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DIFFUSION AND ADOPTION OF GENETIC MATERIALS AMONG RICE BREEDING PROGRAMS IN ASIA

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DIFFUSION AND ADOPTION OF GENETIC MATERIALS AMONG RICE BREEDING PROGRAMS IN ASIA[1]

ABSTRACT

The International Rice Research Institute traced the diffusion of rice genetic materials used as parents from 1965 to 1975 by analyzing randomly selected crosses from 27 agricultural research centers in 10 Asian nations and interviewing the breeders who made the crosses.

Sixty-one percent of the 1965-67 crosses and 84% of the 1974-75 crosses involved at least one semidwarf parent. Crosses that involved a tall variety dropped from 74% in 1965-67 to 45% in 1974-75. In 1965-67, 28% of the total gene pool was semidwarf and 40% tall. Ten years later, the percentage of semidwarfs almost doubled and that of tall and intermediate-statured material dropped sharply, indicating that breeders were increasingly crossing semidwarf parents with other semidwarfs.

Taichung Native 1 (TN1) and IR8 were the most popular gene sources in 1965-67; each was used in about 20% of the crosses. Use of TN1 dropped to only 1% by 1974-75 and use of IR8, to 3%. Use of other semidwarfs from IRRI increased significantly. But the growing use of *locally developed* semidwarfs showed the strongest trend -- from 2% of the 1965-67 crosses to 49% in 1974-75.

The genetic makeup of those local semidwarf parents was traced back two generations; 76 % were progeny of IR8 or other IRRI rices.

Of the 1974-75 crosses, 79-86% were made for increased yield potential, fertilizer response, and lodging resistance; 73% for improved grain quality; and 61% for desired growth duration. Semidwarf parents were almost invariably used for the yield complex; tall varieties, for grain quality.

Lags from the time a variety or line was selected to the fixed-line stage (F_5 or F_6) until its adoption by breeders as a parent averaged 3.2 years. The lag from the time a breeder first became aware of a variety or line until he adopted it for use was 1.3 years. Test nurseries or trials were the breeders' most common sources of introduced materials.

About 70% of the 36 newest varieties released by the Asian centers were semidwarfs (mostly progeny of IR8 or TN1); 86% were developed locally.

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[1]by Thomas R. Hargrove, associate editor, International Rice Research Institute, Los Baños, Laguna, Philippines. Submitted to the IRRI Research Paper Series Committee 6 March 1978.

Their most common favorable traits were high yield potential, desired growth duration, grain quality, and disease resistance.

Ninety-five varieties were cited as being among the 3 most widely grown by farmers in the regions; about 50% were semidwarfs and 35%, tall. Only 10 varieties -- 8 of which were semidwarfs -- were widely grown in more than 1 region; Jaya was most popular, followed by IR8. TN1 and IR8 are ancestors of almost all of the locally developed semidwarfs. About half of the rices had favorable grain quality or growth duration, but few had pest resistance.

All breeders considered diseases and insects as being among four factors that most seriously limit yield; 62% of their crosses were made for pest resistance. Drought and injurious soils were also widely perceived as problems, but few crosses were made for resistance to them.

DIFFUSION AND ADOPTION OF GENETIC MATERIALS AMONG RICE BREEDING PROGRAMS IN ASIA

Although much is known about the spread of the improved semidwarf rice and wheat varieties onto farmers' fields in Asia, Africa, and Latin America, less is known about the earlier movement of the parent varieties through national plant breeding programs. Analysis of the breeding materials used in hybridization programs can help indicate the genetic composition of current and future rice varieties. This provides a measure of the role of the modern varieties in the development of local technology. More important, the information may also help scientists avoid the inherent danger of a lack of genetic diversity in the world's rice crop.

The classic model for research on diffusion and adoption of new technology in agriculture was the Ryan and Gross (1950) study of the diffusion of hybrid seed corn among Iowa farmers in two communities. Much of the diffusion research since has been on the spread of agricultural technology in the highly developed nations. Rogers and Shoemaker (1971), however, found that the mental process involved in diffusion is cross cultural: people everywhere go through similar processes in adoption of innovations. But the diffusion of rice genetic materials among plant breeding programs has never been studied.

Through analysis of hybridization records and interviews with rice breeders the International Rice Research Institute (IRRI) traced the diffusion of genetic materials used as parents from the mid-1960's through the mid-1970's at 14 agricultural research centers in 7 Asian nations (Table 1). The survey was partially funded by The Rockefeller Foundation.

Table 1. Agricultural experiment stations and universities where breeding records were analyzed for a 10-year period, 1975.

Country	Stations surveyed (no.)
Bangladesh	1
India	7
Indonesia	1
Korea	2
Philippines	1
Sri Lanka	1
Thailand	1
Total	14

Crosses made at each center during three time periods were randomly selected from the breeding records and the types of plant materials used were analyzed. Included in the analysis were 119 crosses, involving 277 parents for 1965-67; 147 crosses, involving 351 parents, for 1970-71; and 89 crosses, involving 191 parents, for 1974-75.

DIFFUSION AND ADOPTION OF GENETIC MATERIALS

The percentages of semidwarf, intermediate-statured, tall, and deepwater or floating rices used during each period were calculated on

- a *cross basis*, or the percentage of total crosses in which a variety of each plant type was used as a donor parent, and
- an *individual parent basis*, or the percentage of different types of rice in the total gene pool.

Adoption of semidwarf parents

Sixty-one percent of the 1965-67 crosses involved at least one semidwarf parent; 86% involved a semidwarf by 1970-71, and by 1974-75, semidwarf involvement dropped slightly to 84% (Table 2). Crosses that involved a tall variety dropped from 74% in 1965-67 to 45% in 1974-75.

The intensity of use of semidwarfs as parents in crosses also increased. In 1965-67, 28% of the total parents were semidwarf, and 40% were tall.

Table 2. 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.

Ten years later, the percentage of semidwarf material had almost doubled and the percentages of tall and intermediate-statured materials had dropped sharply. That indicates that breeders were increasingly crossing semidwarf parents to other semidwarfs.

Individual semidwarf parents

The most popular single gene source in the 1965-67 sample of crosses was the Taiwanese variety Taichung Native 1 (TN1), probably the first semidwarf rice developed through hybridization (Athwal 1971). TN1, from the 1949 cross Dee-geo-woo-gen (DGWG)/Tsai-yuan-chung, was released in 1956 and was the prototype model for the later development of IR8. TN1 was used in 22% of the 1965-67 crosses at the 14 centers surveyed. IRRI's first variety, IR8, was used in 20% of the crosses; other IRRI lines were used in 14% (Fig. 1).

By 1970, the use of TN1 dropped sharply, and by 1974-75 TN1 was used as a parent in only 1% of the crosses. The use of IR8 increased slightly by 1970-71, but dropped to only 3% by 1974-75.

The use of IRRI rices other than IR8 increased to about 44% of the 1974-75 crosses. The use of semidwarfs introduced from other countries also increased slightly.

The growing use of *locally developed* semidwarfs showed the strongest trend. While only 2% of the 1965-67 crosses involved a local semidwarf, 49% of the 1974-75 crosses involved at least 1.

Because more than a third of the crosses analyzed were made in India, the data were analyzed to determine if Indian rice breeders differed from breeders in the six other nations in the adoption of genetic materials.

The analysis showed that Indian plant breeders adopted the semidwarf varieties earlier and used them more extensively. In 1965-67, 41% of the Indian crosses involved TN1 (Fig. 2) while only 4-5% in the other countries did (Fig. 3). Twenty-seven percent of the Indian crosses involved IR8 while 16% of the crosses made in the other nations did.

By 1974-75, 75% of the crosses made in the Indian sample involved a locally developed semidwarf, and 21% involved an IRRI parent other than IR8 (Fig. 2). In the other six countries, the major source of semidwarf parents was IRRI (Fig. 3), but there was the same trend toward the use of locally developed semidwarfs.

Semidwarf varieties were used 111 times as parents, involving 83 separate varieties or breeding lines, in all of the 1974-75 crosses.

Genetic composition of local semidwarfs

The ancestry of the parents was traced two generations to determine the

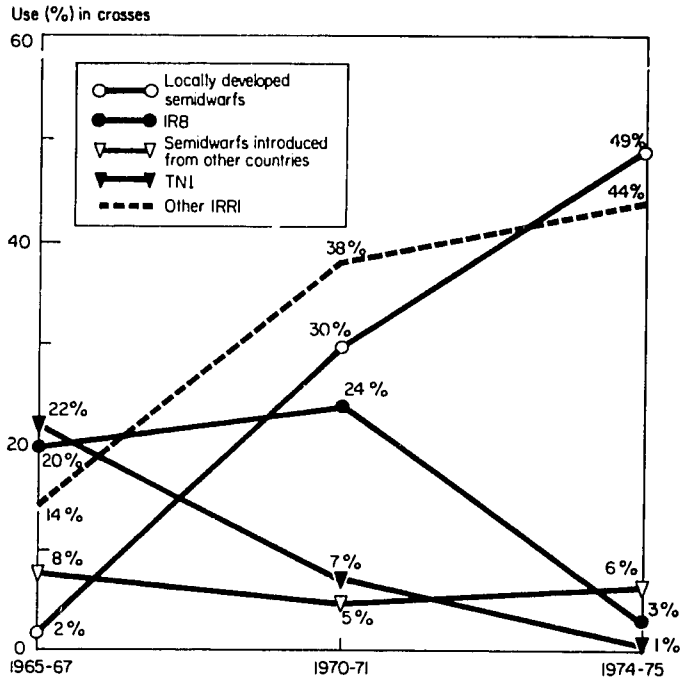

Fig. 1. Use of semidwarf parents in rice breeding programs of 7 Asian nations from 1967 to 1975; 819 parents used in 355 randomly selected crosses at 14 agricultural experiment stations and universities.

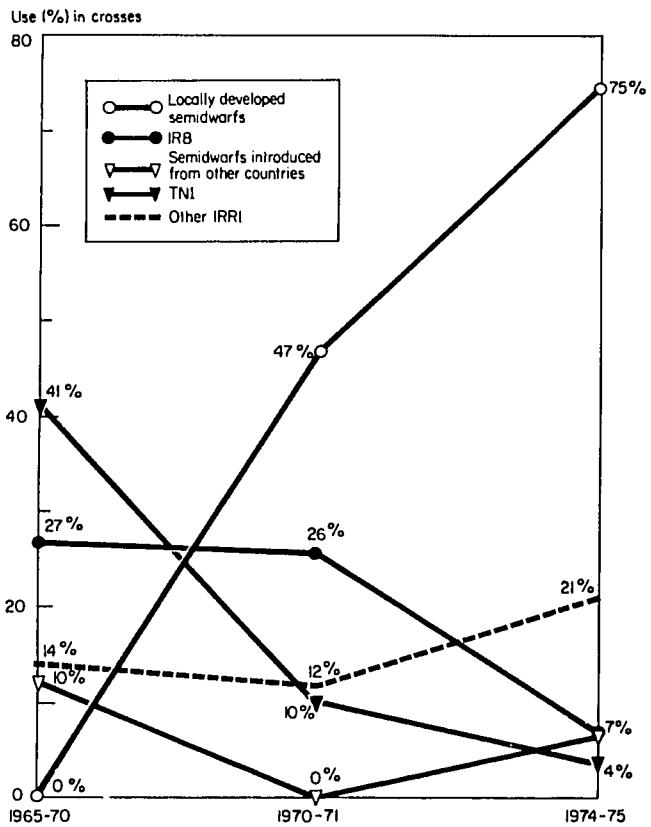

Fig. 2. Use of semidwarf parents in Indian rice breeding programs over a 10-year period. Three hundred parents used in 140 randomly selected crosses at 7 agricultural experiment stations and universities, India, 1965-75.

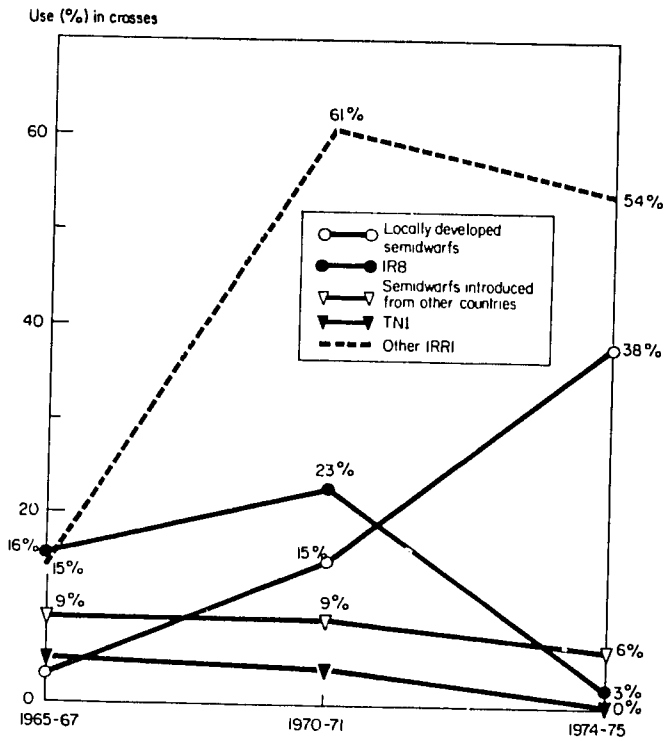

Fig. 3. Use of semidwarf parents in rice breeding programs of 6 Asian nations (excluding India) from 1965 to 1975; 519 parents used in 215 randomly selected crosses at 7 agricultural experiment stations and universities in 6 Asian nations, 1965-75.

source of the dwarfing genes in the locally developed semidwarf parents. Seventy-six percent of the local semidwarfs had IR8 or other IRRI materials as parents (Fig. 4a). For example, the variety K35, used as a parent in India, is from the cross IR8/HR19; and RD1 in Thailand is from Lenang Tawng/IR8. Twenty-four percent of the local semidwarfs, such as the Indian varieties Sona (TN1/GEB24) and Jaya (TN1/T141), were progeny of TN1. Twenty-five percent of the rices had at least two different semidwarf parents; for example Tong-il, often used in Korean crosses, is from the cross IR8//Yukara/TN1.

About 25% of the local semidwarf parents were themselves progeny of local semidwarfs developed earlier. Of those second-generation ancestor semidwarfs, 80% were progeny of TN1 (Fig. 4b); 33% had both TN1 and IR8 in their ancestry. For example, Pusa 33, used in three crosses, is a progeny of a cross of Ratna (TKM6/IR8) with Improved Sabarmati (TN1*3/Basmati 370).

Because TN1, IR8, and most other semidwarfs have the Chinese rice Dee-geo-woo-gen (DGWG) as a common ancestor, more than 80% of the 1974-75 crosses made by 14 centers had the DGWG gene. Thus, although the original stiff-strawed varieties such as TN1 and IR8 were virtually phased out of breeding programs as direct parents by the mid-1970's, almost all the semidwarf parents that replaced them were their progeny.

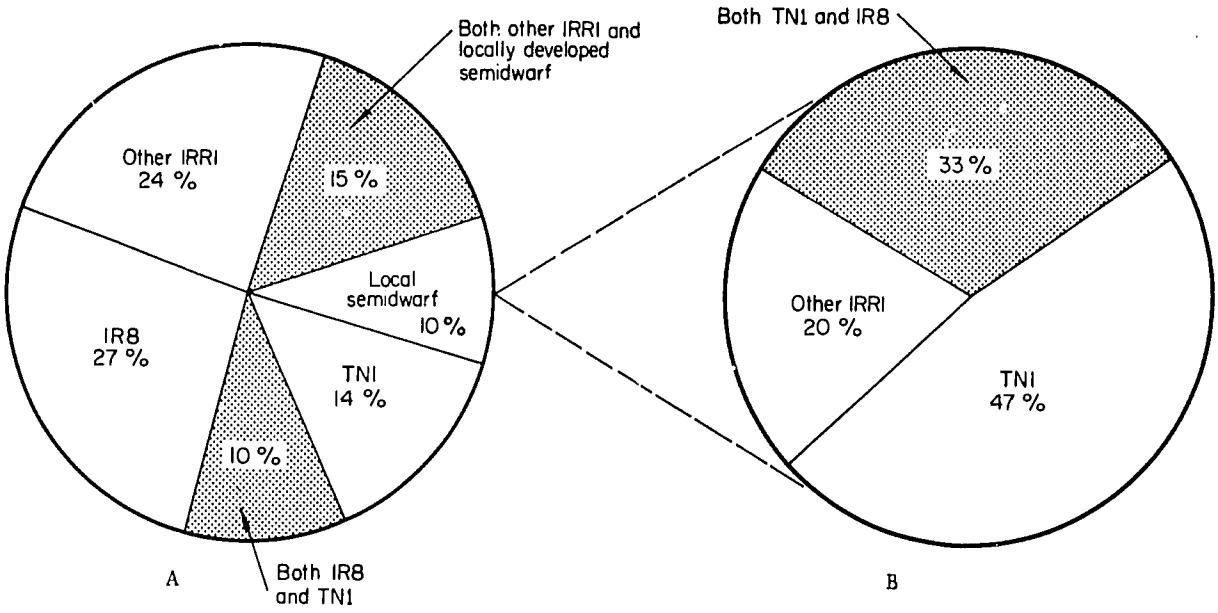

Fig. 4a) Sources of the dwarfing gene in 59 locally developed semidwarf rices used as parents in 1974-75 crosses; b) Sources of the dwarfing gene in the ancestors of local semidwarfs that were used as parents in 1974-75 crosses. The data are from 14 agricultural experiment stations and universities in 7 Asian nations, 1974-75.

Origin, races, and development of parent material

During 1965-67, 42% of all parents used in randomly selected crosses were either local or locally developed. That figure increased to 64% in 1974-75. Concurrently, use of parents from IRRI increased from 17 to 27% and use of parents from other countries decreased from 41 to 9% (largely because of the decrease in use of TN1).

Analysis of the races of the parent material indicated that the semidwarf indica varieties such as IR8 and TN1 largely pushed japonica, ponlai, and other races out of the breeding programs. Indicas made up 79% of the parents used in 1965-67 crosses, and 91% of those used in 1974-75; japonicas declined in use from 11% to 4%. Although ponlais made up 6% of the 1965-67 material, they were almost absent in 1974-75 material (Table 3).

Sixty-four percent of the total parents used in 1965-67 were of hybrid origin. Within 5 years, and through the mid-1970's, 75% of the parents were hybrids (Fig. 5). Interestingly, the use of *unimproved* varieties as parents dropped slightly by 1970-71, but increased to 8% by 1974-75 as programs became increasingly problem oriented and sought original sources of specific genetic traits.

Table 3. 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%.

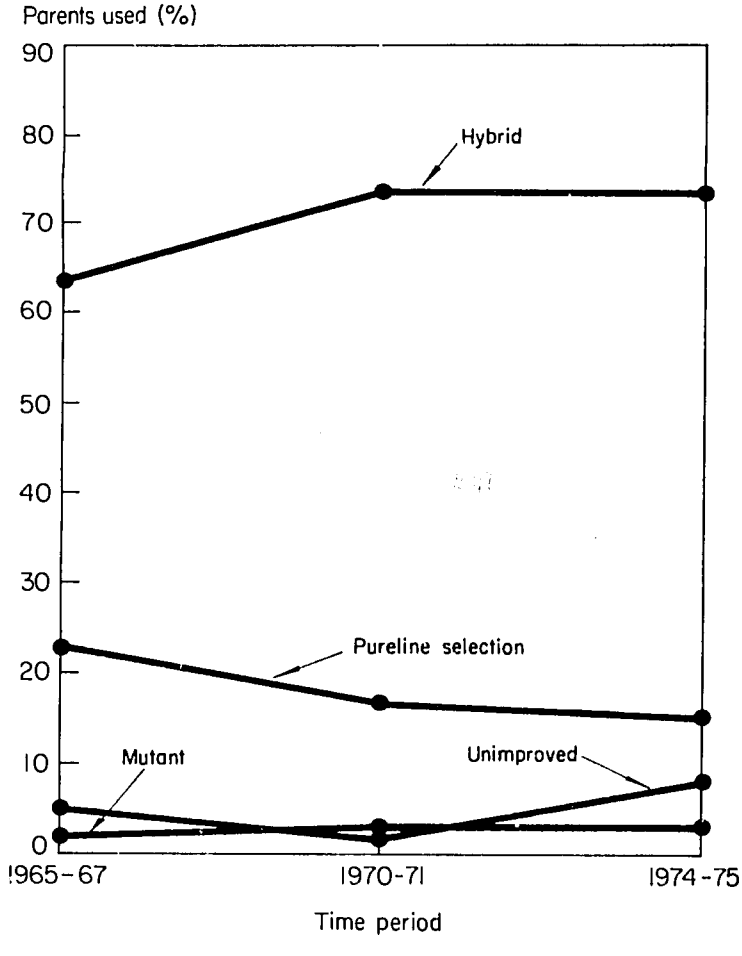

Fig. 5. Method of development of parents used in crosses in national rice breeding programs over a 10-year period; 819 parents used in 355 randomly selected crosses at 14 agricultural experiment stations and universities in 7 Asian nations, 1965-75.

OBJECTIVES OF RICE BREEDERS

The genetic traits for which the breeders said they used each parent in each of the randomly sampled crosses made in 1974-75 were listed to determine the overall breeding objectives. The types of rices used as sources for various characteristics were also listed.

The data were analyzed for 161 crosses, involving 343 parents, at 27 research centers in 10 nations (Table 4).

Increased yield potential was the objective most frequently cited (86% of the crosses), followed by high fertilizer response (85%) and resistance to lodging (79%) (Fig. 6). Improved grain quality was cited for 73% of the crosses, but specific grain-quality objectives varied considerably, indicating a variety of consumer preferences.

Most crosses were aimed at achieving early growth duration but a few were for long duration. The latter crosses were for single-cropped regions with a long monsoon season, where farmers want varieties that mature after the rains have ended.

To determine the types of rices used as parents to convey specific traits, each rice used for each objective in the 1974-75 crosses was classified by plant type. Semidwarf rices were almost invariably used as parents for the yield-fertilizer response-nonlodging complex (Table 5). Sixty-five percent of the times that a breeder used a tall variety in a cross, he hoped to transfer a preferred type of grain from the tall donor into a progeny. Grain quality was a breeding objective 40% of the time that a semidwarf parent was used.

The tall and semidwarf varieties were used about equally as genetic donors of preferred growth duration. Long growth duration was an objective 80% of the times a deepwater or floating parent was used, and photoperiod sensitivity, 90%. That was because farmers in deepwater areas need varieties that mature after the water recedes at the end of the monsoon season.

Table 4. Agricultural experiment stations and universities where breeding records were analyzed, 1975.

Country	Stations surveyed (no.)
Bangladesh	1
India	11
Indonesia	1
Iran	2
Korea	3
Nepal	1
Pakistan	2
Philippines	1
Sri Lanka	3
Thailand	2
Total	27

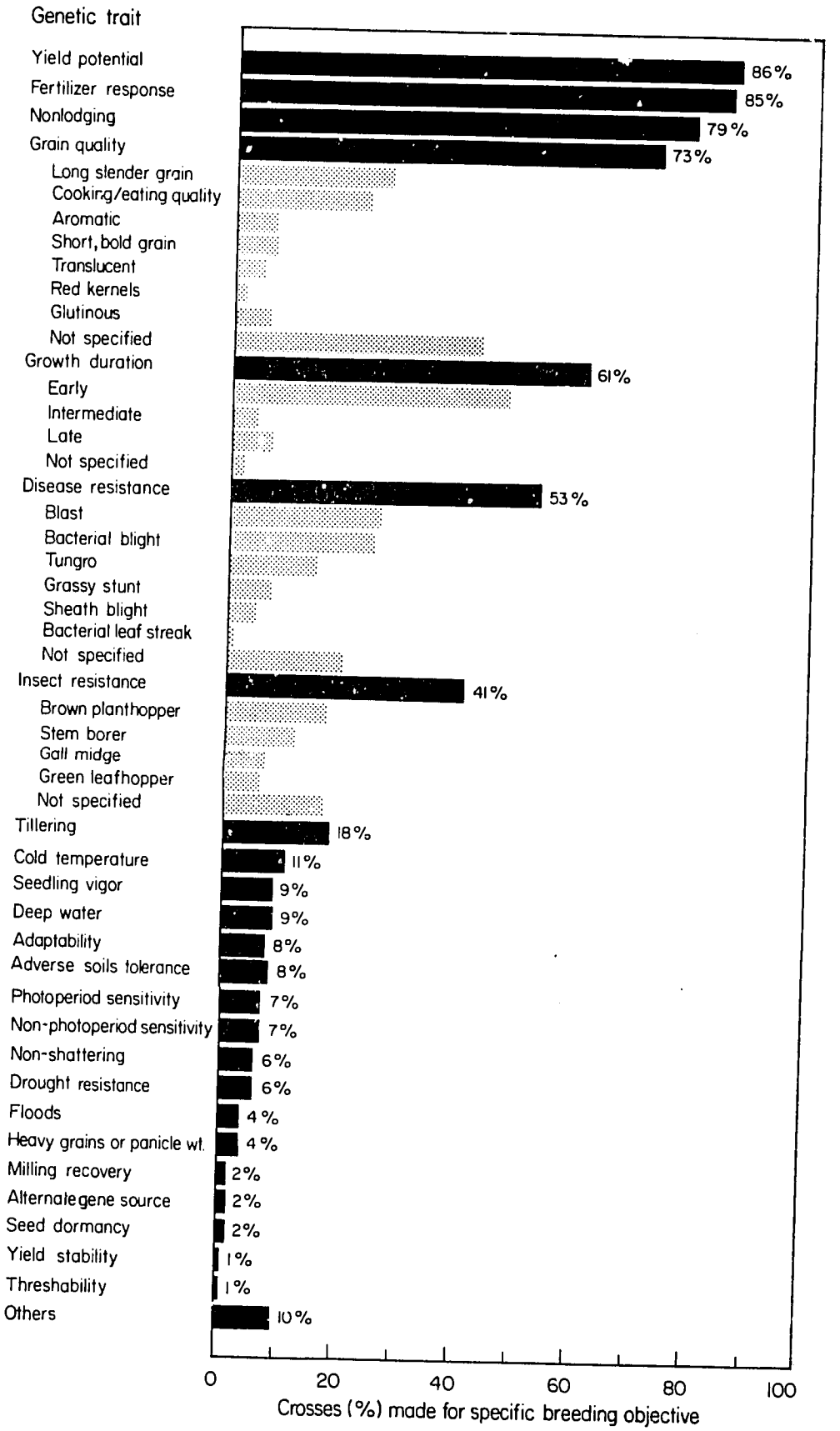

Fig. 6. The objectives for which rice breeders made 161 randomly selected crosses in 1974-75. Twenty-seven agricultural experiment stations and universities in 10 Asian nations, 1975.

Table 5. The frequency with which rice breeders sought desired genetic traits from 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.

Breeding objective	Use (%)[a] as parents			
	Semidwarf	Intermediate	Tall	Floating or deepwater
Lodging	85	40	4	10
Fertilizer response	84	40	5	10
Yield potential	80	51	5	10
Disease resistance	36	64	25	20
Insect resistance	30	15	19	-
Grain quality	40	60	65	20
Growth duration	34	36	31	80
Tillering	10	17	4	-
Seedling vigor	4	17	4	-
Photoperiod sensitivity/ insensitivity	4	2	5	90
Adverse soils tolerance	3	19	9	-
Adaptability	2	13	2	-
Heavy grains or panicle weight	2	4	-	-
Drought resistance	2	4	5	-
Cold tolerance	1	17	11	-
Non-shattering	-	-	5	-
Threshability	-	-	-	-
Alternate gene source	-	2	1	-
Protein content	-	-	-	-
Milling recovery	-	2	1	-
Yield stability	-	-	-	-
Deepwater tolerance	-	4	5	100
Seed dormancy	-	-	1	-
Others	3	11	8	-

[a] Percentage of total times each type of rice was used as a genetic source for each desired trait.

To determine if Asian breeders differed in their reasons for using semidwarfs that were local, from IRRI, or from other countries, the use of semidwarfs for some major traits was analyzed. About half of the 201 semidwarfs used as parents in the total 1974-75 parental pool were from IRRI and 45% were locally developed (Fig. 7a); about 60% of all semidwarfs used for preferred grain quality and for a specific growth duration (usually early) were developed locally (Fig. 7b, c).

On the other hand, 60% of the semidwarfs used as sources of disease resistance and almost 70% of the insect-resistance donors, were introduced from IRRI (Fig. 7d, e). Thus, IRRI material often does not meet local farmer and consumer needs for grain quality and growth duration, but pest resistance is a strong reason for its use.

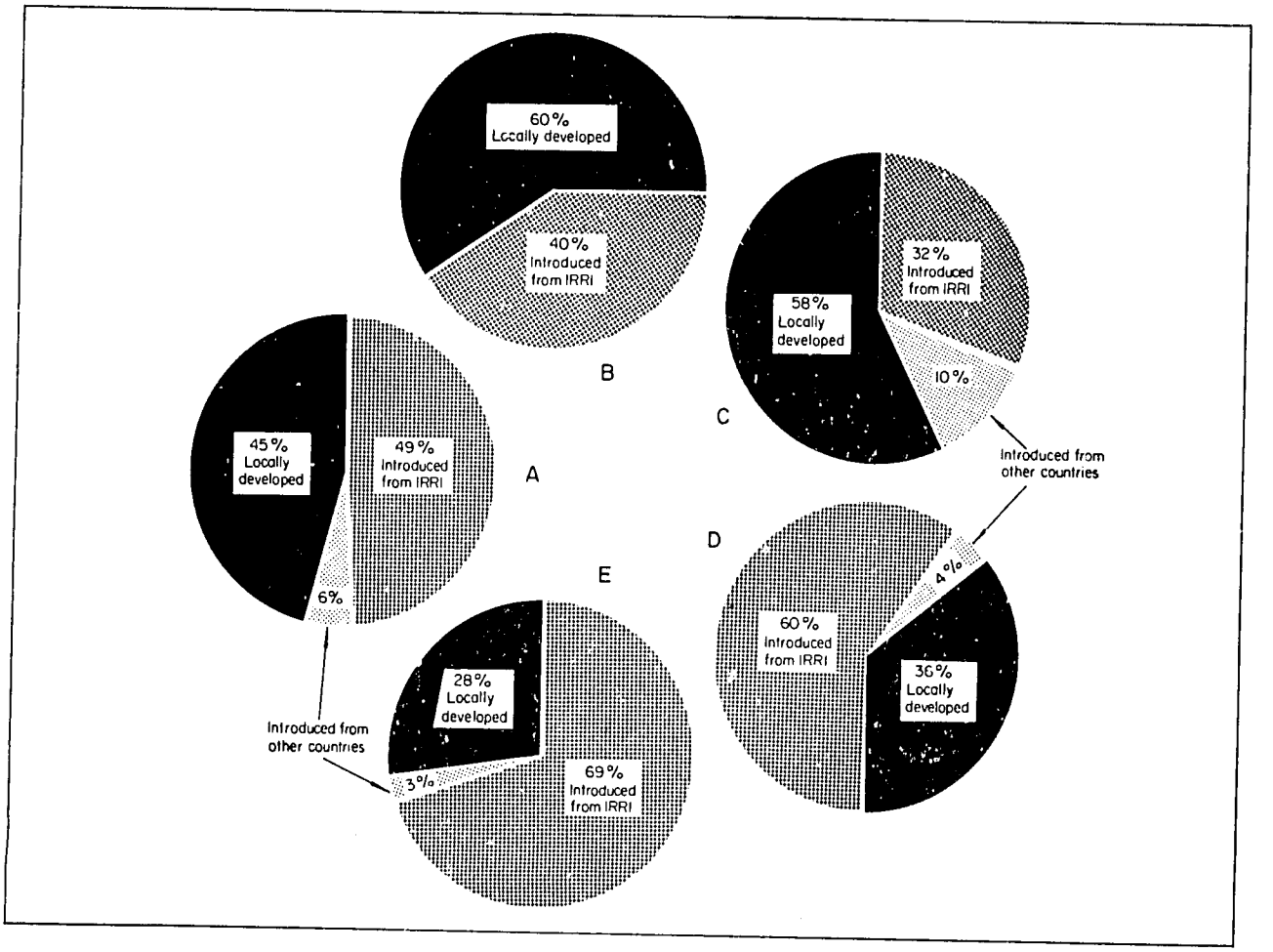

Fig. 7. Sources of semidwarf parents used for different breeding objectives. a) Origin of 201 semidwarf parents. b) Origin of 80 semidwarf parents used for grain quality. c) Origin of 69 semidwarf parents used for growth duration. d) Origin of 73 semidwarf parents used for disease resistance. e) Origin of 61 semidwarf parents used for insect resistance.

Time lag to adoption

For 78 of the rices used in the 1974-75 crosses, the breeders could recall both the year in which the variety or line was developed (to the fixed-line or F_5 or F_6 stage) or the year in which they first heard of a particular rice and the year of its adoption as a parent.

The average lag from the time a variety or line was developed until its adoption was 3.2 years; that from first awareness of the variety or line until adoption averaged 1.3 years.

Sources of introduced material

The breeders were asked how they acquired the parents that they used in the 1974-75 crosses. Half of the parents were already available in the

local germplasm collections. But 79 parents were introduced from outside of the experiment stations. The breeders obtained 61% of the introduced material from test nurseries or trials; they requested 19% from IRRI, and 8% from other sources.

NEWEST VARIETIES

The flow of desirable genes into new rice varieties was traced. Breeders were asked to give the names of the newest varieties released at the 27 stations. A standard *genetic data sheet* was completed for each rice named and each hybrid's ancestry was traced. If a parent of a variety of hybrid origin were itself a hybrid, its ancestors were identified and the incorporation of genes into the varieties was traced several generations. The breeders were also asked to give their perceptions of each variety's genetic strengths and weaknesses.

Types and genetic composition

Thirty-six new varieties were mentioned (Table 6). Of those, 69% were semidwarfs, 25% intermediate-statured, and 6% tall. Ninety-one percent were indicas; 86% were developed locally, and 14% were from IRRI (Table 7). Most of the new varieties were hybrids but three were mutants: CNM25, developed in West Bengal, India, was a mutant of IR8; K84, from Kashmir, was a mutant of T65. One variety from the Indian Punjab, HM95, was classified as both a hybrid and a mutant; it was selected from irradiated progeny of the cross Jhona 349/TN1.

Five of the varieties had locally developed semidwarf parents (Table 6): Sabari was developed from a cross of IR8 with Annapoorna, which was from the cross Ptb10/TN1; one parent of CO39 is Kannagi, which is the varietal name in Tamil Nadu state, India, for Pusa 2-21 (IR8/TKM6); Glutinous Tong-il from Korea is from a cross of Tong-il (IR8//Yukara/TN1) and IR1317; Gati from Indonesia is from Short Sigadis/Basmati (Short Sigadis is from Sigadis/TN1); RD9, from Thailand, is from Luang Yai 34/TN1//W1256///RD2 (RD2 is from TN1/Gam Pai 15).

Seventeen of 24 new semidwarf varieties had IR8 in their ancestry and 10 had TN1. IR8 was a direct parent of 13 of the rices and an ancestor of 6. TN1 was a direct parent of two of the newest varieties and an ancestor of eight.

Genetic strengths and weaknesses

The breeders were asked to name the genetic strengths and weaknesses -- traits that farmers consider desirable and undesirable -- of each of the newest varieties. For almost all 36 new varieties, yield potential, fertilizer response, and lodging resistance were cited as genetic strengths or favored characteristics (Fig. 8).

Table 6. The 36 newest rice varieties released as listed in 1975 by breeders at 27 agricultural experiment stations in 10 Asian nations.

Variety	Stations 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
IET 1039	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[c]	Uttar Pradesh (India)	IR8///CP231/SLO-17//Sigadis
IR24[c]	Nepal	IR8///CP231/SLO-17//Sigadis
BP1-Ri-2	Maligaya (Philippines)	BE3-37-5/IR20
IR841	Sind (Pakistan)	IR262-43-8-11/Khao Dawk Mali
Mehren 69	Kala Shah Kaku (Pakistan)	IR6 (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
Milyang 23	ORD (Korea)	IR1317-316-5-2/IR24
Gati (B-9c)	CRIA (Indonesia)	Short Sigadis[f]/Basmati
	Intermediate-statured	
K78-13	Kashmir (India)	Shi-ei/China 971
K84	Kashmir (India)	Mutant of T65
Karjat 14-7	Maharashtra (India)	IR8/Ziniya 149
BG11-11	Batalagoda (Sri Lanka)	H-7/H8
LD125	Bombuwela (Sri Lanka)	IR262/H7
BR4	BRRI (Bangladesh)	IR20/IR5
RD7	Bangken (Thailand)	C4-63G/GR88//Sigadis
RD9	Bangken (Thailand	LY34/TN1//W1256//RD2[g]
Pelita I/2	CRIA (Indonesia)	IR5/Syntha
	Tall-statured	
RD5	Bangken (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.

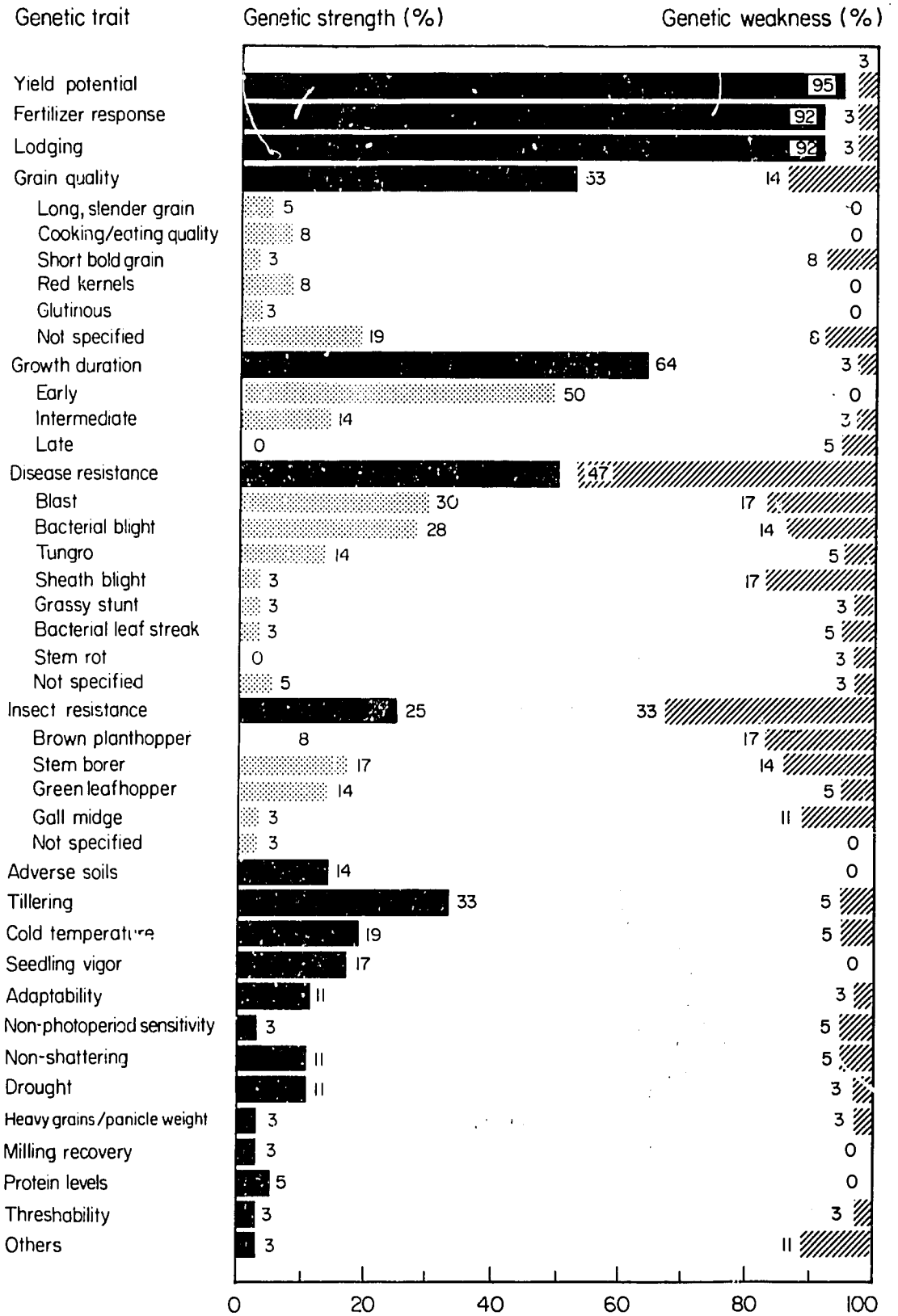

Fig. 8. The genetic strengths and weaknesses of 36 newest rice varieties released at 27 agricultural experiment stations and universities in 10 Asian nations, 1975.

Table 7. Characteristics of 36 newest varieties released by 27 agricultural experiment stations and universities in 10 Asian nations, 1975.

Characteristic	Varieties (%)			
	Tall	Intermediate	Semidwarf	All
Plant type				
Indica	100	78	96	91
Japonica	0	11	0	3
Indica-japonica	0	0	4	3
Ponlai	0	11	0	3
Origin				
Locally developed	100	100	80	86
Introduced from IRRI	0	0	20	14
Method of development[a]				
Hybrid	50	89	96	91
Mutant	0	11	4	8
Pureline selection	50	0	0	3

[a] HM95 was classified as both a hybrid and a mutant; it was selected from irradiated progeny of the cross Jhona 349/TN1.

A definite growth duration was a favored trait of 64% of the varieties, earliness accounted for 50%. Grain quality was cited as a genetic strength of 53% of the new varieties, and as a weakness of 14%. Individual grain-quality traits varied widely, indicating the diversity of consumer preferences. Red kernels were a favored trait (8%) in southern India, Kashmir, and Sri Lanka.

The breeders cited resistance to at least one disease as a favored trait of 50% of the new rices, and disease susceptibility as a weakness of 47%.

MOST WIDELY GROWN VARIETIES

The diffusion of desirable genes onto rice farmers' fields was traced by analyzing the genetic composition of the most popular varieties in each region. Breeders named the three main varieties grown by farmers within the areas served by their experiment stations. At stations where more than one breeder was interviewed, each breeder named the three most popular varieties within a major subregion served by the station. For each rice named, genetic data were compiled.

Types and genetic composition

The breeders cited 95 rices, comprising 73 different varieties, as being among the most widely grown in 31 regions. Forty-five percent of the rices cited were semidwarf and 35% were tall.

Only 10 of the rices were cited in 2 or more regions: of them 8 were semidwarfs. Jaya was cited as widely grown in 8 of the 15 regions surveyed in India. The second most cited variety was IR8, but IR8 was a parent or ancestor of four of the remaining six semidwarfs. TN1 was in the ancestry of three of the rices (Table 8).

Ninety-two percent of all varieties cited as most widely grown in the regions were indicas (Table 9). About 60% were locally developed, about 30% were introduced from IRRI, and 10% were introduced from another country. More than 60% were hybrids. Tall varieties showed a high degree of location specificity -- none was widely grown in more than one region.

Genetic strengths and weaknesses

The reasons given by the breeders for the popularity of each of the 95 widely grown varieties among farmers were compiled and analyzed as genetic strengths. The unfavorable traits were compiled as genetic weaknesses.

Yield potential was cited as a genetic strength, or as a major reason for the popularity of 60% of the most widely grown rices (Fig. 9). It was

Table 8. The 10 rice varieties that were cited as among the three most widely grown by farmers in two or more regions. From 95 widely grown varieties cited by 31 rice breeders at 27 agricultural experiment stations and universities in 10 Asian nations, 1975.

Variety	Locations	Genetic makeup	Origin
		Semidwarf varieties	
Jaya	India, 8 regions	TN1/T141	Local
IR8	India, (4 regions); Nepal, Bangladesh, Pakistan (1 region)	Peta/Dee-geo-woo-gen	IRRI
IR20	India, 2 regions; Bangladesh	Peta*3/TN1//TKM6	IRRI
Ratna	India, 2 regions	TKM6/IR8	Local
Tong-il	Korea, 2 regions	IR8//Yukara/TN1	Local
Mehren 69	Pakistan, 2 regions	IR6 (Siam 29/Dee-geo-woo-gen)	IRRI
BG34-8	Sri Lanka, 2 regions	IR8*//PP/Mas///H501	Local
IR26	Philippines, Indonesia	IR24/TKM6	IRRI
		Intermediate-statured varieties	
Pankaj	India, 2 regions	IR5 sel. (Peta/T. Rotan)	IRRI
Mahsuri	India, 2 regions	Taichung 65/Mayang Ebos 80//Mayang Ebos 80	International Rice Commission

Table 9. Characteristics of 95 rices cited at 27 agricultural experiment stations and universities in 10 countries, 1975, as among the 3 most widely grown varieties by farmers.

Characteristic	Varieties (%) widely grown				
	Tall	Intermediate	Semidwarf	Floating	All
Plant type					
Indica	97	69	95	100	92
Japonica	-	19	-	-	3
Indica-japonica	-	12	5	-	4
Indica-javanica	3	-	-	-	1
Origin					
Locally developed	97	13	44	100	59
Introduced from IRRI	-	37	54	-	31
Introduced from other country	3	50	2	-	10
Method of development[a/]					
Unimproved	36	-	-	67	15
Pureline selection	49	-	2	33	19
Mutant	-	-	2	-	1
Hybrid	15	81	96	-	62

[a/] The method of development of three introduced varieties of intermediate stature (China 972, China 988, and China 1039) could not be determined, so the total percent of all varieties does not equal 100.

cited as a a genetic weakness of 11% -- low yields were a major fault, but farmers grew the varieties for other reasons. Susceptibility to lodging was cited as a weakness of 34% of the rices. Grain quality was considered a major reason for the popularity of 53% of the widely grown varieties; inferior grain quality was a genetic weakness of 24%.

Fifty-two percent of the popular rices had desirable growth duration. Earliness was the preferred trait of 32% of those with desirable growth duration; medium and late maturity was a genetic strength of 20%. Resistance to at least one disease was listed as a positive trait of only 23% of the farmers' preferred varieties; susceptibility to disease was cited as a weakness of 53%. Only 17% were insect resistant.

Genetic traits and plant height

To determine if specific genetic traits were more likely to be found among tall, intermediate, or semidwarf rices, the genetic strengths were analyzed on the basis of plant height. Only 24% of the tall varieties were cited for high yield potential, 12% for fertilizer response, and none for lodging

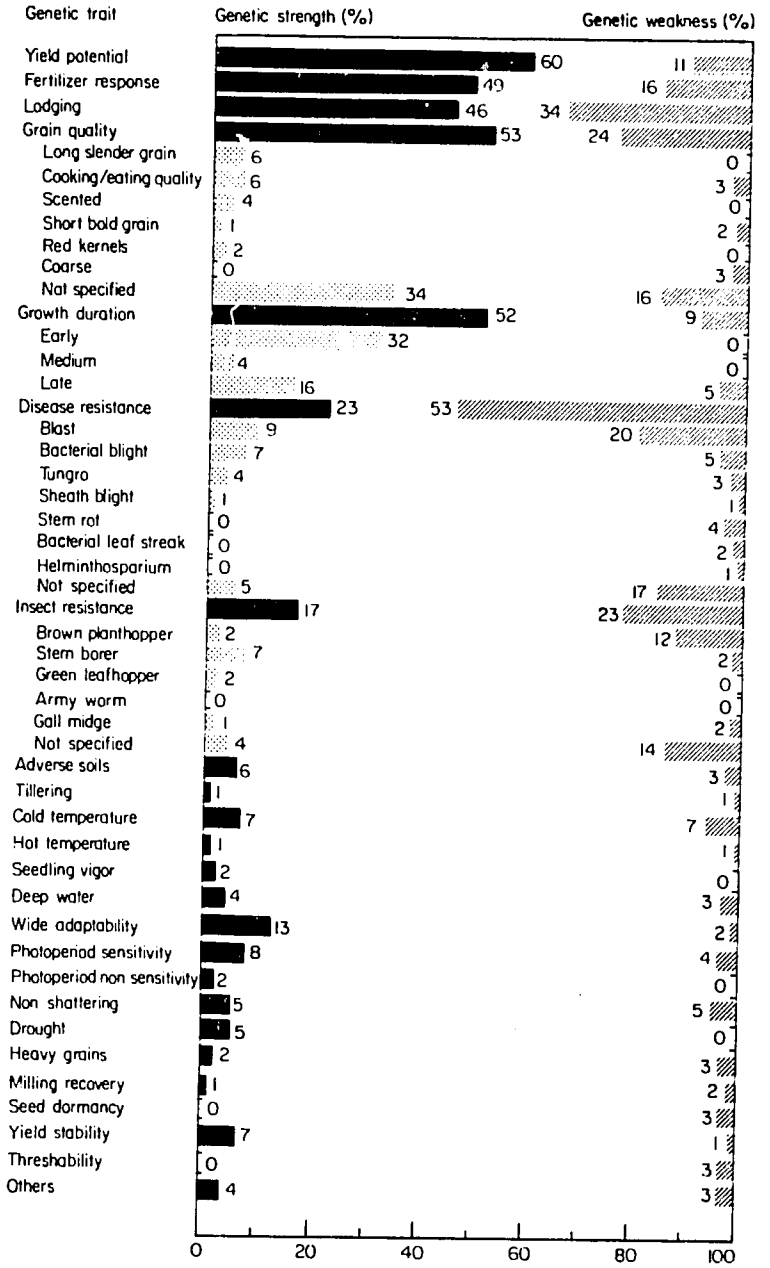

Fig. 9. The genetic strengths and weaknesses of the 96 rices cited as the most widely grown in 31 regions of 10 Asian nations in 1975.

resistance (Table 10). About 75% of the semidwarfs were cited for good yield potential and 72% for fertilizer response and lodging.

The tall varieties generally had good (locally preferred) grain quality. Of the 60% of the tall varieties with favorable growth characteristics, 33% were cited for earliness and 27% for lateness. But most semidwarfs cited for favored growth duration were early maturing.

Pest resistance, seldom cited as a strength of the tall varieties, was more often cited as a strength of the semidwarfs.

Table 10. Genetic strengths of 95 tall, intermediate-statured, semidwarf, and floating rices named as most widely grown on farmers' fields in 31 regions as cited by 31 rice breeders at 27 agricultural experiment stations in 10 Asian nations, 1975.

Genetic strength	Varieties (%) cited for genetic strength			
	Tall	Intermediate	Semidwarf	Floating
Yield potential	24	75	74	0
Fertilizer response	12	44	72	0
Lodging	0	56	72	0
Grain quality	79	56	28	33
Long, slender	15	12	4	0
Cooking/eating quality	6	12	2	0
Scented	12	0	0	0
Red kernel	3	0	0	0
Short, bald	3	0	0	0
Glutinous	3	0	0	0
Not specified	37	32	22	33
Growth duration	60	44	38	100
Early	33	19	30	0
Intermediate	0	6	6	0
Late	27	19	0	100
Not specified	0	0	2	0
Disease resistance	18	36	36	0
Blast disease	6	6	15	0
Bacterial blight	3	12	6	0
Grassy stunt virus	0	0	2	0
Tungro disease	0	0	6	0
Sheath blight	0	6	0	0
Not specified	9	12	8	0
Insect resistance	9	6	24	0
Brown planthopper	0	0	4	0
Green leafhopper	0	0	4	0
Stem borer	0	0	8	0
Not specified	9	0	8	0
Adverse soils tolerance	3	12	4	0
Adaptability	12	37	6	0
Cold tolerance	12	19	0	0
Nonshattering	9	12	4	0
Insensitivity to photoperiod	15	6	2	100
Deep water	0	6	0	100
Yield stability	3	0	12	0
Seedling vigor	6	0	0	0
Drought resistance	0	12	6	0
Tillering	0	0	2	0
Milling recovery	3	0	0	0
Heavy grains or panicles	0	0	0	66
Others	3	6	6	0

COMPARISON OF BREEDERS' PERCEPTIONS OF PROBLEMS AND THEIR BREEDING OBJECTIVES

The breeders' perceptions of the extent and severity of environmental and pest problems that farmers face in their fields were measured (Hargrove 1978) and compared with their breeding objectives.

Every breeder rated diseases and insects as one of four major environmental problems (Table 11). In making 62% of the crosses, the same breeders hoped to incorporate genetic resistance to at least one disease or insect into future varieties. Drought was considered a major problem but only 6% of the randomly selected crosses attempted to incorporate drought resistance. Only 8% of the crosses were made for tolerance for injurious soils, a problem in 60% of the areas.

The breeders' perceptions of the major diseases and insects within the areas served by the experiment stations were compared with their breeding objectives (Table 12). The most widespread field pest was the stem borer -- one of the four major pests in farmers' fields in 57% of the areas. But

Table 11. Rice breeders' perceptions of the biological or environmental factors that most limit rice production on farmers' fields within the areas served by their experiment stations and the percentages of crosses for resistance to each problem area (breeding objectives), 35 breeders at 27 agricultural experiment stations and universities in 10 Asian nations, 1975.

Biological or environmental factor	Area (%) where factor was a major constraint[a]	Crosses (%) made for resistance[b]
Diseases and insects	100	62[c]
Drought	85	6
Injurious soils	60	8
Excessive monsoon cloudiness	48	0
Floods	36	4
Cold temperature	30	11
Deep water	12	9
Hot temperature	9	0
Waterlogged soils	3	2
Other	6	0

[a] Percent of 35 rice breeders that rated each stress as one of the four most serious problems limiting production on farmers' fields in the regions served by each experiment station.

[b] Determined by analyzing genetic traits that breeders at 27 experiment stations sought to incorporate into future varieties through 161 randomly selected crosse made in 1974-75 (see Fig. 6).

[c] Refers to the 30% of crosses in which at least one parent was used to transfer resistance to at least one disease or insect into progeny, plus the 32% that involved both disease and insect resistance.

Table 12. Rice breeders' perceptions of the major disease and insects that limit rice production on farmers' fields and the percentages of crosses made for resistance to each pest; 35 breeders at 27 agricultural experiment stations and universities in 10 Asian nations, 1975.

Pest	Areas (%) where factor was a major constraint[a]	Crosses (%) made for resistance[b]
Stem borer	57	12
Bacterial blight	54	25
Brown planthopper	45	17
Blast disease	42	26
Gall midge	39	7
Tungro	24	15
Sheath blight	18	5
Helminthosporium	0	0
Striped virus[c]	9	0
Grassy stunt virus	6	7
Sheath rot	6	0
Green leafhopper	-	6
Other insects	35	0
Other diseases	21	-

[a] Percent of 35 rice breeders that rated each pest as one of four most serious pest problems limiting production on farmers' fields in the regions served by each experiment station.

[b] Determined by analyzing genetic traits that breeders sought to incorporate into future varieties through 161 crosses at 27 experiment stations (see Fig. 6).

[c] In Korea only.

only 12% of the crosses were made for stem borer resistance -- which emphasizes the fact that no germplasm that is truly resistant to stem borer is available to breeders.

The brown planthopper was cited as a problem in 45% of the regions; 17% of the crosses involved hopper resistance. The brown planthopper is the vector of grassy stunt virus disease, a major problem in only 6% of the regions. Resistance to grassy stunt was an objective of 7% of the crosses. That might indicate that grassy stunt could become a more serious problem in the future.

IMPLICATIONS

Although farmers in the irrigated regions of Asia rapidly adopted the first semidwarf rice varieties, TN1 and IR8, in the late 1960's, Asian plant breeders adopted them as parent materials in their breeding programs even earlier. IR8 was released in 1967, but in about 20% of the crosses

made around that time, it was already being used -- often identified by its experimental line number.

Although almost none of the semidwarfs used in 1965-67 crosses were locally developed, 38% of the crosses involved a local semidwarf within 5 years. Interestingly, it takes from 3 to 5 years to select progeny of a cross to the fixed-line (F_5 or F_6) stage. By 1974-75, about half of the crosses involved a local semidwarf -- progeny of those earlier crosses with IR8 and TN1.

The greater tendency of rice breeders in India to use locally developed semidwarf materials than that of breeders in other countries may reflect older, stronger, and more numerous breeding programs there. The same trend toward the use of local semidwarfs was found in the other countries.

The breeders tended to use local semidwarfs as donors of desired grain quality and growth duration, but they used IRRI material more often as donors of insect and disease resistance. That indicates that IRRI material often does not meet local farmer and consumer needs for grain quality and growth duration, but that a strong reason for its use is its pest resistance. That finding may also be a clue to the reason why breeders tend to use locally developed -- rather than IRRI -- semdiwarfs as parents.

The diffusion of semidwarf genetic materials into breeding programs could have had negative as well as positive effects. It certainly contributed to genetic erosion in current and future varieties; more than 80% of the 1974-75 crosses and most of the newest varieties carry the Dee-geo-woo-gen (DGWG) gene for dwarfism.

The breeders acquired most of their introduced genetic materials from tests and trials; that may indicate that the strategy of the International Rice Testing Program (IRTP) -- sending out uniform nursery sets of the best rices from both the national programs and from IRRI for simultaneous testing at many locations -- offers an opportunity to diversify the genetic base of the world's rice crop.

Although the breeders perceived environmental stresses such as drought or injurious soils as important factors limiting rice yields on farmers' fields, analysis of their crosses shows that tolerance or resistance to those stresses seldom were breeding objectives. That suggests that more emphasis should be placed on providing breeding programs with improved genetic materials suited to such stresses.

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