 agricultural stations in 10 Asian nations.

Characteristics	Varieties (%)							
	Semidwarf		Intermediate		Tall		All	
	1975	1984	1975	1984	1975	1984	1975	1984
Plant height	69	54	25	31	6	15	—	—
Origin								
Locally developed	80	78	100	71	100	90	86	78
Introduced from IRRI	20	11	0	19	0	0	14	12
Introduced from other countries	0	11	0	10	0	10	0	10
Method of development								
Hybridization	96	95	89	85	50	80	91	90
Mutant	4	0	11	5	0	10	8	3
Pureline selection	0	5	0	10	50	10	3	7

Table 5. Characteristics of 95 rices cited in 1975 at 27 agricultural research centers as among the 3 most widely grown varieties by farmers, and of 71 rices cited in 1984 at 23 stations in 10 countries.

Characteristics	Varieties									
	Semidwarf		Intermediate		Tall		Floating		All	
	1975	1984	1975	1984	1975	1984	1975	1984	1975	1984
Plant height	45	66	17	11	35	21	3	2	—	—
Origin										
Locally developed	44	58	13	100	97	67	100	100	59	65
Introduced from IRRI	54	38	37	0	0	0	0	0	31	25
Introduced from other countries	2	4	50	0	3	33	0	0	10	10
Method of development										
Unimproved	0	0	0	0	36	47	67	100	15	11
Pureline selection	2	4	0	0	49	13	33	0	19	6
Mutant	2	2	0	0	0	0	0	0	1	1
Hybridization	96	94	81	100	15	40	0	0	62	82

In 1975, 10 varieties were cited as widely grown in 2 or more regions; in 1984, 7 were grown in at least 2 regions.

In 1975 Jaya was the most popular locally developed variety, grown extensively in eight regions, and IR8 was the most popular IRRI variety (7 regions).

In 1984 Jaya was still the most popular local variety (5 regions), but IR36 was the predominant IRRI variety (4 regions).

Forty-five percent of the widely grown varieties in 1975, and 34% in 1984, carried Cina cytoplasm (Table 2).

IR varieties

In 1980 we traced the genealogy of 15 IR varieties named in the Philippines (IR8 through IR42). All were from crosses at IRRI involving 11 parents that traced to 18 original land races (traditional native varieties) from 8 countries. The 1985 release of IR64 and IR65 brought the total to 29 IR varieties. The 14 varieties named since IR42 trace to 28 original land races, including 10 that were not in the ancestry of the first 15 varieties.

For example, 20 original land races from 8 countries are in the pedigree of IR64 (Fig. 5).

All of the first 15 IR varieties traced maternally to Cina; 8 of the 14 subsequent varieties were maternal progeny of Cina (Fig. 6).

Finally, we traced the female parentage of 50,308 crosses (1962-84) made at IRRI; 38% of the females are derived maternally from Cina. The trend, however, is rapidly declining. Although about 50% of the crosses made in 1974 had Cina cytoplasm, only 20% of the crosses made in 1984 traced maternally to Cina (Fig. 7). Appendix 1 lists those crosses for which Cina is the ultimate female progenitor.

DISCUSSION

Changes in rice breeding from 1975 to 1984 suggest that Asian breeders were largely successful in meeting mid-1970 objectives of incorporating genetic resistance and agro-ecologic adaptation into the high-yielding semidwarf package. Semidwarf and intermediate-statured varieties — progeny of earlier crosses — were used more in the 1980s than in the 1970s as genetic sources of preferred grain quality, growth duration, drought and adverse soils tolerance, and insect and disease resistance.

The greater intensity of crossing for resistance to pests and environmental problems might also reflect the incorporation of such traits in today's semidwarf and intermediate-height varieties.

Interestingly, breeders said that the proportion of rice land planted to semidwarfs increased over the past decade, but the same breeders, at the same research centers, were releasing taller varieties.

The IRTP plays a powerful role in the movement of varieties across national borders into farmers' fields But even more important may be IRTP's international movement of parental materials — genetic building blocks for the development of new varieties. Breeders acquired 70% of the introduced parents used in 1984 crosses from IRTP trials.

IRTP nurseries clearly have a tremendous potential to spread new genes. But IRTP also has the potential to spread the same genes — combined into hundreds of "new" parents — across the rice-growing world.

We are concerned about the cytoplasmic similarity of many popular farm varieties, of new varieties, and of female parents used in 1984 hybridizations.

First, some background on Cina (Fig. 8), and how it became the maternal base of so many improved rice varieties, is necessary.

In 1914, Cina was introduced into Indonesia from China (30) (actually Cina may have originated in Indochina — because farmers in some areas of West Java today call it *Saigon Rice*) (B. Siwi, pers. comm.). In the 1930s Cina became the most popular rice variety in Indonesia because of its photoperiod insensitivity, yield, and grain quality (25, 31).

In the early 1930s, plant breeders in Indonesia made the cross Cina/Latisail, from which Peta (as well as Mas, Intan, Bengawan, Cahaya, Fajar, Pelopor, and Salak) were selected (30). Farmer selection of those varieties continued throughout World War II, when leaders of Indonesia's plant breeding program were interned.

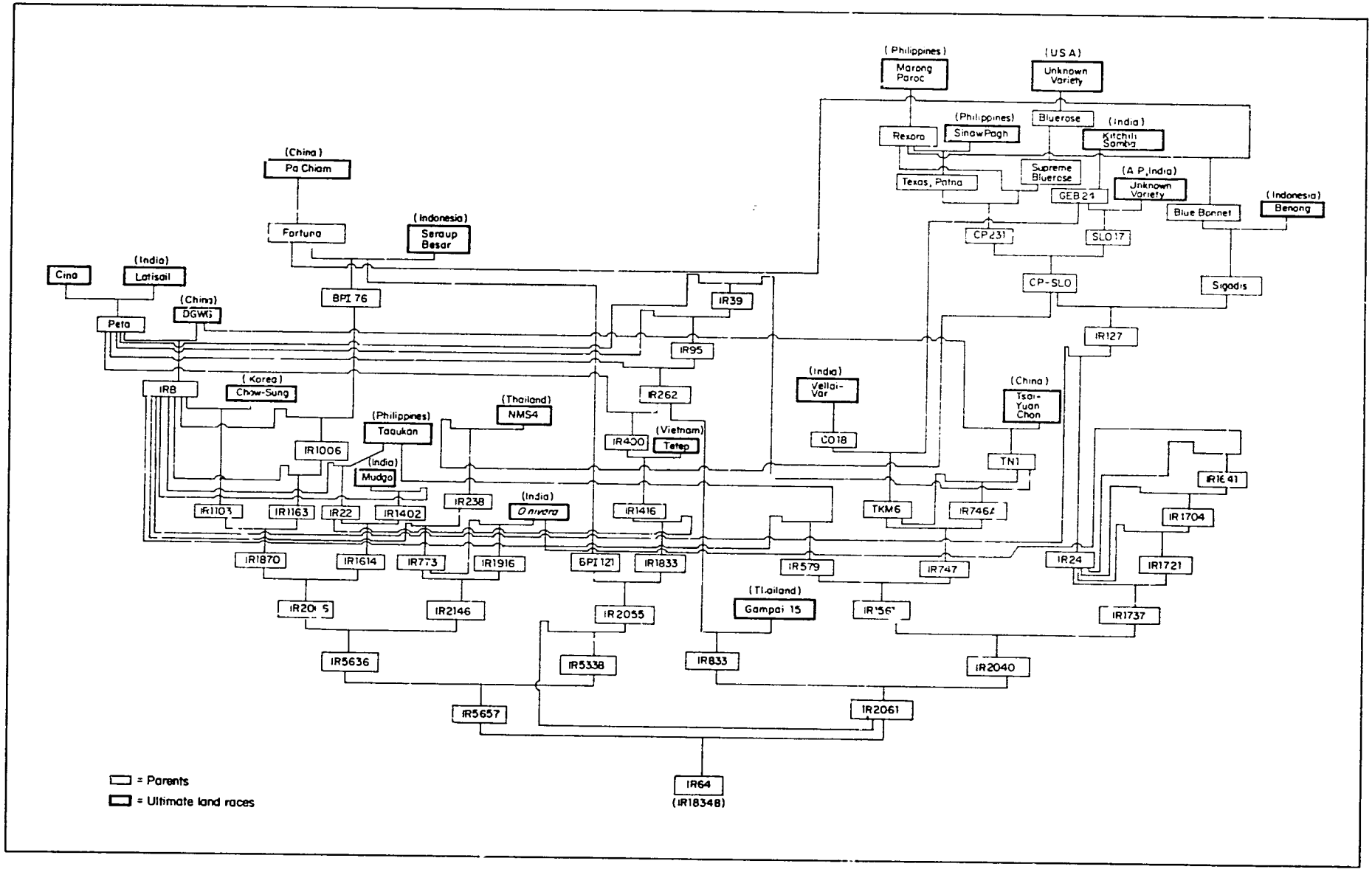
Because of its erect leaves, plant vigor, and sturdy stems (8), Peta was used as the female parent in the 1962 IRRI cross Peta/DGWG that produced IR8; in Peta/T. Rotan, from which IR5 was selected; and in crosses such as Peta/BPI 76, which produced the popular Philippine variety C4-63. Plant breeders at IRRI and in national programs subsequently crossed IR8 and other Peta derivatives, usually as female parents, to combine still more favorable traits, such as disease resistance or grain quality, with the rugged, high-yielding semidwarf plant type.

Why were semidwarfs used mainly as females? First, plant breeders tend to use cultivars that carry recessive genes for readily identifiable traits as female parents. Tallness is dominant to dwarfism — so after use of the semidwarf as the female, tall F_1 plants tell the breeder that he made a successful hybridization. If the F_1 plants are short, however, the breeder knows that the semidwarf self-pollinated. Thus, the female semidwarf/male tall combination can prevent the waste of a plant generation of time.

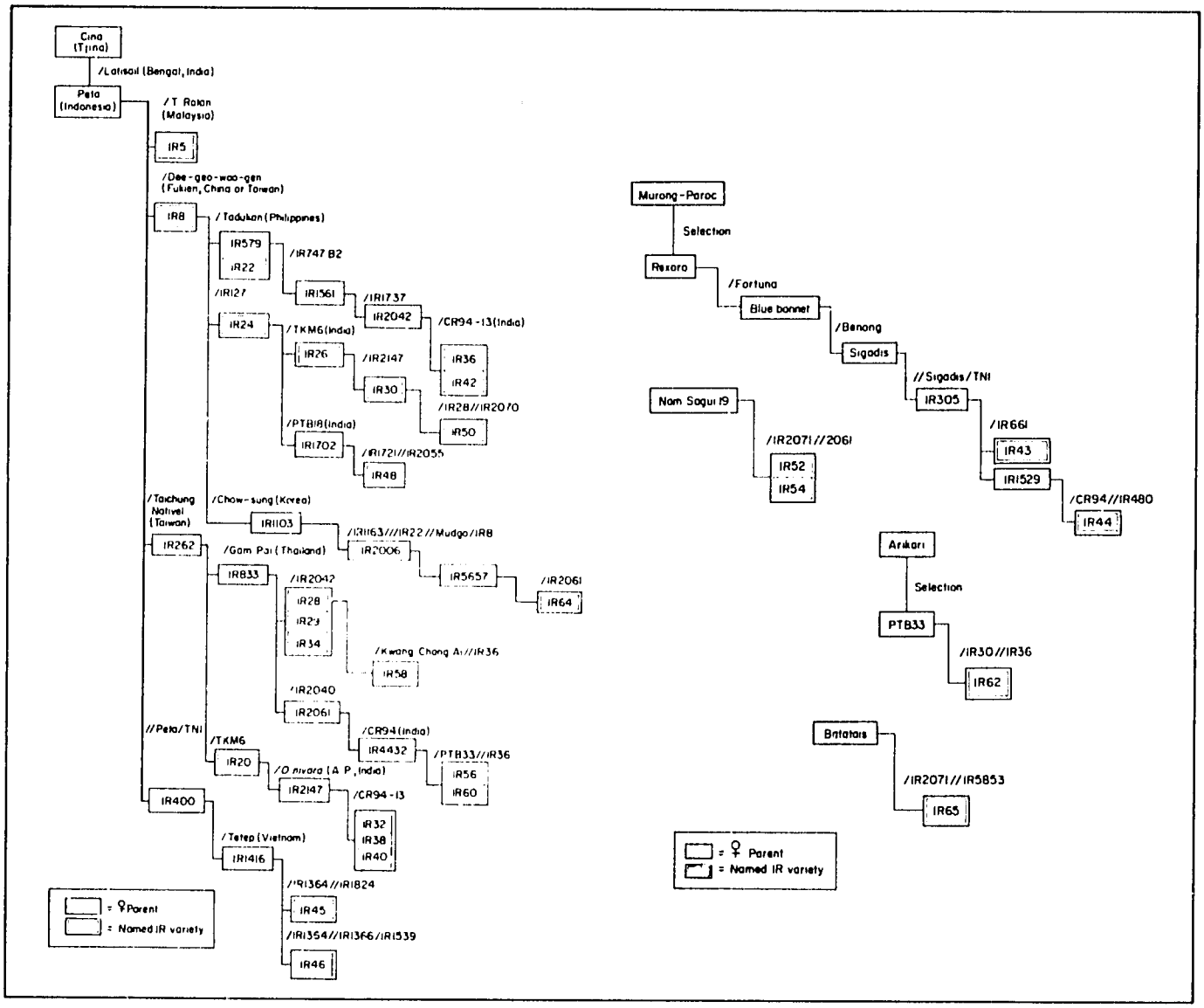
It is also more convenient to use semidwarfs as females because tall females usually must be staked to prevent lodging.

The genealogies of improved rice varieties across Asia appear disturbingly similar. In fact, these similarities simplify this type of research. Once we have traced genealogies of a relatively few popular parents, it is fairly easy to trace the parentage of most improved Asian varieties — because those parents are crossed again and again.

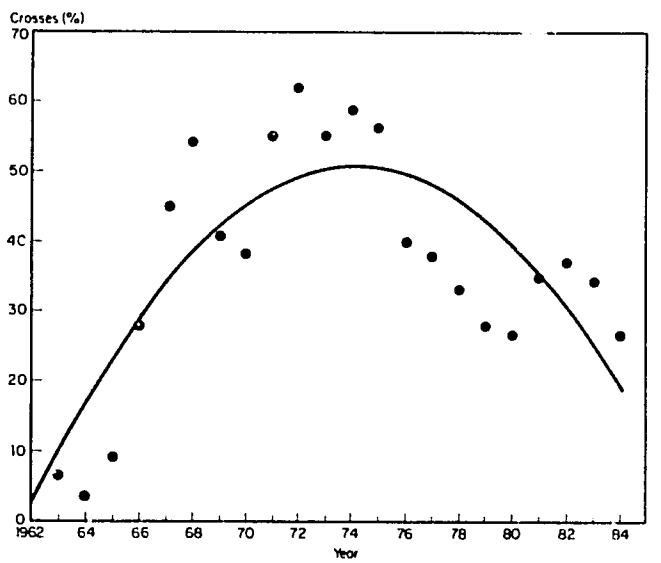
We doubt that this situation is specific to rice, or to Asia. An examination of, for example, maize breeding in the Americas or Europe might reveal a similar situation.



5. Twenty land races, or traditional rice varieties, from 8 nations are in the genetic ancestry of IR64, released in May 1985. Female parents are always on the left, male parents on the right.



6. Maternal derivation of IR varieties. Female parents are in boxes on the left, male parents are on the right.

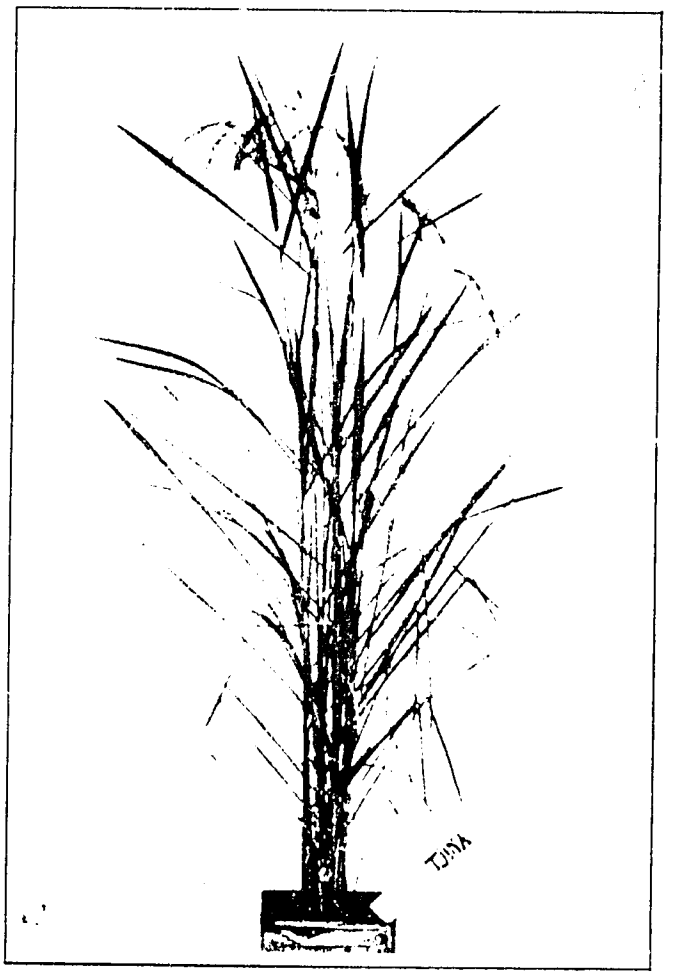


7. IRRI crosses in which female parents trace maternally to Cina. Crosses No. 1-50, 308, 1962-84.

The implications of the maternal similarity in rice should be drawn with caution. The 1970 attack of southern corn leaf blight on the U.S. maize crop is the only recorded pest epidemic that was specifically conditioned by cytoplasmic uniformity. All F_1 hybrid maize strains that carried the Texas male sterile cytoplasm suddenly became susceptible to a new strain of *H. maydis*.

Farmers have intensively grown many rice varieties with Cina cytoplasm under varied pest pressures for at least 15 yr. No weakness in Cina cytoplasm has been detected. Also, improved rice varieties have not generally been adopted as uniformly and across such huge contiguous areas as hybrid maize in the USA.

But the spectre of southern corn leaf blight lingers. Developed countries can more easily absorb losses from such epidemics and can correct such situations more quickly. Within 2 yr of the blight epidemic, almost all U.S. farmers were planting new F_1 maize varieties without Texas male sterile cytoplasm.



8. A photo of Cina (then spelled Tjina) reproduced from a 1941 bulletin of the General Agricultural Experiment Station, Bogor, Indonesia. The photo caption (translated from Dutch) reads "A plant of the awnless (tjereh) variety Tjina, shortly after completion of flowering. This is the most widely planted variety in the Dutch East Indies. Tjina has a sturdy plant type, with long, thick culms and beautiful panicles. The kernels, when ripe, are of good quality and thresh easily. The plant tillers well and the stems have a slightly spreading habit" (33).

The resources to respond to such an emergency in rice-growing Asia are far more limited. A widescale epidemic in Asian rice could mean widespread famine.

We should also mention that the male sterility of the widely grown indica-type hybrid rices of central and southern China are derived from a single cytoplasmic source, a wild rice plant (Wild Abortive) found in 1970 on Hainan Island (5, 18). Those hybrids are of the F_1 generation so their cytoplasm should be virtually identical.

Although the rice cytoplasm situation is posing no immediate threat, it should be sufficient concern to demand a prompt broadening of the maternal (and indeed, the overall) genetic base of modern rices.

In 1980 papers, published by IRRI (11) and in Crop Science (12), we offered suggestions for broadening the genetic (and particularly the cytoplasmic) base of future improved rice varieties. We repeat and expand upon those suggestions:

1. Rice scientists should diversify the maternal origin of future rice varieties released to farmers. If possible, release varieties with non-Cina cytoplasm, and with diverse genetic background for resistance to pests such as brown planthopper and bacterial blight.
2. When possible do not use, as female parents, cultivars such as Peta or its sister lines (Mas, Intan, etc.) that trace maternally to Cina. Also remember that other popular parents such as C4-63 and the Indonesian variety Syntha (Bengawan/Sigadis) carry Cina cytoplasm. (This would not necessarily preclude use of those varieties as male parents.)
3. The genetic sources of cytoplasm and of traits such as pest resistance of cultivars entered in IRTP and national nursery trials might be identified in the nursery booklets.
4. The IRTP could help diversify the genetic base of rice by assembling nursery sets of improved cultivars with *new* genetic sources of desired traits.
5. Strong and autonomous local breeding programs should be encouraged.
6. Scientists should mount a major effort to identify and use sources of dwarfism other than DGWG.
7. Tests might be conducted to determine if cultivars that carry Cina cytoplasm differ from those with other cytoplasm in resistance or susceptibility to pests.
8. The biological and social forces that caused rice breeders to use semidwarfs as female parents in crosses probably apply to other crops. For example, wheat farmers (and, we presume, wheat breeders) have extensively adopted semidwarf wheat varieties across the Third World. We suggest an examination of genetic diversity, including the maternal base, of other major crops.

The authors of this paper maintain, through the International Rice Genetic Survey, records of the parentage of 53,000 hybridizations made in national programs plus more than 900 post-IR8 varieties and almost 1,400 older varieties such as Bluebonnet 50 and TKM 6. We will gladly provide, on request, whatever data we have on any cultivar to any rice scientist.

The genetic recycling from rice farmers' fields into national and international breeding programs and back to farmers' fields is a fascinating journey that deserves subsequent research. Seeds of popular farm varieties cross borders. The improved varieties of any crop, in any country, are combinations of the best materials developed in many countries.

Consider GEB 24, which in the 1920s, *general economic botanists* in Coimbatore, India, selected from the traditional Kitchili Samba. GEB 24 was a good variety and thus, a popular parent. Scientists at Tirurkuppam crossed GEB 24 with CO 18 to develop TKM 6. Subsequent crosses combined, into dozens of improved varieties, TKM 6's insect resistance with other favorable traits derived from varieties such as Gampai 15 from Thailand, Tetep from

Vietnam, CR 94-13 from India, Marong-Paroc from the Philippines, Sigadis from Indonesia, or Bluebonnet 50 from the USA. Progeny of those crosses, such as RD 25 from Thailand, Bogowonto from Indonesia, Ratna and Pusa 33 (India), BR 10 (Bangladesh), and IR36 and IR50 (IRRI) found their way back to rice fields across Asia — but combined with other traits that farmers demand. And those varieties become the parents of a next generation. . . .

In constantly evolving genetic combinations, genes return to their origin: the rice fields of Asia.

REFERENCES CITED

1. Ahokas, H. 1983. Cytoplasmic male sterility in barley 12. Associations between disease resistance and restoration of MSM1 fertility in the wild progenitor of barley. Theor Appl. Genet. 65:67-71.
2. Athwal, D. S. 1971. Semidwarf rice and wheat in global food needs. Q. Rev. Biol. 46(1):1-34.
3. Barker, R., R. W. Herdt, and B. Rose. 1985. Trends in production and sources of growth. Pages 40-41 *in* The rice economy of Asia. Resources for the Future, Washington, D. C. in cooperation with International Rice Research Institute, Manila.
4. Chandraratna, M. F., and K. Sakai. 1960. A biometrical analysis of matroclinous inheritance of grain weight in rice. Heredity 14:365-373.
5. Chang, T. T. 1984. Conservation of rice genetic resources: luxury or necessity? Science 224 (4646):251-256.
6. 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.
7. Dalrymple, D. G. 1985. The development and adoption of high-yielding varieties of wheat and rice in developing nations. Am. J. Agric. Econ. 67.
8. Harahap, Z., M. D. Pathak, and H. M. Beachell. 1981. Genetic evaluation and utilization – a multidisciplinary strategy. Pages 81-96 *in* Rice research strategies for the future. International Rice Research Institute, Los Baños, Philippines.
9. Hargrove, T. R. 1979. The diffusion and adoption of semidwarf rice cultivars as parents in Asian rice breeding programs. Crop Sci. 19(5):571-574.
10. Hargrove, T. R., and V. L. Cabanilla. 1979. The impact of semidwarf rice varieties on Asian rice breeding programs. Biol. Sci. 29(12):731-735.
11. Hargrove, T. R., W. R. Coffman, and V. L. Cabanilla. 1979. Genetic interrelationships of improved rice varieties in Asia. IRRI Res. Pap. Ser. 10. 31 p.
12. Hargrove, T. R., W. R. Coffman, and V. L. Cabanilla. 1980. Ancestry of improved Asian cultivars of rice. Crop Sci. 20(6):721-727.
13. Harland, S. C., and E. King. 1957. Inheritance of mildew resistance in Fragaria with special reference to cytoplasmic effects. Heredity 11.287 (abstr.).
14. Herdt, R. W., and C. Capule. 1983. Adoption, spread and production impact of modern rice varieties in Asia. International Rice Research Institute. Los Baños, Philippines. 54 p.
15. Hirai, A., and T. Ishibashi. 1985. Structure of rice chloroplast DNA. *In* Proceedings of the International Rice Genetic Symposium. International Rice Research Institute, Los Baños, Philippines (in press)
16. International Rice Research Institute. [1982]. IR36, the world's most popular rice. IRRI, Los Baños, Philippines. (a brochure)
17. 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 Breed. Abstr. 45:3:2.
18. Lin, S., and L. Yuan. 1980. Hybrid rice breeding in China. Pages 35-51 *in* Innovative approaches to rice breeding. Selected papers from the 1979 International Rice Research Conference. International Rice Research Institute, Los Baños, Philippines.
19. Machado, V. S., and J. D. Bandeen. 1982. Genetic analysis of chloroplast atrazine resistance in *Brassica campestris* – cytoplasmic inheritance. Weed Sci. 30:281-285.
20. 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 Sci. 18:440-442.
21. Mercado, A. C., and R. M. Lantican. 1961. The susceptibility of cytoplasmic male sterile lines of corn to *Helminthosporium maydis* Nish and Miy. Philipp. Agric. 45(5):235-243.
22. Nagaich, B. B., M. D. Upadhya, O. Prakash, and S. J. Singh. 1968. Cytoplasmically determined expression of symptoms of potato virus crosses between species of capsicum. Nature 220:1341-1342.
23. National Academy of Sciences. Genetic vulnerability of food crops. Washington, D.C., USA.
24. Paddock, P., and W. Paddock. 1967. Famine 1975. America's decision: who will survive? Little, Brown and Co. Ltd., Canada.
25. Parthasarathy, N. 1972. Rice breeding in tropical Asia up to 1960. Pages 5-29 *in* Rice breeding. International Rice Research Institute, Los Baños, Philippines.
26. Pathak, M. D., H. M. Beachell, and F. Andres. 1973. IR20, a pest- and disease-resistant high-yielding rice variety. Int. Rice Comm. Newsl. 22(3):1-8.
27. Rath, G. G., and S. Y. Padmanabhan. 1972. Cytoplasmic effect on the leaf blast reaction in rice. Curr. Sci. 41:338-339.
28. Ryan, B., and N. Gross. 1950. Acceptance and diffusion of hybrid corn seed in two Iowa communities. Iowa Agricultural Experiment Station, Iowa State College of Agriculture and Mechanical Arts, Ames, Iowa, Research Bulletin 372, January 1950.
29. Suzuki, D. T., A. J. F. Griffiths, and R. C. Lewontin. 1981. An introduction to genetic analysis. Freeman, New York.
30. Van Der Muellen, J. G. J. 1950. Rice improvement by hybridization and results obtained. Contrib. Gen. Agric. Res. Stn. 116:1-38.
31. Van Der Muellen, J. G. J. 1941. De rejstselectie in nederlandsch indie. Contrib. Gen. Agric. Res. Stn. 52:1-87.
32. Washington, W. J., and S. S. Maan. 1974. Disease reaction of wheat with alien cytoplasms. Crop Sci. 14:903-905.
33. Wu, R., Z. Peng, T. Kao, E. Moon, and Y. Cai. 1985. Molecular cloning and sequencing of rice genes. *In* Proceedings of the International Rice Genetic Symposium. International Rice Research Institute, Los Baños, Philippines. (in press)
34. United Nations, Department of International and Social Affairs. 1983. 1981 statistical yearbook. New York.

Appendix 1. IRRI crosses that trace maternally to Cina. Crosses 1-50,308 (1962-84).

IR5
IR8-IR9
IR13
IR39
IR84-IR86
IR95
IR130
IR132-IR133
IR262
IR283-IR284
IR286
IR299-IR300
IR306
IR314
IR400-IR403
IR407-IR408
IR426
IR436-IR437
IR442
IR447
IR460
IR469
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
IR968
IR972
IR983
IR987-IR988

IR1001
IR1005-IR1018
IR1042
IR1061-IR1067
IR1092-IR1119
IR1130-IR1139
IR1147
IR1149
IR1154-IR1186
IR1190-IR1191
IR1200
IR1207
IR1224-IR1227
IR1229-IR1233
IR1236-IR1239
IR1241
IR1244-IR1227
IR1229-IR1233
IR1236-IR1239
IR1241
IR1244-IR1245
IR1249-IR1254
IR1257
IR1259-IR1270
IR1285-IR1287
IR1289
IR1296-IR1298
IR1300
IR1302
IR1311-IR1315
IR1337-IR1339
IR1343-IR1344
IR1351
IR1355-IR1365
IR1367
IR1371
IR1382-IR1384
IR1391
IR1403-IR1412
IR1415-IR1416
IR1420-IR1425
IR1432-IR1433
IR1446-IR1449
IR1471-IR1476
IR1478-IR1486
IR1493-IR1500
IR1507-IR1511
IR1513
IR1514
IR1522-IR1524
IR1528
IR1532
IR1538-IR1549
IR1559-IR1571
IR1573-IR1603
IR1614-IR1616
IR1618-IR1636
IR1641
IR1644-IR1647
IR1649-IR1653
IR1683-IR1689
IR1694
IR1696-IR1711
IR1713-IR1721
IR1723-IR1726
IR1729

IR1734
IR1737
IR1742-IR1745
IR1747-IR1748
IR1751
IR1755-IR1794
IR1813-IR1828
IR1831-IR1833
IR1835-IR1837
IR1844-IR1845
IR1847-IR1862
IR1867-IR1884
IR1889-IR1905
IR1908-IR1909
IR1911-IR1914
IR1916-IR1921
IR1926-IR1927
IR1932
IR1934-IR1935
IR1966
IR1968-IR1981
IR1986-IR2038
IR2040-IR2043
IR2046-IR2053
IR2057-IR2067
IR2069-IR2071
IR2073-IR2077
IR2079-IR2089
IR2099-IR2101
IR2146-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
IR2431-IR2438
IR2447-IR2503
IR2506-IR2515
IR2539-IR2548
IR2571-IR2620
IR2638
IR2687-IR2692
IR2695-IR2696
IR2698-IR2700
IR2706-IR2708
IR2710-IR2712
IR2714-IR2722
IR2728
IR2741-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
IR2896-IR2906
IR2929-IR2933
IR2984-IR3015
IR3020-IR3036
IR3040-IR3061
IR3067-IR3076
IR3124-IR3214
IR3229-IR3240
IR3255-IR3262
IR3265-IR3266
IR3268-IR3274
IR3288
IR3292-IR3297
IR3302-IR3310
IR3314-IR3321
IR3324-IR3351
IR3353-IR3368
IR3371
IR3379-IR3389
IR3395-IR3404
IR3406
IR3429-IR3434
IR3436-IR3437
IR3440-IR3443
IR3453-IR3483
IR3488
IR3501-IR3510
IR3526-IR3549
IR3558-IR3570
IR3587-IR3593
IR3633-IR3644
IR3649-IR3678
IR3682-IR3685
IR3803-IR3841
IR3848-IR3882
IR3904-IR3914
IR3954-IR3997
IR4031-IR4040
IR4043-IR4056
IR4062-IR4204
IR4210-IR4243
IR4271
IR4300-IR4316
IR4344-IR4353
IR4362
IR4366-IR4371
IR4378
IR4382-IR4399
IR4403-IR4411
IR4417-IR4423
IR4432-IR4454
IR4465-IR4466

IR4468-IR4518
IR4520-IR4549
IR4556-IR4557
IR4562-IR4582
IR4585-IR4591
IR4596-IR4597
IR4601-IR4605
IR4608-IR4620
IR4624-IR4630
IR4632-IR4633
IR4635-IR4644
IR4661-IR4673
IR4675-IR4724
IR4727-IR4733
IR4741-IR4742
IR4755-IR4764
IR4787-IR4891
IR4900-IR4929
IR4934-IR4944
IR4955-IR4976
IR5010-IR5014
IR5020-IR5026
IR5074-IR5080
IR5104-IR5112
IR5130
IR5141-IR5177
IR5181-IR5366
IR5392-IR5396
IR5445
IR5480-IR5482
IR5488
IR5496-IR5497
IR5533-IR5534
IR5536-IR5619
IR5624
IR5628-IR5677
IR5681
IR5688
IR5693-IR5694
IR5699-IR5703
IR5705-IR5736
IR5739-IR5743
IR5752-IR5766
IR5777-IR5779
IR5781-IR5828
IR5838-IR5845
IR5851
IR5869
IR5871
IR5879-IR5880
IR5895
IR5915-IR5925
IR5927-IR5928
IR5936
IR5938-IR5965
IR5968-IR5969
IR5973-IR5974
IR6047-IR6080
IR6127-IR6149
IR6188-IR6253
IR6359
IR6370-IR6374
IR6443-IR6468
IR6471-IR6475
IR6483-IR6492
IR6498-IR6534

Appendix 1 continued

IR6545-IR6552
IR6558-IR6803
IR6822-IR6863
IR6892-IR6918
IR6936-IR6945
IR6956-IR6990
IR6998-IR7007
IR7070-IR7072
IR7108
IR7111-IR7113
IR7119-IR7120
IR7147-IR7162
IR7193-IR7194
IR7196-IR7519
IR7529-IR7602
IR7617-IR7626
IR7632-IR7654
IR7701-IR7704
IR7739-IR7743
IR7789-IR7819
IR7839-IR7850
IR7893-IR7913
IR7958
IR7960-IR7961
IR7964
IR7967-IR8013
IR8018-IR8024
IR8076-IR8078
IR8080
IR8083-IR8089
IR8097-IR8165
IR8097-IR8165
IR8174-IR8192
IR8203-IR8204
IR8207-IR8217
IR8237-IR8239
IR8257-IR8270
IR8272-IR8273
IR8275-IR8276
IR8278
IR8288-IR8330
IR8417-IR8424
IR8454-IR8469
IR8496-IR8505
IR8533-IR8633
IR8637-IR8751
IR8753-IR8782
IR8791-IR8799
IR8810
IR8838-IR8840
IR8870-IR8875
IR8923
IR8930-IR8936
IR8938
IR8942-IR8945
IR9009-IR9014
IR9018-IR9045
IR9074-IR9076
IR9083-IR9085
IR9094-IR9101
IR9128-IR9149
IR9155-IR9242
IR9248-IR9251
IR9271-IR9273
IR9294-IR9395
IR9397-IR9400
IR9408-IR9437
IR9443
IR9456
IR9458-IR9467
IR9491-IR9504
IR9510
IR9513-IR9519
IR9541
IR9549-IR9574
IR9577-IR9619
IR9624-IR9663
IR9665-IR9696
IR9729-IR9732
IR9743-IR9770
IR9780-IR9842
IR9844-IR9851
IR9854-IR9855
IR9868
IR9887
IR9900-IR9905
IR9917-IR9961
IR9965
IR9967-IR9978
IR9988-IR9997
IR10000
IR10124-IR10137
IR10164-IR10175
IR10191-IR10206
IR10235
IR10246-IR10250
IR10254-IR10255
IR10767-IR10770
IR10772-IR10790
IR10855-IR11005
IR11016-IR11047
IR11105-IR11113
IR11116-IR11134
IR11136-IR11306
IR11361-IR11369
IR11371-IR11372
IR11434-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
IR12821-IR12825
IR12902-IR12904
IR12941-IR12945
IR12977-IR12984
IR12987-IR12990
IR13015-IR13041
IR13043-IR13044
IR13047
IR13135-IR13137
IR13142-IR13157
IR13195-IR13274
IR13277-IR13386
IR13403-IR13404
IR13406-IR13407
IR13427-IR13429
IR13511-IR13512
IR13517-IR13518
IR13597-IR13604
IR13612-IR13614
IR13617-IR13618
IR13624-IR13641
IR13643-IR13646
IR13675-IR13678
IR13693-IR13710
IR13714-IR13718
IR13723-IR13726
IR13732-IR13763
IR13770-IR13774
IR13868-IR13883
IR13895-IR13938
IR13945-IR13963
IR13973-IR14009
IR14042-IR14044
IR14108
IR14125-IR14126
IR14137-IR14138
IR14141-IR14144
IR14147-IR14152
IR14155-IR14156
IR14169-IR14171
IR14176
IR14187-IR14188
IR14202-IR14210
IR14218-IR14221
IR14232-IR14235
IR14260-IR14261
IR14284-IR14286
IR14298-IR14299
IR14302
IR14313-IR14314
IR14336-IR14337
IR14344-IR14352
IR14365-IR14371
IR14374-IR14462
IR14498-IR14581
IR14638-IR14656
IR14664-IR14666
IR14692-IR14724
IR14733-IR14890
IR14892-IR14896
IR15084
IR15088-IR15090
IR15123
IR15203-IR15205
IR15207-IR15214
IR15216-IR15218
IR15238-IR15271
IR15284-IR15292
IR15316
IR15327
IR15329-IR15331
IR15335-IR15337
IR15341-IR15343
IR15357-IR15359
IR15366-IR15368
IR15374-IR15395
IR15412-IR15415
IR15448-IR15453
IR15455-IR15466
IR15493-IR15496
IR15519-IR15539
IR15544-IR15546
IR15559-IR15565
IR15619-IR15620
IR15660-IR15666
IR15670-IR15678
IR15680-IR15702
IR15705
IR15734-IR15737
IR15745
IR15748
IR15751
IR15756-IR15763
IR15767-IR15769
IR15776-IR15807
IR15809-IR15849
IR15877-IR15882
IR15899-IR15905
IR15908-IR15919
IR15971-IR15976
IR15987
IR15990-IR15991
IR16289-IR16290
IR16315-IR16347
IR16445-IR16452
IR16458-IR16465
IR16475-IR16489
IR16582-IR16593
IR16602-IR16606
IR16628-IR16648
IR16652-IR16686
IR16695-IR16713
IR16718-IR16721
IR16724-IR16728
IR16734-IR16738
IR16743-IR16771
IR16776-IR16780
IR16786-IR16876
IR16889-IR17127
IR17171-IR17173
IR17263
IR17270-IR17316
IR17336-IR17340
IR17354
IR17357-IR17366
IR17371-IR17391
IR17409-IR17418
IR17448-IR17465
IR17477-IR17487
IR17501-IR17514
IR17588-IR17589
IR17697-IR17707
IR17779-IR17782
IR17791-IR17793
IR17933-IR17958
IR17971-IR17979
IR17986-IR17987
IR17990-IR17994
IR18002-IR18055
IR18072-IR18118
IR18137-IR18138
IR18140-IR18177
IR18184-IR18185
IR18189-IR18310
IR18321-IR18370
IR18554-IR18566
IR18581-IR18583
IR18739-IR18740
IR18835
IR18838-IR18864
IR18892
IR18914
IR18916-IR18918
IR18955
IR19045
IR19066-IR19070
IR19091-IR19092
IR19175-IR19182
IR19205-IR19226
IR19230-IR19287
IR19300-IR19315
IR19320-IR19321
IR19323-IR19330
IR19332-IR19333
IR19341-IR19389
IR19396-IR19436
IR19441-IR19458
IR19468-IR19502
IR19506-IR19510
IR19605-IR19610
IR19621-IR19629
IR19633-IR19637
IR19645-IR19656
IR19664-IR19669
IR19676-IR19685
IR19714-IR19772
IR19832-IR19846
IR19854-IR19863
IR19898-IR19901
IR19954-IR19955
IR19971-IR20002
IR20026-IR20040
IR20078-IR20091
IR20093-IR20101
IR20112-IR20115
IR20144-IR20216
IR20221-IR20258
IR20263-IR20291
IR20307-IR20335
IR20337-IR20351
IR20365-IR20408
IR20474-IR20483
IR20541-IR20565
IR20571-IR20575
IR20580-IR20621
IR20634-IR20643
IR20699-IR20702
IR20826
IR20831-IR20834
IR20837-IR20841
IR20856-IR20857
IR20859-IR20867
IR20871-IR20873
IR20890-IR20911
IR20913
IR20918-IR20919
IR20924-IR20933
IR21018-IR21019
IR21103-IR21115
IR21277-IR21287
IR21302-IR21306
IR21327-IR21369
IR21388-IR21414

Appendix 1 continued

IR21439-IR21487
IR21489-IR21539
IR21552-IR21553
IR21555-IR21556
IR21602-IR21607
IR21734
IR21745-IR21747
IR21771
IR21821-IR21832
IR21834-IR21855
IR21871-IR21872
IR21894-IR21899
IR22005-IR22006
IR22010
IR22028
IR22053-IR22071
IR22073-IR22074
IR22084-IR22095
IR22112-IR22118
IR22147
IR22150-IR22151
IR22164-IR22279
IR22328-IR22333
IR22427-IR22441
IR22477-IR22482
IR22563-IR22572
IR22576-IR22585
IR22905-IR22908
IR22926-IR22950
IR22952-IR22954
IR22957-IR22970
IR22974
IR22983-IR22986
IR23204-IR23208
IR23231-IR23263
IR23281-IR23304
IR23307-IR23309
IR23363-IR23395
IR23419-IR23442
IR23560-IR23626
IR23636-IR23675
IR23698-IR23717
IR23793-IR23795
IR23839-IR23871
IR23876-IR23943
IR23963-IR23983
IR24024-IR24030
IR24091-IR24142
IR24154-IR24220
IR24324
IR24570-IR24572
IR24582-IR24590
IR24596-IR24637
IR24646-IR24657
IR24678-IR24679
IR24710-IR24722
IR24726-IR24764
IR24794-IR24799
IR24845-IR24882
IR24908-IR24962
IR25014-IR25031
IR25034-IR25042
IR25096-IR25190
IR25252-IR25260
IR25266-IR25274
IR25278-IR25281
IR25397-IR25403
IR25410-IR25413
IR25475-IR25483
IR25507-IR25510
IR25515-IR25551
IR25562-IR25573
IR25633-IR25634
IR25643-IR25646
IR25664
IR25675-IR25684
IR2569.-IR25693
IR25700-IR25718
IR25727
IR25735-IR25737
IR25862-IR25863
IR25880
IR25901-IR25905
IR25917-IR25922
IR25959-IR25967
IR26294-IR26303
IR26316-IR26539
IR26652-IR26657
IR26727-IR26733
IR26752-IR26755
IR26838-IR26847
IR26879-IR26880
IR26883-IR26886
IR26901-IR26907
IR26909
IR26911-IR26912
IR26919
IR26921-IR26923
IR26930
IR26932-IR26933
IR26935
IR26949-IR26950
IR26957-IR26960
IR26969-IR26973
IR26980-IR26985
IR27006-IR27010
IR27029
IR27050-IR27055
IR27066-IR27070
IR27080-IR27103
IR27121-IR27159
IR27219-IR27242
IR27288-IR27305
IR27507-IR27519
IR27563-IR27579
IR27585-IR27614
IR27772-IR27781
IR27812-IR27815
IR27830
IR27832-IR27835
IR27840-IR27844
IR27849-IR27850
IR27889-IR27896
IR28066-IR28074
IR28111-IR28112
IR28120-IR28130
IR28138-IR28171
IR28186-IR28201
IR28254-IR28269
IR28274-IR28282
IR28284
IR28437-IR28680
IR28682-IR28704
IR28895-IR28922
IR28938-IR28941
IR28943-IR28963
IR28972-IR28984
IR29247
IR29251-IR29253
IR29256-IR29260
IR29263
IR29265
IR29285-IR29306
IR29319-IR29338
IR29376-IR29385
IR29417-IR29418
IR29448-IR29455
IR29468-IR29499
IR29525-IR29541
IR29641-IR29647
IR29757-IR29759
IR29790-IR29795
IR29823-IR29825
IR29870-IR29921
IR29934-IR29965
IR30003-IR30038
IR30105-IR30107
IR30111-IR30121
IR30145-IR30149
IR30179-IR30196
IR30225-IR30245
IR30250-IR30254
IR30262-IR30265
IR30297-IR30301
IR30311-IR30314
IR30319-IR30323
IR30328-IR30330
IR30379
IR30430-IR30438
IR30452-IR30455
IR30469-IR30475
IR30485-IR30488
IR30493-IR30516
IR30519-IR30538
IR30544
IR30549-IR30552
IR30555-IR30556
IR30558
IR30563
IR30572-IR30574
IR30576-IR30599
IR30607-IR30619
IR30632-IR30631
IR30642-IR30646
IR30649-IR30656
IR30664-IR30666
IR30671
IR30680-IR30681
IR30702-IR30706
IR30729
IR30755
IR30761-IR30762
IR30766-IR30788
IR30810-IR30836
IR30855
IR30870-IR30873
IR31165-IR31205
IR31250-IR31252
IR31750-IR31759
IR31766
IR31803-IR31826
IR31939-IR31964
IR31993-IR31999
IR32037-IR32038
IR32056-IR32059
IR32079-IR32083
IR32102
IR32107-IR32108
IR32110
IR32112
IR32118-IR32196
IR32201-IR32208
IR32226-IR32228
IR32240-IR32244
IR32253-IR32332
IR32365-IR32367
IR32374-IR32401
IR32421-IR32428
IR32436-IR32440
IR32471-IR32485
IR32549-IR32604
IR32697-IR32705
IR32728-IR32735
IR32749-IR32759
IR32775-IR32781
IR32795-IR32798
IR32809-IR32834
IR32863-IR32864
IR32866-IR32893
IR33024-IR33031
IR33126-IR33129
IR33136-IR33169
IR33236-IR33242
IR33328-IR33330
IR33338-IR33348
IR33390-IR33428
IR33482-IR33493
IR33498
IR33547-IR33561
IR33563-IR33573
IR33576-IR33617
IR33621-IR33625
IR33630
IR33676-IR33680
IR33724-IR33753
IR33775-IR33777
IR33779-IR33804
IR33865-IR33868
IR33871
IR33875-IR33880
IR33886-IR33887
IR33889-IR33892
IR33894
IR33919-IR33927
IR33937-IR33962
IR34009-IR34017
IR34020-IR34021
IR34190-IR34211
IR34213-IR34216
IR34258
IR34264-IR34278
IR34292-IR34305
IR34321-IR34322
IR34298-IR34329
IR34347-IR34348
IR34351
IR34395-IR34396
IR34398-IR34420
IR34490-IR34493
IR34508-IR34509
IR34515
IR34522
IR34530
IR34544-IR34548
IR34582-IR34606
IR34653-IR34667
IR34674-IR34679
IR34687-IR34691
IR34753-IR34801
IR34805-IR34809
IR34859-IR34861
IR34871-IR34873
IR34901-IR34915
IR34925-IR34928
IR34953-IR34959
IR34965-IR34982
IR35101-IR35155
IR35165-IR35171
IR35175
IR35177
IR35179-IR35182
IR35186-IR35188
IR35190-IR35191
IR35194
IR35211-IR35213
IR35233-IR35236
IR35255-IR35256
IR35273-IR35280
IR35286-IR35315
IR35334-IR35340
IR35354-IR35357
IR35359-IR35362
IR35394-IR35408
IR35422-IR35465
IR35481-IR35520
IR35542-IR35543
IR35563-IR35571
IR35655
IR35662-IR35712
IR35955-IR36013
IR36034-IR36035
IR36059-IR36100
IR36209-IR36224
IR36228-IR36233
IR36235
IR36240
IR36247-IR36250
IR36262-IR36263
IR36300-IR36313
IR36354-IR36359
IR36363-IR36369
IR36405-IR36414
IR36448-IR36451
IR36460
IR36465-IR36473
IR36952-IR36599
IR36601-IR36604
IR36606-IR36608
IR36677-IR36723
IR36736-IR36745
IR36751-IR36807
IR36817-IR36864
IR36870-IR36879
IR36894-IR36898
IR36942-IR36953
IR37007-IR37072
IR37089-IR37131
IR37148-IR37240
IR37248-IR37262
IR37275-IR37290

Appendix 1 continued

IR37321-IR37354
IR37376-IR37384
IR37401
IR37408-IR37413
IR37419-IR37423
IR37428-IR37430
IR37472-IR37473
IR37475-IR37476
IR37480
IR37497-IR37500
IR37508-IR37509
IR37548
IR37550-IR37581
IR37623
IR37625-IR37650
IR37669-IR37670
IR37673
IR37692-IR37697
IR37707
IR37722-IR37739
IR37746-IR37770
IR37810-IR37822
IR37832-IR37844
IR37874-IR37875
IR37877
IR37879-IR37888
IR37892-IR37903
IR37905-IR37908
IR37931-IR37968
IR37971-IR37998
IR38130-IR38198
IR38270-IR38274
IR38292
IR38301-IR38302
IR38306-IR38307
IR38323-IR38335
IR38342
IR38346
IR38366-IR38389
IR38396-IR38401
IR38428
IR38450
IR38455
IR38458
IR38540
IR38554-IR38559
IR38581-IR38583
IR38591-IR38606
IR38620-IR38629
IR38657-IR38666
IR38704-IR38708
IR38711
IR38713-IR38719
IR38775-IR38797
IR38807-IR38808
IR38837-IR38843
IR38845
IR38847-IR38848
IR38852-IR38869
IR38886-IR38893
IR38912
IR38914
IR38917-IR38920
IR38930-IR38949
IR38952-IR38955
IR38975-IR38980
IR38996
IR39023-IR39036

IR39059-IR39070
IR39078-IR39101
IR39106-IR39108
IR39118-IR39121
IR39132-IR39141
IR39201-IR39205
IR39212-IR39215
IR39247-IR39257
IR39259-IR39260
IR39300-IR39358
IR39362-IR39400
IR39404-IR39441
IR39446-IR39461
IR39470-IR39474
IR39480-IR39483
IR39499-IR39501
IR39507-IR39539
IR39542-IR39557
IR39576-IR39586
IR39612
IR39627
IR39653-IR39654
IR39664-IR39665
IR39670-IR39671
IR39690-IR39711
IR39721-IR39730
IR39741-IR39757
IR39761-IR39763
IR39774
IR39790-IR39891
IR39896-IR39897
IR39901-IR39904
IR39908-IR39914
IR39916-IR39922
IR39924
IR39932-IR39935
IR39949-IR39951
IR39966-IR39980
IR40069-IR40127
IR40130-IR40144
IR40164-IR40181
IR40193-IR40201
IR40229-IR40256
IR40342-IR40371
IR40395-IR40397
IR40465-IR40470
IR40487-IR40496
IR40569-IR40679
IR40683-IR40690
IR40721-IR40747
IR40758-IR40762
IR40768-IR40786
IR40799-IR40817
IR40838-IR40840
IR40847-IR40857
IR40866-IR40872
IR40902-IR40904
IR40911-IR40932
IR40963-IR40974
IR41056-IR41060
IR41114-IR41117
IR41121-IR41132
IR41138-IR41149
IR41151
IR41312-IR41374
IR41441-IR41442
IR41444-IR41454
IR41457-IR41461

IR41464-IR41465
IR41470-IR41471
IR41474-IR41475
IR41478-IR41480
IR41494-IR41496
IR41502-IR41503
IR41505-IR41507
IR41510
IR41512-IR41531
IR41535
IR41542-IR41544
IR41546-IR41559
IR41561
IR41710-IR41712
IR41735-IR41744
IR41777-IR41778
IR41811
IR41832
IR41835
IR41848-IR41852
IR41869-IR41888
IR41911-IR41917
IR41919-IR41921
IR41928-IR41937
IR41939-IR41948
IR41960-IR41969
IR41984-IR42004
IR42033-IR42049
IR42062-IR42067
IR42074-IR42085
IR42105-IR42118
IR42169-IR42202
IR42208-IR42212
IR42224-IR42233
IR42241-IR42245
IR42349-IR42367
IR42371-IR42375
IR42388-IR42391
IR42430-IR42432
IR42438-IR42453
IR42476-IR42[illegible]
IR42482-IR42483
IR42540-IR42545
IR42558-IR42588
IR42592-IR42594
IR42618-IR42620
IR42631-IR42635
IR42642-IR42643
IR42666-IR42668
IR42670
IR42676
IR42683
IR42695-IR42696
IR42706
IR42709-IR42710
IR42736
IR42738
IR42748-IR42749
IR42764-IR42772
IR42786
IR42794-IR42802
IR42816
IR42823-IR42827
IR42851-IR42924
IR42932-IR42946
IR42976-IR42977
IR42983-IR42990
IR42999-IR43001

IR43003-IR43005
IR43012-IR43016
IR43021-IR43023
IR43026-IR43027
IR43030
IR43032
IR43033
IR43053-IR43058
IR43089-IR43105
IR43113-IR43115
IR43133-IR43145
IR43149-IR43172
IR43185
IR43223-IR43225
IR43228-IR43229
IR43233-IR43235
IR43237-IR43243
IR43247-IR43249
IR43284-IR43297
IR43314
IR43320-IR43321
IR43324
IR43361
IR43365-IR43367
IR43374
IR43376-IR43382
IR43384-IR43387
IR43401
IR43405-IR43406
IR43415-IR43417
IR43422
IR43427
IR43980-IR43996
IR44049
IR44073
IR44105-IR44142
IR44156
IR44158-IR44159
IR44176-IR44186
IR44193-IR44196
IR44205-IR44214
IR44222
IR44245-IR44250
IR44260
IR44271-IR44274
IR44277-IR44281
IR44283-IR44285
IR44288
IR44291-IR44296
IR44298-IR44300
IR44304
IR44316-IR44317
IR44334-IR44338
IR44351-IR44355
IR43433-IR43434
IR43446-IR43447
IR43455-IR43458
IR43462-IR43464
IR43469-IR43476
IR43512-IR43514
IR43516
IR43546-IR43548
IR43551
IR43555
IR43560-IR43561
IR43592
IR43596
IR43607-IR43609

IR43616-IR43623
IR43666-IR43683
IR43689
IR43699-IR43703
IR43718-IR43735
IR43756-IR43771
IR43783-IR43829
IR43855-IR43857
IR43964-IR43972
IR44351-IR44355
IR44386
IR44407-IR44408
IR44427-IR44429
IR44455-IR44458
IR44504
IR44545-IR44576
IR44578-IR44581
IR44591-IR44599
IR44602-IR44607
IR44615-IR44626
IR44638-IR44655
IR44677-IR44679
IR44689-IR44695
IR44709-IR44710
IR44715-IR44720
IR44726-IR44729
IR44732-IR44733
IR44736-IR44737
IR44764-IR44766
IR44781-IR44788
IR44803
IR44809
IR44811
IR44825-IR44829
IR44831-IR44833
IR44839-IR44841
IR44852-IR44859
IR44910
IR44919
IR44941-IR44995
IR45006-IR45049
IR45060-IR45088
IR45102-IR45110
IR45152-IR45162
IR45167-IR45170
IR45189-IR45198
IR45201-IR45219
IR45229-IR45233
IR45236-IR45242
IR45251-IR45256
IR45263-IR45264
IR45267-IR45268
IR45273-IR45277
IR45283-IR45289
IR45299-IR45302
IR45311-IR45317
IR45425
IR45429
IR45431-IR45434
IR45437
IR45443
IR45463
IR45508-IR45511
IR45514-IR45516
IR45518-IR45535
IR45537-IR45538
IR45572-IR45574
IR45578-IR45579

Appendix 1 continued

IR45585-IR45587
IR45591-IR45593
IR45675
IR45701-IR45703
IR45705-IR45706
IR45708-IR45727
IR45735-IR45737
IR45854-IR45862
IR45878-IR45881
IR45889-IR45891
IR45962-IR46039
IR46042-IR46059
IR46098-IR46101
IR46104-IR46105
IR46111-IR46124
IR46130-IR46133
IR46138-IR46140
IR46153-IR46154
IR46156-IR46167
IR46173-IR46176
IR46178
IR46186
IR46188-IR46190
IR46193-IR46194
IR46196
IR46198
IR46205
IR46220-IR46222
IR46224-IR46227
IR46237
IR46253-IR46274
IR46281-IR46288
IR46300-IR46301
IR46308-IR46316
IR46318
IR46362-IR46367
IR46369
IR46373
IR46418
IR46423-IR46424
IR46429-IR46431
IR46434-IR46436
IR46440-IR46442
IR46481-IR46485
IR46487-IR46511
IR46518-IR46521
IR46523-IR46524
IR46532-IR46534
IR46538-IR46539
IR46544
IR46548-IR46554
IR46558
IR46582
IR46584-IR46591
IR46593-IR46603
IR46615-IR46619
IR46622
IR46630-IR46639
IR46645-IR46651
IR46655
IR46660-IR46665
IR46668-IR46681
IR46688
IR46690-IR46694
IR46710-IR46719
IR46733-IR46734
IR46747-IR46750
IR46754
IR46773
IR46783-IR46786
IR46791
IR46795
IR46797-IR46798
IR46808
IR46817-IR46819
IR46823
IR46984-IR47000
IR47028-IR47069
IR47076-IR47085
IR47117-IR47141
IR47147-IR47186
IR47251-IR47252
IR47295-IR47302
IR47306-IR47308
IR47315-IR47316
IR47326
IR47328-IR47332
IR47363
IR47395
IR47452-IR47488
IR47492-IR47495
IR47497-IR47501
IR47505-IR47523
IR47620-IR47628
IR47630-IR47633
IR47636-IR47637
IR47658-IR47662
IR47709
IR47737-IR47783
IR47796-IR47822
IR47832-IR47837
IR47848-IR47870
IR47879-IR47881
IR47888
IR47912-IR47918
IR47924-IR47928
IR47932
IR47938-IR47940
IR47944-IR47952
IR47965-IR47968
IR47981-IR47986
IR48005-IR48016
IR48024-IR48035
IR48039-IR48040
IR48042-IR48045
IR48047
IR48120-IR48123
IR48133-IR48134
IR48166-IR48168
IR48172-IR48173
IR48175-IR48176
IR48190-IR48191
IR48193
IR48203-IR48204
IR48209
IR48223-IR48246
IR48280
IR48282
IR48286-IR48292
IR48294-IR48295
IR48298-IR48301
IR48306-IR48307
IR48309
IR48326-IR48335
IR48338-IR48342
IR48362-IR48370
IR48374-IR48389
IR48400-IR48403
IR48406-IR48408
IR48418-IR48423
IR48426-IR48428
IR48434-IR48436
IR48438-IR48442
IR48444
IR48447-IR48449
IR48487-IR48492
IR48506-IR48516
IR48522-IR48529
IR48623
IR48634-IR48641
IR48678-IR48681
IR48686-IR48692
IR48707
IR48723-IR48724
IR48736-IR48739
IR48749-IR48751
IR48765-IR48773
IR48777-IR48784
IR48788
IR48801-IR48802
IR48817
IR48846-IR48848
IR48905-IR48913
IR48942-IR48943
IR49005-IR49008
IR49026-IR49063
IR49084-IR49086
IR49103
IR49105-IR49107
IR49112
IR49148-IR49170
IR49179
IR49192
IR49234-IR49236
IR49247
IR49445-IR49460
IR49489-IR49525
IR49533-IR49541
IR49578-IR49592
IR49594-IR49597
IR49599-IR49602
IR49624-IR49628
IR49678
IR49683-IR49686
IR49699-IR49700
IR49712
IR49716-IR49723
IR49776-IR49777
IR49830
IR49853-IR49859
IR49861-IR49863
IR49872-IR49879
IR49884-IR49885
IR49912-IR49921
IR49937-IR49948
IR49967
IR49970-IR49975
IR49984
IR50043-IR50062
IR50081-IR50082
IR50109-IR50110
IR50129-IR50132
IR50135-IR50137
IR50139
IR50152-IR50172
IR50175
IR50189-IR50194
IR50252-IR50256
IR50302-IR50308

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

Stamp

Airmail

ISSN 0115-3862

Other papers in this series

TITLES OF NUMBERS 1-45 ARE LISTED ON THE LAST PAGE OF NO. 46; THOSE OF NUMBERS 46-70 ARE ON THE LAST PAGE OF NO. 71-80.

No. 71 The development and diffusion of rice varieties in Indonesia
No. 72 Levels of resistance of rice varieties to biotypes of the BPH, *Nilaparvata lugens*, in South and Southeast Asia
No. 73 Growing season analyses for rainfed wetland fields
No. 74 San Bartolome: beyond the green revolution
No. 75 Pathotypes of *Xanthomonas campestris* pv. *oryzae* in Asia
No. 76 Focusing field research on future constraints to rice production
No. 77 An international survey of methods used for evaluation of cooking and eating quality of milled rice
No. 78 Research on algae, blue-green algae, and phototrophic nitrogen fixation at the International Rice Research Institute (1961-81), summarization, problems, and prospects
No. 79 Seed-derived callus culture for selecting salt-tolerant rices
No. 80 Economic limitations to increasing shallow rainfed rice productivity in Bicol, Philippines
No. 81 Irrigation system management research and selected methodological issues
No. 82 Interdisciplinary challenges and opportunities in international agricultural research
No. 83 Comparative analysis of cropping systems: an exploratory study of 14 rainfed sites in the Philippines
No. 84 Rapid generation advance of rice at IRRI
No. 85 Physicochemical characterization of iron-toxic soils in some Asian countries
No. 86 New rice technology, intrarural migration, and institutional innovation in the Philippines
No. 87 RICEMOD: a physiologically based rice growth and yield model
No. 88 Sensitivity tests of the environmental variables in RICEMOD
No. 89 Sensitivity tests of the crop variables in RICEMOD
No. 90 New rice technology and labor absorption: comparative histories of two Philippine rice villages
No. 91 Calculating the private benefits of farm machinery: a microcomputer application
No. 92 Cropping systems research in the Pangasinan Project
No. 93 Estimating risk of fertilizer use in rainfed rice production
No. 94 Sensitivity tests of the enviromental variables in IRRIMOD
No. 95 Sensitivity tests of the crop and management variable in RICEMOD
No. 96 Fertilizer transfer to floodwater during deep placement
No. 97 Interaction between fertilizer and weed control methods in Philippine upland rice: estimates from farmer's fields
No. 98 Training needs of information services in agricultural research and educational organizations in Asia: a 9-country survey
No. 99 Soil sickness caused by continuous cropping of upland rice, mungbean, and other crops
No. 100 Changes in input use and grain yields in lowland rice farms in three Philippine provinces
No. 101 The economics of hybrid rice production in China
No. 102 Rice ratooning
No. 103 Growth and development of rice grown in deep water
No. 104 Faridpur: a computer-assisted instruction model for rainfed lowland rice
No. 105 A reading and listening comprehension test in English for nonnative speakers applying for training at IRRI
No. 106 Rice grassy stunt virus 2: a new strain of rice grassy stunt in the Philippines
No. 107 Physical losses and quality deterioration in rice postproduction systems
No. 108 Copublication of IRRI materials: a survey of translators and publishers
No. 109 Classification of Philippine rainfall patterns
No. 110 Contributions of modern rice varieties to nutrition in Asia

19