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CONTRIBUTIONS OF MODERN RICE VARIETIES TO NUTRITION IN ASIA

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Four Symposiums Commemorate IRRI 25th Year

IRRI hosted four symposiums from 27 May to 14 Jun to commemorate its 25th anniversary: the International Rice Genetics Symposium (IRGS), the International Rice Research Conference (IRRC), the 25th Anniversary Symposium, and the FAO International Rice Commission (IRC) meeting.

Seventy-seven papers were presented during the 14 technical sessions of the IRGS, 27-31 May. Some of the world's foremost scientists of molecular biology and genetic engineering attended the symposium.

The meeting led to the formation of a Rice Genetics Cooperative designed to foster cooperation in basic genetic research to apply genetic engineering techniques to rice improvement. At the first meeting of the coordinating committee, standing committees were established for gene symbolization, nomenclature, and linkage; genetic stocks; genetic engineering; and a rice genetics newsletter.

IRGS technical sessions included discussions of systematics and evolution; varietal diversities and reproductive barriers; karyotype, polyploids, and trisomics; linkage maps; genetics of morphological, physiological, and quantitative traits; stress tolerance; disease resistance; insect resistance; cytoplasmic male sterility and fertility restoration; mutagenesis; tissue and cell culture; and genetic engineering. IRRI will publish the proceedings.

The IRRC, 1-5 Jun, had technical sessions on collaborative research, the forward edge in rice research, impact and development of rice-based farming systems research, irrigated rice culture, the International Rice Testing Program, and grain quality and marketing. The six papers presented during the grain quality and marketing session will be published.

During the IRRC, Kiyoharu Oono of the National Institute of Agrobiological Resources, Japan, gave the first Shouichi Yoshida Memorial Lecture. The lecture, titled *Tissue culture application in rice improvement*, honored Yoshida, IRRI principal scientist and head of Plant Pathology from 1966 until his death in January 1984.

The 25th Anniversary Symposium, 5-8 Jun, was inaugurated by Philippine President Ferdinand E. Marcos. Participants of the multilevel seminar included political leaders, members of the Consultative Group on International Agricultural Research and Technical Advisory Committee, former and present IRRI trustees, former IRRI directors general, agricultural experts, and scientists.

Special lectures were given by Madame Imelda R. Marcos, Philippine First Lady, and Minister Achmad Affandi of Indonesia. Other events were the issuance of commemorative stamps by the Philippine Post Office, awards to

Philippine outstanding farmer Serapio San Felipe receives his award from IRRI Director General M. S. Swaminathan and President Ferdinand E. Marcos of the Philippines

outstanding farmers, and an exhibit of rice cultivation tools and ritual objects. (See related story on p. 3.) A multimedia presentation titled "The Power of Cooperation: 25 Years of the International Rice Research Institute" was presented by IRRI staff and scholars, and a special publication humanizing the results of 25 years of partnership in rice research was released.

The series of symposiums concluded with the IRC meeting, 10-14 Jun. It drew member participants from 37 countries and observers from 8 countries and 5 international organizations. Participants reviewed progress and problems in rice research and development, and attended briefings and field tours of the Maligaya Rice Research and Training Center and the Philippine National Food Authority. This was the first meeting of the IRC, which was founded in 1948, at IRRI.

a. Philippine First Lady Imelda R. Marcos spoke on "Ecology and Equity: Foundations for Sustainable Agricultural Development." b. Minister Buta Singh of India visited IRRI demonstration plots with G. S. Khush, IRRI plant breeder. c. Minister G. M. Braks of The Netherlands is greeted by J. R. Cowan, IRRI consultant.

Thirteen of the 14 recipients of Outstanding Farmer Awards presented during IRRI's 25th anniversary posed for this photograph at the entrance to the research center. They are, from left, Marto Sufuan, Indonesia; Mohd. Nor bin Kahlan, Malaysia; Sumardi, Indonesia; Vo Van Chung, Vietnam; Abul Kalam Azad, Bangladesh; Nekkanti Subba Rao and Sandar Jagjit Singh Hara, both from India; Serapio San Felipe, Philippines; Etsuko Tada, Japan; Sova Rani Dey, India; Yeon Do Kim, Korea; Qu Yong Shou, China; and Koichi Kimura, Japan. Wiboon Inclai, Thailand, is not pictured.

Accomplishments, Challenges: Topic of IRRI 25th Anniversary Symposium

Rice Research: Accomplishments and Challenges, IRRI's 25th anniversary symposium, was one of four symposiums held between 27 May and 14 Jun to mark 25 years of progress in rice research.

The 25th anniversary symposium was inaugurated by Philippine President Ferdinand E. Marcos at Malacañang Palace, where he presented IRRI awards to 14 outstanding farmers from 10 Asian nations. The outstanding farmers were selected from nominees submitted by national research and extension agencies and other agricultural development groups. (See related story on this page.)

During the opening ceremonies, Philippine Assistant Postmaster General Pedro P. Gambalan presented newly issued IRRI commemorative stamps to President Marcos and M. S. Swaminathan, IRRI director general.

Ministers of agriculture of 17 countries or their representatives discussed the role of science and technology in rice production and agricultural progress.

The series of lectures was opened by Minister He Kang of China, who described how China combined variety and technology improvement, land reform, and cooperative farming to triple rice yields between 1949 and 1984. Between 1979 and 1984 rice yields increased an average 225 kg/ha per year. Similarly, Minister Buta Singh of India discussed the pathways through which Indian rice production doubled during the past 20 yr and complimented IRRI on its role in that increase.

In a special 25th anniversary lecture, Minister Achmad Affandi of Indonesia talked of the "rice revolution in Indonesia." He described how Indonesia increased rice production from 10 million tonnes in 1970 to 25 million in 1984, and discussed strategies for agricultural stability and development.

Eugene F. Whelan, president of the World Food Council, spoke of "sharing, cooperating, and working together" to feed the world's people. He emphasized the global aspects of cooperation between developed and developing countries.

Madame Imelda R. Marcos, Philippine First Lady and Minister of Human Settlements, recognized IRRI achievements in a special lecture. During her visit, she also opened an international food fair and toured the experiment farm.

The papers presented during the symposium will be published by IRRI.

A special feature of the anniversary celebration was an exhibit of two Philippine rice farming traditions. Exhibited were implements used by Ifugao and Tagalog farmers in traditional rice cultivation and ritual objects related to rice. The Ifugao people constructed the rice terraces and irrigation systems of Banaue, and many still follow age-old cultivation practices. Tagalog farmers live in the rice bowl of the Philippines; today, most of them plant modern rices and utilize improved technology.

IRRI Recognizes Outstanding Rice Farmers

IRRI honored 14 outstanding rice farmers from 10 Asian countries during its 25th Anniversary Symposium.

The farmers — two of them women — received their awards, carved wooden trophies and citations, from Philippine President Ferdinand E. Marcos during ceremonies at Malacañang Palace.

The outstanding farmers were Mr. Abul Kalam Azad, Bangladesh; Mr. Qu Yong Shou, China; Mr. Sandar Jagjit Singh Hara, Mr. Nekkanti Subba Rao, and Mrs. Sova Rani Dey, all of India; Rahayu Farmers' Group of West Java (represented by Sumardi) and the Sumber Karya Tani Farmers' Group of East Java (represented by Marto Sufuan), Indonesia; Mrs. Etsuko Tada and Mr. Koichi Kimura, Japan; Mr. Yeon Do Kim, Korea; Mr. Mohd. Nor bin Kahlan, Malaysia; Mr. Serapio San Felipe, Philippines; Mr. Wiboon Inclai, Thailand; and Mr. Vo Van Chung, Vietnam.

The farmers, each of whom farms about 5 hectares, were selected by IRRI from among those nominated by national research and extension agencies, the FAO, and other agricultural development groups. The common bond linking this diverse group is their willingness to try new technologies and share their knowledge and experience with fellow farmers.

In a special discussion with IRRI scientists, the farmers described their farming practices and recommended research that would help them the most. They also held a press conference with Philippine newspaper, radio, and television reporters, and toured IRRI laboratories and experimental fields and Philippine farms.

M. S. Swaminathan, IRRI director general, said, "We live in this world as guests of green plants, which tap sunlight, and of farm families who cultivate those plants for human and animal consumption. On the occasion of its 25th anniversary, IRRI has chosen to salute the rice farmers of the world, since they are the ultimate consumers and judges of the products of scientific research."

Swaminathan emphasized that the outstanding farmers not only grow rice successfully, but share their knowledge and skill with others. "Such farm leaders have a spirit of self-reliance and social commitment. Their self-interest is secondary to that of the community," he said.

New IRRI Publications

The following new publications are available for purchase at the Communication and Publications Department, IRRI, P.O. Box 933, Manila, Philippines.

IRRI highlights 1984
International rice research: 25 years of partnership
Illustrated guide to integrated pest management in rice in tropical Asia, by W. H. Reissig, E. A. Heinrichs, J. A. Litsinger, K. Moody, L. Fiedler, T. W. Mew, and A. T. Barrion
Genetic evaluation for insect resistance in rice, by E. A. Heinrichs, F. G. Medrano, and H. R. Rapusas
Education for agriculture
A farmer's primer on growing rice, by B. S. Vergara (Pampango and Spanish editions)
Field problems of tropical rice (French, Tagalog, Waray, Pampango, and Ilokano editions)

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

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CONTRIBUTIONS OF MODERN RICE VARIETIES TO NUTRITION IN ASIA[1]

ABSTRACT

Rice is the dominant food in countries with the most undernourished people. It also provides the main source of income and employment for millions of small farmers and rural landless workers. Increased rice yields improve nutrition by increasing food availability and producer incomes. IRRI research addresses nutrition through: focusing on resource-poor farmers in nonirrigated environments, enhancing protein content through shorter-duration varieties and better fertilizer management, improving grain quality and consumer acceptance, testing rice digestibility, reducing seasonality of supply in rice-based cropping systems, and reducing postharvest losses in drying. The release of modern rice varieties and complementary investments in fertilizer and irrigation have increased food supply and led to declining real rice prices in several Asian countries. Technological change in rice has also increased the income of farm operators and landless laborers. These changes in income and prices should mean improved purchasing power for the malnourished.

[1] By J. C. Flinn and L. J. Unnevehr, agricultural economists, IRRI. The section on Nutritive Evaluation of Rice was contributed by B. O. Juliano and C. M. Perez, Cereal Chemistry Department, IRRI. Submitted to IRRI Research Paper Series Committee December 1983.

CONTRIBUTIONS OF MODERN RICE VARIETIES TO NUTRITION IN ASIA

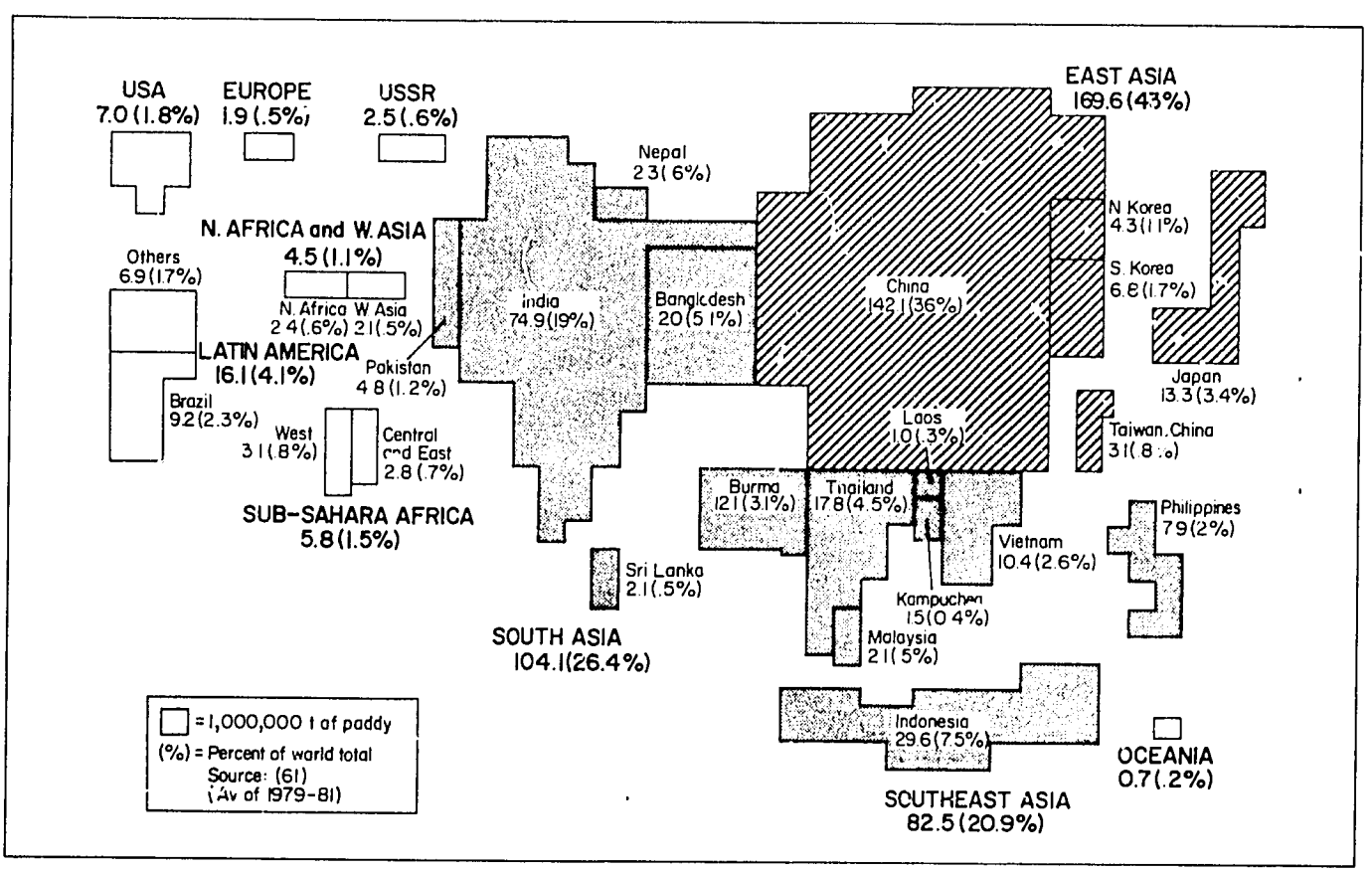
Rice is the major source of energy in human diets of tropical Asia, and in parts of Africa and Latin America. It also supplies these populations one-quarter to one-half of their daily available protein. Rice occupies one-third of the area planted to cereals in developing countries and covers about 50% more area than wheat, the second most important cereal (32). Thirty-six developing countries grow more than 100,000 ha of rice. More than one-half fall within the World Bank's lowest income group, with annual average incomes of less than $300/capita.

Rice as a crop has many dimensions. First, rice is the dominant food in countries with highest population densities and the most undernourished people. Second, in the densely populated monsoon areas of tropical Asia, rice provides the highest food staple cereal yield per hectare. Third, rice producers in the tropics are mostly small farmers who use labor-intensive production methods. Finally, rice provides the staple diet and the main source of income and employment for millions of small farmers and rural landless workers.

The International Rice Research Institute (IRRI) has global responsibility for rice and focuses on Asia where more than 90% of the world's rice is produced and consumed (Fig. 1).

IRRI research and training are conducted in partnership with other international research centers and agencies and with national rice programs. The Institute's contribution to rice production and human nutrition cannot be isolated from the achievements of national rice programs. The greatest impact of IRRI's collaborative research, on production or on rice consumers, has been in Asia (Table 1). Modern rice varieties (MVs) covered some 30 million ha in 10 major rice growing countries of South and Southeast Asia in 1980, and now provide more than 37% of all rice grown in those countries.

This paper examines the nutrition status of Asians and the role of rice in improving Asian nutrition. It summarizes nutritional implications of biotechnical research at IRRI: research that directly alters the nutritional content of rice and research that helps increase rice availability through



1. The world's rice production.

Table 1. Estimated population and rice hectarage in major rice-consuming countries, 1980.

	Population (millions)	Rice consumers (millions)	Rice hectarage ('000)		
			Total	% of world total	% MV
China (mainland)	956	600	34,400	23.9	66
India	660	416	39,794	27.9	37
Indonesia	147	118	8,917	6.2	55
Japan	116	81	2,474	1.7	98
Bangladesh	90	81	10,233	7.1	16
Pakistan	80	24	1,991	1.4	47
Vietnam	50	45	5,407	3.7	20
Philippines	49	38	3,521	2.4	70
Thailand	48	38	9,449	6.6	10
Korea (Rep)	38	36	1,232	0.9	32
Burma	35	32	4,751	3.3	40
China (Taiwan)	17	12	704	0.5	100
Sri Lanka	15	14	785	0.5	56
Nepal	15	9	1,257	0.9	26
Malaysia (Peninsular)	13	10	680	0.5	44
Korea, DPR	15	14	773	0.5	--
African countries[a]	70	35	5,229	3.5	
Latin America[b]	137	69	8,228	5.7	
Total[c]	2,572	1,688	144,164	100	

[a]With av annual consumption of 50 kg/ha per person: Egypt, Malagasy, Sierra Leone, Gambia, Guinea, Ivory Coast, Liberia, Senegal, and Mauritius. It is assumed that 50% of the people are rice eaters. [b]Brazil, Costa Rica, Panama, Cuba, Dominican Republic, Guyana, and Surinam. It is assumed 50% of the people are rice eaters. [c]Also including Kampuchea, Lao People's Republic, Hongkong, Singapore, Bhutan, Portuguese Timor, and Macao. Sources: (35, 44). See (47) and (55) for a critique of procedures, problems, and limitations inherent in estimating food availability and requirements as calculated in Table 2.

higher yields or reduced unit production costs. Finally, this paper considers the impact of modern variety adoption on rice consumption and incomes of the Asian poor.

NUTRITIONAL STATUS OF ASIAN DIETS

Nutritional status in Asia

Per capita food production has generally improved in Asia over the past 10 yr, except in Bangladesh, India, Kampuchea, and Nepal. It grew faster in Asia than in other regions of the developing world (1). FAO-calculated trends in per capita calorie and protein consumption for Asian countries follow a similar trend (Table 2). Table 2 shows that calorie deficiencies, on average, are most pronounced in Bangladesh, India, Kampuchea, Laos, Nepal, and Vietnam.

Recommended daily requirements for dietary protein are not published by FAO because of lack of agreement on the figures and their calculation (60, 65). However, dietary protein intakes of about 0.5 and 0.6 g/kg per day are probably sufficient to cover most populations except for young children or pregnant and nursing women (45). Therefore, 40-45 g/head per day of protein is probably adequate, with a safety margin, for long-term maintenance of adult Asians. On this basis, protein intake of most Asians, on average, appears adequate, or only marginally deficient compared to calorie intake. Thus, rice's primary dietary role in relief of malnutrition is as a calorie source.

Focusing on calories and protein ignores equally important dimensions of undernutrition such as deficiencies in Vitamin A, iron and folic acid, and B vitamins. Chong (10) reports widespread Asian iron-deficiency anemia in children and women, and Vitamin A deficiency, a common cause of blindness. Regional nutritional disorders include pellagra in maize- or sorghum-dependent societies, kwashiorkor in communities deficient in protein (such as those depending on cassava as their basic food), and goiter in parts of Nepal and Indonesia (11). Malnutrition may also stem from nutritional ignorance (e.g., vitamin A deficiency in the Philippines), or from crops containing nutritionally toxic compounds (e.g., lathyrism in parts of India, dietary goitrogen), or from social custom (e.g., zinc deficiency from dependence on unleavened bread in the Middle East). Since causes of malnutrition and nutritional disorders are diverse, feasible remedies will vary from place to place (56).

Income and nutrition

Average dietary figures are deceptive because they mask the extent of poverty-induced malnutrition. The extent of poverty, when basic needs are scarcely met at the minimum level required for survival, for a number of Asian countries, is listed in Table 3. Proportionally, poverty appears highest in Bangladesh and India and in Indonesia and Nepal (not shown in Table 3) but in absolute numbers in India.

As incomes rise within low-income countries, so does per capita consumption of calories and protein (Table 4). Reutlinger and Alderman (51) combined this relationship with income distribution data to estimate the proportions of developing country populations whose calorie intake fell below FAO/WHO recommendations (Table 5). They estimated that more than 600 million Asians had inadequate calorie intake in the early 1970s. If food production would increase fast enough to ensure constant prices through 1990, then the population proportion with inadequate diets would fall, but the absolute number would increase by more than 100 million. If food prices increased by as little as 1% a year, an additional 50 million Asians would have inadequate diets. Asia would continue as the region with the most malnourished people.

Rice in Asian diets

Patterns of cereal grain consumption differ throughout Asia, but rice and wheat dominate (Fig. 2). Rice is the most important food source in the major river deltas – the Ganges-Brahmaputra in Bangladesh and Eastern India, the Irrawady in Burma, the Chao Phraya in Thailand, and the Mekong in Laos, Kampuchea, and Vietnam – and in Nepal, where rice provides nearly 90% of dietary calories (Table 6). It is also the dominant food of millions in India and China. Countries in South Asia – Pakistan, India, and Nepal – produce rice and wheat, often in rotation, although Pakistan (Asia's second

Table 2. Daily per capita calorie and protein consumption, and estimated calorie requirements.[a]

Country	Calorie					Protein (g)		
	1965	1975	1980	FAO/WHO recommendation	RQ[b] (%)	1965	1975	1980
Bangladesh	1960	1763	1952	2310	85	41	39	43
Burma	2020	2220	2303	2160	107	45	57	60
China	2099	2337		2360	–	54	61	–
Japan	2547	2776		2340		74	85	–
India	2150	1791	1906	2210	86	55	45	46
Indonesia	1920	2037	2342	2160	105	42	42	48
Kampuchea	2160	1713	1998	2220	90	56	42	46
Korea, Rep. of	2280	2703	2977	2340	127	59	74	81
Malaysia	2310	2544	2662	2230	119	52	54	59
Nepal	2020	2029	1927	2200	88	51	49	46
Pakistan	2190	2207	2313	2310	100	59	59	61
Philippines	1890	2052	2318	2260	103		49	52
Sri Lanka	2080	2020	2250	2220	101	47	40	43
Thailand	2190	2332	2314	2220	104	48	48	47
Vietnam	2260	2105	1961	2160	91	52	52	47

[a]Daily per capita protein and calorie supplies were from ADB (1) and FAO/WHO recommended requirements for calories were from FAO (18).
[b]RQ is the percentage of calorie requirement met in 1980 based on FAO/WHO standards.

Table 3. Estimated proportion of Asian populations living in poverty.

Country	Mid-60s below $75 GNPC	Mid-70s below $200 NGPC[a]	Percentage of reduction in poverty	Q1[b]	Population mid-70s (millions)	Population in poverty (millions)
Bangladesh	57.9	64	−10.5	−4.2	78.16	50.02
China			–	7.2	–	–
India	66.9	46	29.9	2.05	608.19	277.47
Korea, Rep. of	17	8	57.9	8.31	34.68	2.77
Malaysia	15.5	12	20.6	−0.47	11.92	1.43
Pakistan	57.9	43	25.7	6.02	70.90	30.49
Philippines	30	33	−10.0	6.04	42.07	13.88
Sri Lanka	63	14	77.8	6.52	13.50	1.89
Thailand	44.3	32	27.8	−0.76	41.39	13.24

Sources: Dowling and Soo (14) and ADB (1) for population estimates for 1975. [a]$75 in the mid-1960s is somewhat higher than $200 adjusted for purchasing power parity in the mid-1970s. Therefore, improvements in poverty reduction are probably overstated. [b]Q1 is the annual percentage of change in real per capita income of the lowest quintile of the population.

Table 4. Per capita daily consumption of calories and proteins for households of different income levels in Indonesia, India, Philippines, and Sri Lanka.[a]

Group	All	Consumption of income group				
		Lowest	2d	3d	4th	Highest
				Calories		
Java, Indonesia, 1963-64	1,600	1,072	1,347	1,572	1,868	1,809
Maharashtra, India, 1958	2,100	1,120	1,560	1,850	2,315	2,935
Sri Lanka, 1969-70	2,264	2,064	2,272	2,474	2,540	2,641
India, rural, 1960	2,028	1,557	1,805	1,945	2,933	–
India, urban, 1960	2,028	1,094	1,214	1,421	1,324	–
Philippines, rural 1978	1,769	1,660	1,830	1,976	1,966	2,194
Philippines, urban 1978	1,872	1,576	1,711	1,909	2,015	2,228
				Total protein (g)		
Java, Indonesia	29.4	17.7	23.0	28.9	35.6	37.0
Maharashtra, India	59.7	30.7	45.0	52.8	63.3	78.7
Sri Lanka	53.8	47.4	54.0	59.7	62.2	66.0
India, rural	52.4	38.7	47.3	52.8	83.5	–
India, urban	52.4	33.6	34.3	40.0	35.9	–
Philippines, rural	50.3	46.4	51.7	54.7	59.8	93.4
Philippines, urban	58.2	45.6	52.5	63.5	72.4	

[a]Income groups for Java, Indonesia were: households with a per capita monthly expenditure of less than Rp 6000, Rp 6000-10,000, Rp 10,000-16,000, Rp 16,000-30,000, and more than Rp 30,000. For Maharashtra, India: households with a per capita monthly expenditure of Rs 0-8, Rs8-11, Rs11-13, Rs13-24, and Rs24 or more. For Sri Lanka: households with a per capita monthly expenditure of Rs 0-200, Rs200-399, Rs400-799, Rs800-999, and Rs10,000 or more. For India, rural and urban: households with a per capita monthly expenditure of Rs 0-20, Rs21-35, Rs36-480, and Rs80 or more. For the Philippines: households with a per capita monthly expenditure of ₱0-499, ₱500-999, ₱1,000-1,499, ₱1,500-1,999, and ₱2,000 or more. Source: Barker and Herdt (4) and FNRI (21).

Table 5. Projected number of people and share of population with calorie intakes below requirements in several Asian countries, and by region.

	No. of people with calorie deficits (millions)[a]					
	1973		Projected to 1990[a]			
			Constant food price		1% annual increase in food price	
Asia						
Indonesia	82	(.66)	54	(.30)	69	(.37)
Pakistan	44	(.67)	37	(.35)	43	(.40)
Philippines	28	(.70)	34	(.54)	36	(.57)
India	420	(.72)	500	(.60)	533	(.64)
Sri Lanka	8	(.62)	8	(.44)	9	(.49)
Thailand	20	(.49)	10	(.17)	12	(.20)
Malaysia	4	(.34)	2	(.14)	3	(.16)
Korea	8	(.25)		(.00)		(.01)
Subtotal	613	(.67)	643	(.49)	707	(.53)
Latin America	115	(.46)	103	(.26)	111	(.27)
Middle East	49	(.47)	47	(.30)	57	(.33)
Africa	31	(.61)	39	(.42)	43	(.46)
Total	808	(.61)	832	(.42)	913	(.46)

[a]Estimates of people with calorie deficits by Asian country differ from totals because country population for 1980 comes from World Bank (64), not Reutlinger and Alderman (51). Figures in parentheses are percentages of the total population. Source: (51); calorie requirements based on FAO/WHO estimates.

largest rice exporter) is the one Asian country where more wheat is consumed than rice. The countries of insular Asia produce little wheat, with rice forming 40-60% of energy intake. Where rice is the dominant calorie source, it is also the dominant protein source. More than one-half the protein intake in Bangladesh, Burma, Indonesia, Kampuchea, Laos, Thailand, and Vietnam is derived from rice. Because rice protein lacks some essential amino acids, a diet dependent on rice protein can lead to vitamin malnutrition. Clearly, only diversity in diet ensures nutritional balance.

Table 6. Contribution of rice to daily per capita calorie and protein consumption.

	Contribution of rice to diet[a]				Rate of growth of rice from 1963 to 1975[b] as source of:	
	Calories		Protein			
	Calories	%	g	%	Calories (%)	Protein (%)
Bangladesh	1401	75	26	64	-.91	-.91
Burma	1704	77	40	71	1.59	1.58
China	810	35	14	23	1.47	1.51
India	606	31	11	24	-1.19	-1.21
Indonesia	1179	56	23	52	2.47	2.44
Japan	907	32	16	19	-2.03	-2.06
Kampuchea	1696	91	29	64	-0.91	-0.93
Korea, S	1288	48	23	31	0.23	0.30
Lao	1576	80	37	68	0.17	0.18
Malaysia	1169	45	26	37	0.74	0.74
Nepal	1805	37	21	42	1.14	1.15
Pakistan	245	11	5	7	2.95	2.99
Philippines	854	40	15	30	0.16	0.16
Sri Lanka	861	42	16	39	-1.36	-1.36
Thailand	1527	69	27	57	-0.02	0.00
Vietnam	1415	67	29	56	-0.66	-0.65

[a]Source: (19). [b]Centered on 3-yr av.

Rice's contribution to dietary calorie and protein intake in Burma, China, Indonesia, Nepal, and Pakistan increased by more than 1%/yr from 1963 to 1975 (Table 6, right column). However, its relative importance declined in India,

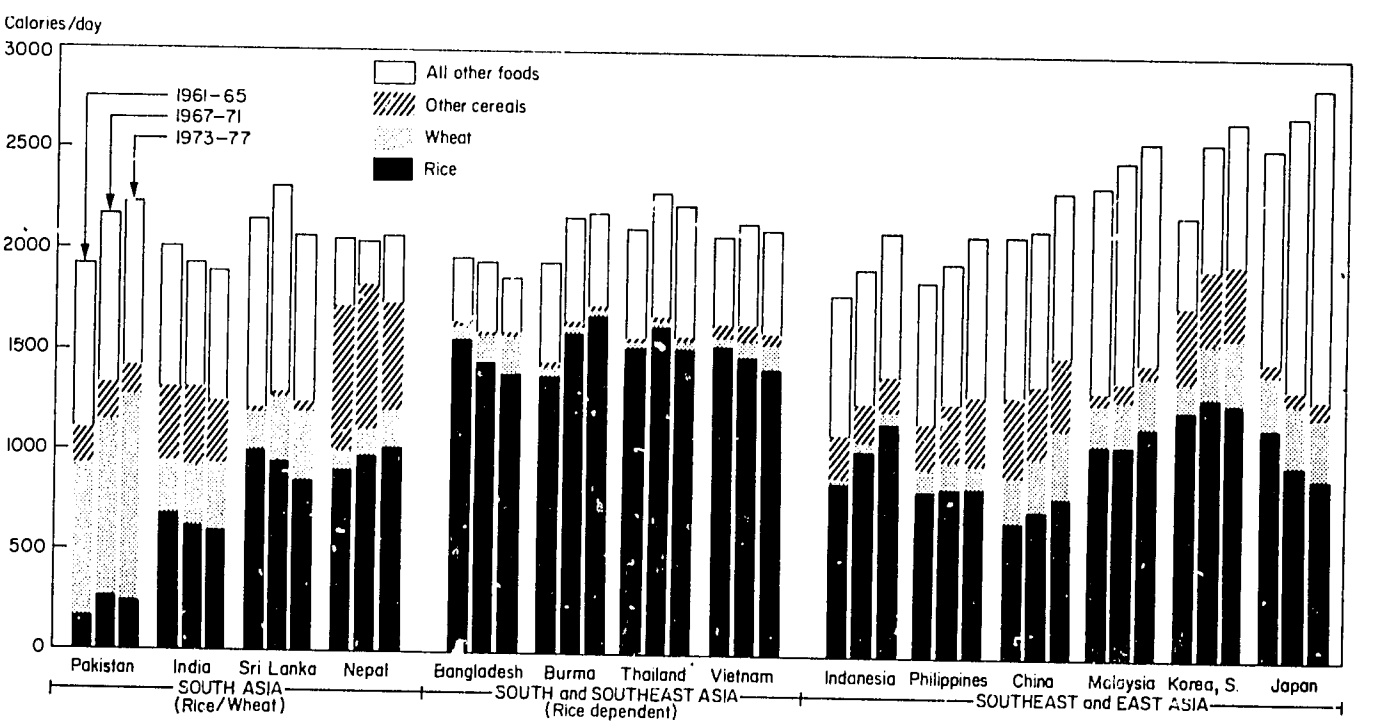


Table 7. Average yearly net imports[a] (000 t) of wheat and rice in Asia, by region (4).

	China	India	Rice/wheat South Asia[b]	South and Southeast rice dependent[c]	East and Southeast insular Asia[d]	All
			Net imports of rice			
1960-64	-639	519	180	-2,806	1,910	-836
1965-69	-1,045	467	77	-890	1,329	-62
1970-74	-2,021	98	-298	-418	1,221	-1,418
1975-79	-1,176	-120	622	-2,199	1,510	-2,647
			Net imports of wheat			
1960-64	4,307	4,199	1,715	145	4,954	15,320
1965-69	4,815	5,825	1,916	321	6,858	19,735
1970-74	4,282	3,315	1,863	1,839	9,326	20,625
1975-79	6,760	886	1,824	2,451	10,814	22,735

[a]Positive figures are net imports, negative (-) are net exports. [b]Pakistan, Sri Lanka, Nepal. [c]Bangladesh, Burma, Thailand, Vietnam, Khmer. [d]Japan, DPR Korea, R. Korea, Taiwan Province, the Philippines, W. Malaysia, Indonesia.

Japan, and Sri Lanka, as wheat consumption increased, supplied by growth in national production (in Bangladesh and India), or by increased imports (in Bangladesh, Japan, and Sri Lanka) (Table 7).

Rice can improve incomes

Malnutrition is not just a problem of food availability; it is also a problem of income distribution. Because rice is a major source of income in rural Asia, increased productivity can reduce malnutrition by providing better incomes for the rural poor. Thus, increased rice yields improve nutrition in two ways: increasing food availability and increasing producer incomes.

NUTRITIONALLY RELATED RESEARCH AT IRRI

IRRI research by rice culture type

IRRI considers three broad criteria when setting research objectives (35). First is efficiency. IRRI considers the expected benefits of investing research funds in each culture type. Second is comparative advantage. IRRI considers what it can do better than other research agencies. It aims to solve problems that national programs cannot or are unwilling to handle. Third is equity. IRRI seeks to develop technology for regions where modern varieties have had least impact. In these less favored deep water and dryland areas, people have remained poor and malnourished, compared to population in the more favorable rice environments.

Past and projected allocations of IRRI resources across rice environments appear in Table 8. IRRI directs more resources toward rainfed and deep water environments than efficiency alone would dictate. Equity and the comparative lack of progress overwhelmingly justify developing rice technology to reduce the income and nutrition gap of communities resident in less favorable environments (35).

Table 8. Past and projected balance of IRRI senior scientific staff efforts aimed at major rice-growing environments, compared with anticipated economic returns from production increases (35).[a]

Environment	1978-80 average distribution (%)	1984-85 projected distribution (%)	Projected benefits (%)
Irrigated	41	37	67
Rainfed wetland	38	42	23
Rainfed dryland	13	13	4
Deepwater and floating	8	8	6
Total	100	100	100

[a]The projections are based on an intended shift of some activities from irrigated to rainfed rice. Provided total staff expands, research on dryland and deep water and floating rice will increase, although the relative input will remain constant.

Enhancing nutritional characteristics

The nutritional value of rice compares favorably with that of other cereals and is superior to those of root crops (Table 9). Calorie-protein malnutrition in rice-eating Asia reflects low consumption levels because people are poor, not because of the inherent nutritional composition of rice. Therefore, technical change which increases per hectare rice yields directly enhances calorie and protein supplies. It also increases returns to producers and, because supplies are increased, helps keep rice prices at reasonable, stable levels, a particular advantage for low-income rice consumers.

Breeding for higher yields per hectare. A principal objective of IRRI's crop improvement program is to develop improved germplasm with high total and head rice yields, and agronomic and quality characteristics adapted to the range of physical and market environments where rice is important. Seeking high, stable yields has nutritional implications; milled rice endosperm is about 90% carbohydrate, so increasing per hectare rice yields directly and quantitatively increases calorie supplies.

The yield potential of modern rice varieties has not materially changed since IR8 was released in 1966. However, the high levels of disease and insect resistance of recent cultivars (Table 10, left panel) has allowed farm yields to continue to remain high with reduced dependence on insect protection or disease control. Second-generation cultivars mature earlier, often allowing two or three rice crops where only one or two were previously possible

Table 9. Composition of rice and selected foods per 100 g edible portion (17).

Food	Units	Composition of food, 100 g edible portion							
		Energy (calories)	Protein	Fat	Fibre	Iron (mg)	Thiamin	Riboflavin	Niacin
			(g)				(micrograms)		
Rice – brown		354	7.6	1.8	0.7	2.8	.34	.07	5.0
– milled		366	6.4	0.8	0.3	1.9	.10	.05	2.1
– parboiled		364	6.7	1.0	0.6	1.2	.20	.08	2.6
Wheat flour		364	10.5	1.0	0.3	2.9	.06	.05	0.9
Maize white		349	9.1	4.2	2.3	2.8	.29	.11	2.1
Sorghum, milled		357	7.6	2.4	0.6	3.6	.33	.18	3.9
Millet, milled		363	9.4	2.5	0.5	2.0	.20	.07	1.7
Cassava, flour		363	1.1	0.5	2.2	1.0	.02	.03	0.6
Sweet potato, flour		339	2.2	0.9	3.0	2.0	.24	.09	1.5

Table 10. Disease and insect reaction and growth duration of IRRI varieties.

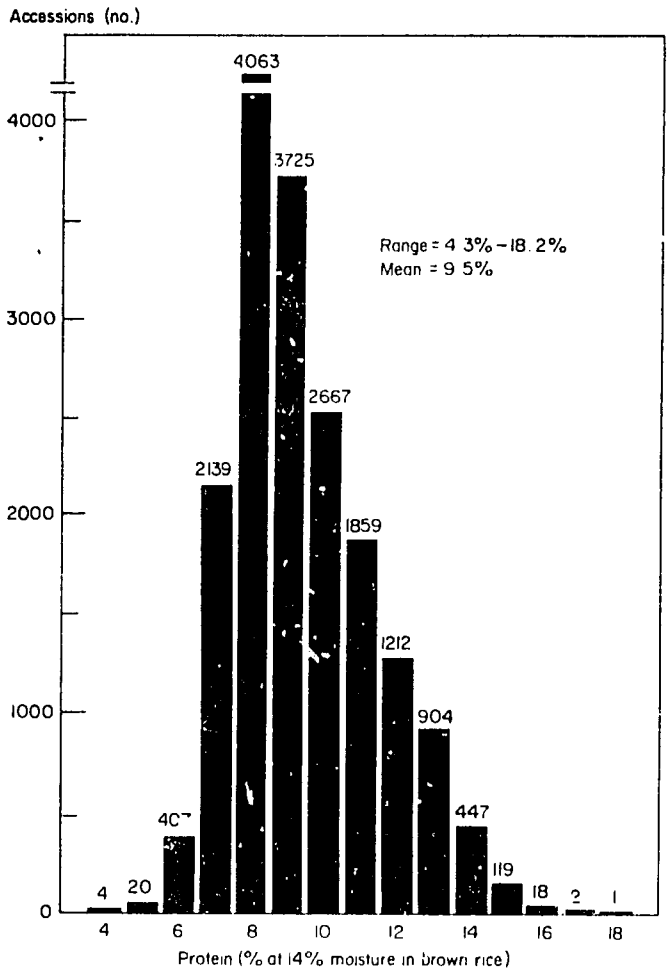
Variety	Release date	Disease and insect reaction (Philippines)[a]										Growth duration (d)
		BL	BB	GS	TG	BPH biotypes			GLH	SB	GM	
						1	2	3				
IR5	1967	MR	S	S	S	S	S	S	MR	MS	S	140
IR8	1966	S	S	S	S	S	S	S	MR	S	S	130
IR20	1969	MR	R	S	MR	S	S	S	MR	MR	S	125
IR22	1969	S	R	S	S	S	S	S	S	S	S	125
IR24	1971	S	S	S	S	S	S	S	MR	S	S	120
IR26	1973	MR	R	S	MR	R	S	R	MR	MR	S	130
IR28	1974	R	R	R	R	R	S	R	R	S	S	105
IR29	1974	R	R	R	R	R	S	R	R	S	S	115
IR30	1974	MS	R	R	R	R	R	MR	MR	MR	S	110
IR32	1975	MR	R	R	R	R	R	MR	MR	MR	S	140
IR34	1975	R	R	R	R	R	S	R	R	MR	S	130
IR36	1976	R	R	R	R	R	R	MR	MR	MR	R	110
IR38	1976	R	R	R	R	R	R	MR	R	MR	R	125
IR40	1977	R	R	R	R	R	MR	S	MR	MR	R	120
IR42	1977	R	R	R	R	R	R	S	MR	MR	R	135
IR44	1978	MR	R	S	R	R	R	MR	MR	MR	S	130
IR46	1978	R	R	S	R	R	R	R	MR	S	S	130
IR48	1978	MR	R	R	R	R	R	S	MR	S	S	140
IR50	1980	MS	R	R	R	R	R	MR	R	MR	S	105
IR52	1980	MR	R	R	R	R	R	S	R	MR	–	115
IR54	1982	R	R	R	R	R	R	S	R	MR	–	120
IR56	1982	R	R	R	R	R	R	R	R	MR	–	110
IR58	1983	R	R	R	R	R	R	MR	R	MR	–	100
IR60	1983	R	R	R	R	R	R	R	R	MR	–	105

[a]BL = blast, BB = bacterial blight, GS = grassy stunt, TG = tungro. BPH = brown planthopper, GLH = green leafhopper, SB = stem borer, GM = gall midge. S = susceptible, MR = moderately resistant, R = resistant.

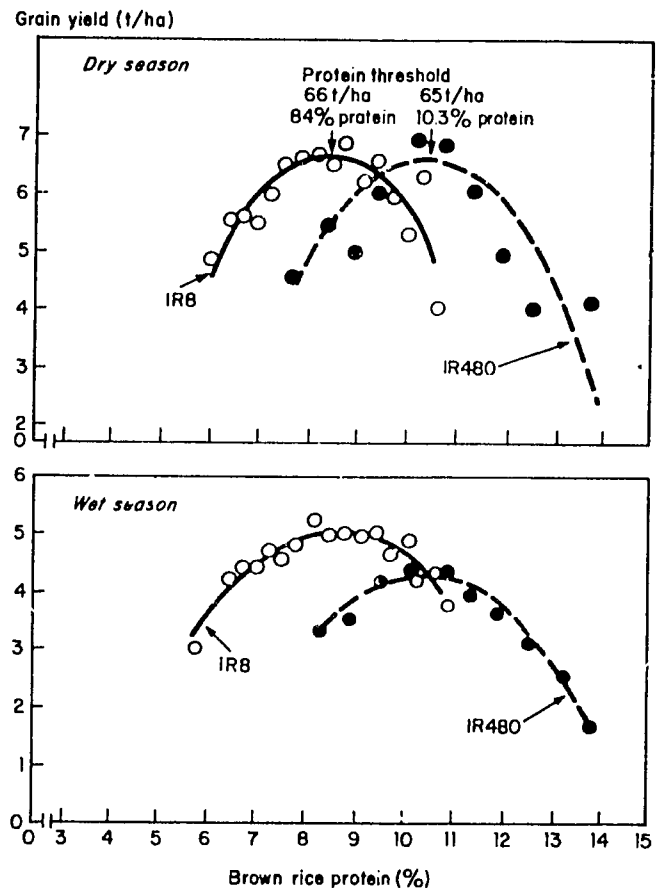
(Table 10, right column). Most IRRI cultivars were primarily bred for irrigated conditions, however, many perform equally well in shallow rainfed environments. Other varieties were selected for rainfed (e.g., IR46, IR52) or upland (IR43, IR45) conditions.

IRRI established a breeding program for F_1 rice hybrids in close collaboration with Chinese rice scientists in 1978. Under commercial farm production in China, hybrid rices have shown at least a 16% yield advantage over conventional rice (25), although the yield advantage under experimental conditions has been somewhat higher. The general relevance of hybrid rice to South and Southeast Asian farming systems, and social and institutional organizations, has yet to be determined. However, this innovation provides an opportunity to markedly improve yields (62).

Breeding for higher protein. Increasing the protein content of rice could markedly increase dietary protein intake because of rice's dominance in Asian diets. Therefore, IRRI began a breeding program in 1966 to increase milled rice protein content by two percentage points (38). IRRI has screened more than 26,000 accessions from the world germplasm collection for protein content. The brown rice protein content of these samples ranged from 4.3 to 18.2%, with most entries having about 8% (Fig. 3). A number of these high-protein entries were crossed with IR8. However, these high-protein lines yielded less than IR8 or were disease and insect susceptible. The heritability of high protein



3. Protein in brown rice of 17,587 accessions in IRRI's world collection, dry season crop. Chemistry Department, IRRI, 1978 (34).



4. The "protein threshold" is the point beyond which increases in protein levels are accompanied by decreases in rice yields. The protein threshold for the experimental line IR480-5-9 (from 964 observations) is considerably higher than that of IR8 (538 observations) (33).

also was low when these selections were crossed with a pest-resistant parent.

Protein content is also strongly influenced by weather and fertility management (23). Furthermore, after a point there is a trade-off between grain yield and protein content (Fig. 4).

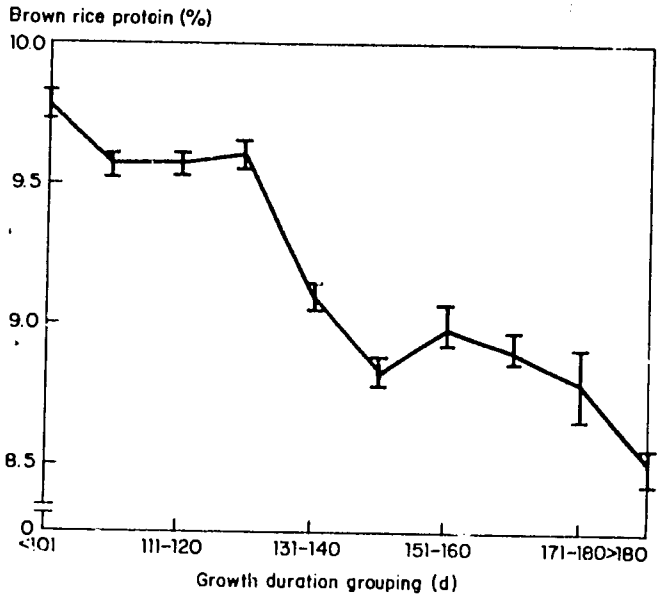
An assessment of the difficulties and uncertainty in payoff in breeding for protein content, against the urgency of breeding for yield, pest resistance, and tolerance for environmental stress, resulted in protein becoming a secondary objective in favor of others (40).

IRRI no longer has a specific protein improvement program. However, all entries in replicated yield trials are analyzed for protein content and any with consistently low scores are not released. Some entries have shown consistently higher protein levels than the 7-8% modal value generally found in the Philippines. A classic example is IR480-5-9, high in protein (> 11%) and equivalent in yield to IR8 (12). This cultivar is frequently used as the standard high-protein rice in IRRI-associated feeding experiments. However, it is highly susceptible to bacterial leaf blight and has not been released as a variety.

Early-maturing varieties average higher protein content (Fig. 5). Initially, researchers thought this relationship was associated with the lower yields of early-maturing varieties. However, IRRI's more recently selected early-maturing cultivars yield as well as the late-maturing varieties, but have retained an advantage in protein content (Table 11). For example, IR36, now grown on an estimated 11 million ha worldwide (43), and IR58, with a similar yield but earlier maturity than IR36, have a protein content about 1% higher than that of other varieties in many tests.

However, it is not clear whether these varieties increased the average protein content of rice in the market. Samples of rice from retail markets in the Philippines showed a 7% average protein content whereas samples from Thailand showed 7.4% (59). This result was unexpected because the Philippine samples were primarily MVs – IR36 varieties and more recent ones – whereas the Thai samples were traditional varieties (TVs). Differences in fertilizer management between experiment station trials and farmer's fields may partly explain the relatively low protein in Philippine market samples compared to those reported in Figure 5.

Higher protein through management. Efficient fertilizer use can increase rice protein. For example, basal application of slow-release N-fertilizers such as sulfur-coated urea, or deep point placement of urea supergranules, increases N efficiency by as much as one-third compared to urea applied



5. Relationship between brown rice protein content and growth duration of 13, 224 varieties from the IRRI germplasm bank (36).

Table 11. Grain yield and protein content of four rices (brown) varying in growth duration, from replicated yield trials, 1978-82 dry seasons (36).

Variety or line	Growth duration (d)	1978	1979	1980	1982	Mean
		Protein (%) of brown rice				
IR42	131	8.2	8.3	8.8	7.8	8.3
IR8	124	7.1	7.3	7.7	7.7	7.4
IR36	110	8.6	8.5	10.2	8.8	9.0
IR58	104	8.8	8.6	10.2	9.2	9.2
		Grain yield (t/ha)				
IR42	131	6.5	6.6	6.4	6.7	6.5
IR8	124	3.4	7.2	3.4	5.4	4.9
IR36	110	6.0	6.9	5.5	6.3	6.2
IR58	104	5.8	6.9	5.7	6.3	6.2

in split doses (7). These fertilizer-efficient application methods also increase rice protein by about 1% over conventionally applied prilled urea (Table 12). Topdressing N fertilizer at the heading stage also increases grain protein content and because the grain is slightly harder, also increases head rice milling recovery (53).

In summary, breeding specifically for high protein in rice grains does not seem productive. Other options, such as the use of early-maturing varieties and fertilizer placement, can increase protein content by one percentage point or more without yield loss. These high-protein cultivars and management systems provide rice consumers a nutritional bonus at no extra cost. For example, if the protein content of commercial milled rice increased by one percentage point, from 7 to 8%, persons consuming 1000 cal/day as rice would increase their intake of high-quality rice protein by more than 10%, i.e., from 20 to 23 g per day, without observable changes in food habits or rice prices.

Grain quality. All IRRI breeding materials are evaluated for milling recovery, grain size, shape and appearance, and cooking and eating characteristics. Milling recovery is the quantity of milled and head rice produced from a unit of rough rice. Cooking quality is important because it affects taste, which, with grain size, shape, and appearance, determines market acceptability and price.

The maximum milling recovery possible per unit of rough rice is about 70% because unmilled rice also contains 20-22% hulls and 8-10% bran and embryo (Table 13). Head rice recovery is an inherited trait, although environmental factors such as temperature and humidity during ripening and postharvest handling influence grain breakage during milling (41).

Properties of the rice kernel starch largely determine cooking and eating characteristics. Amylose content, the linear starch fraction in the grain, largely determines cooked rice texture (37). Intermediate-amylose rices cook moist and tender and do not harden after cooling. Many traditional rice varieties of Southeast Asia are this type.

Table 12. Effect of sources of urea and their application method on rice protein content, 1980-82 dry and wet seasons (7).

Source of urea	Application method	Rice protein[a] (%) 1980 Dry season	1980 Wet season	1981 Dry season	1981 Wet season	1982 Dry season	1982 Wet season	Mean
No fertilizer nitrogen		8.7	9.7	8.8	8.2	7.7	7.5	8.4
Prilled	Researchers' split[b]	9.9	10.9	9.3	8.7	8.6	8.0	9.2
Sulfur-coated	Broadcast and incorporated[b]	11.2	12.4	10.3	9.1	9.9	8.5	10.2
Supergranule	Placement[b]	10.9	11.9	10.2	9.0	9.0	8.3	9.9
Prilled	Researchers' split[c]	10.6	11.7	10.3	9.2	9.3	8.7	10.0

[a]Av of 14 rice entries and 4 replications. [b]Nitrogen rates were 58 kg N/ha during the wet season and 87 kg N/ha during the dry season, except during the 1980 dry season, when the rate was 108 kg N/ha. [c]Nitrogen rates were 90 kg N/ha during the wet season and 158 kg N/ha during the dry season, except during the 1980 wet season, when the rate was 85 kg N/ha.

Table 13. Grain quality characteristics of IR rice varieties.

	Milling characteristics			Grain size, shape, appearance			Cooking characteristics		
Variety	% hulls	% total milled rice	% head rice	Length	Shape	Chalkiness	Gelatinization temperature	Amylose type	Gel consistency
IR5	22	68	40	Medium	Medium	White belly	Intermediate	High	Soft
IR8	26	71	36	Medium	Medium	White belly	Low	High	Hard
IR20	22	70	62	Medium	Medium	Translucent	Intermediate	High	Medium
IR22	22	71	63	Long	Slender	Translucent	Low	High	Hard
IR24	21	70	57	Long	Slender	Translucent	Low	Low	Soft
IR26	24	69	63	Medium	Medium	Translucent	Low	High	Medium
IR28	22	72	61	Long	Slender	Translucent	Low	High	Hard
IR29	25	71	63	Medium	Slender	Opaque	Low	Waxy	Soft
IR30	23	70	55	Medium	Medium	Translucent	Intermediate	High	Soft
IR32	23	67	64	Long	Slender	Translucent	Intermediate-low	High	Soft
IR34	21	69	50	Long	Slender	Translucent	Low	High	Hard
IR36	21	71	57	Long	Slender	Translucent	Intermediate	High	Medium
IR38	22	71	65	Long	Slender	Translucent	Low	High	Hard
IR40	21	73	63	Medium	Medium	Translucent	Intermediate	High	Medium-hard
IR42	22	71	52	Medium	Medium	Translucent	Low	High	Hard
IR43	26	62	38	Long	Medium	Translucent	Low	Low	Soft
IR44	22	68	46	Long	Slender	Translucent	Intermediate	High	Hard
IR45	27	59	33	Long	Slender	Translucent	Low	High	Medium-hard
IR46	22	67	51	Long	Slender	Translucent	Intermediate	High	Soft
IR48	21	69	48	Long	Slender	Translucent	Low	Intermediate	Medium
IR50	22	64	50	Long	Slender	Translucent	Intermediate	High	Medium
IR52	22	68	46	Long	Slender	Translucent	Low	High	Hard
IR54	22	67	59	Long	Slender	Translucent	Intermediate-low	High	Hard
IR56	22	68	61	Long	Slender	Translucent	Low	High	Hard
IR58	20	71	65	Long	Medium	Translucent	Low	High	Hard
IR60	19	70	56	Long	Slender	Translucent	Low	High	Hard

Data were provided by the IRRI Plant Breeding Department.

High-amylose rices harden after cooling and are less preferred. Most IR varieties have this characteristic (Table 13). Consumers distinctly prefer low- to intermediate-amylose rices. In the Philippines at least, the potential returns of breeding for intermediate-amylose rices appear attractive (59). Among high-amylose rices, those with soft gel consistency and intermediate gelatinization temperature are preferred because they approach the quality of intermediate-amylose rices.

Improving yields and pest resistance will continue to be higher priority than improving grain quality. However, improving grain quality is a main goal of IRRI's breeding program for irrigated rices in the eighties (39). The low correlation between yield and quality attributes suggests that quality can probably be improved without reducing yield potential (Table 14).

Nutritive evaluation of rice

An increase in protein content is accompanied by a slight decrease in protein quality. Greater brown rice protein content means greater endosperm protein with a slight drop in lysine, the limiting amino acid in rice proteins. The Cereal Chemistry Department has conducted nutrition experiments in cooperation with the Agricultural Research Laboratory, Denmark, the Harvard School of Public Health, Osaka City University, and the Food and Nutrition Research Institute, Manila The results indicate that the increase in protein content more than compensates for the slight drop in protein quality, since usable protein increases with an increase in protein content (15, 52).

Cooking affects rice protein digestibility. Nitrogen balance studies with growing rats compared raw and cooked milled rices. These studies indicated that true digestibility is consistently lower in cooked rice (16). However, cooking improved the biological value (nitrogen uptake). Thus,

Table 14. Simple correlation coefficients between rice yield and grain quality attributes of IRRI lines.[a]

Year	Entries (no.)	Grain quality characteristics			
		Amylose	Gel. temp.	Gel consistency	Head rice
I Dry season					
1981	588	0.06	0.01	−0.03	0.06
1982	368	0.05	0.00	−0.04	0.07
1983	496	0.18*	[b]	−0.05	0.23*
II Wet season					
1980	498	0.18*	0.14*	−0.05	0.14*
1981	422	0.01	−0.01	−0.10*	0.14*
1982	492	0.12*	0.13*	−0.01	−0.09

[a]Calculated from data provided by Grain Quality Laboratory, Plant Breeding Program, IRRI. An asterisk (*) implies significance at 5% level or better. [b]No score available.

cooked and raw rice have similar net protein utilization. Amino acid digestibility is 100% for lysine and 82% for cystine; starch and energy digestibility remained high after cooking. About 15% of cooked rice protein body is indigestible in man and is excreted as intact fecal protein particles (57). These particles represent the core portion of large spherical protein bodies and have less than 2% lysine content. Thus, it is the poor-quality protein fraction that is rendered indigestible by cooking. This explains the higher biological value obtained for cooked rice compared to raw rice.

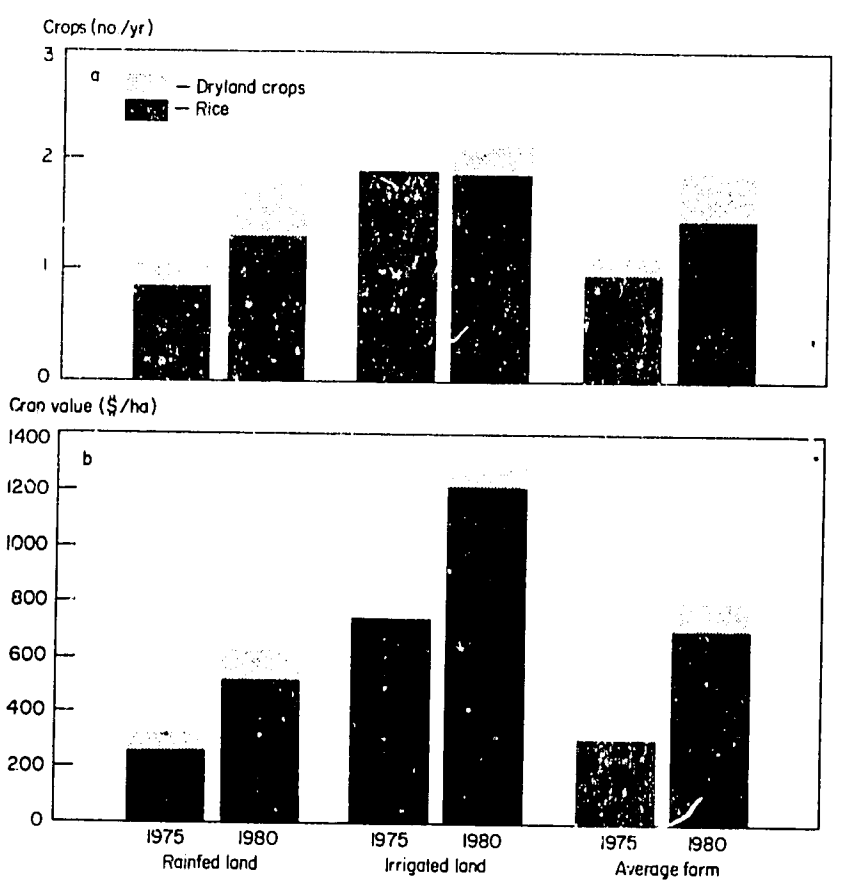
Brown rice has more protein, minerals, and lipid, and its protein has higher lysine content than milled rice (50). Because it also has higher vitamin content, brown rice has been advocated to be more nutritious than milled rice. However, comparison of the protein utilization of brown, undermilled, and milled rice based on N-balance studies of children and rats (36) showed no differences in protein absorption and retention. The energy and fat content of brown rice were less utilized than those of milled rice.

As a weaning food, rice gruel has low energy density and inadequate protein. IRRI and the Food and Nutrition Research Institute of the National Science and Technology Authority, Manila, conducted nutritional evaluation of rice-based weaning foods. This research sparked creation of the Nutritional Evaluation Laboratory (NEL) in Manila, funded by USAID. NEL facilities were used to study protein requirements of young Philippine children consuming local rice-based diets. Studies on the effect of starch properties on energy density of gruels indicated that energy density may be improved 14-22% by adding oil and 20-50% by parboiling the rice.

Earlier studies on parboiling brown rice indicated decreased thiamine content due to heat degradation. However, parboiling also moved thiamine into the endosperm. Loss and diffusion both depend on the severity of heat treatment (43). Studies on the effect of prolonged parboiling on nutritive value were prompted by the increasing popularity of pressure-parboiled rice in India. Rat feeding trials indicated a slightly lower digestible energy and protein digestibility for rices parboiled at different lengths of time, as compared to raw rice. But the higher biological value of parboiled rices makes up for the lower digestibility, hence the net protein utilization is similar for raw and parboiled rices (36). Also, parboiled rice gives greater head rice recovery after milling than does raw rice.

Rice production systems

IRRI develops technology appropriate to resource-poor Asian rice farmers, to enable more intensive land use through multiple cropping of rice and other crops. Production technology, therefore, is designed to be scale neutral if not biased specifically toward the circumstances of small farms. There is strong evidence that resource-based factors such as tenure and farm size do not determine whether farmers adopt MVs (29). Rather, the variety's suitability to the



6. a. By adopting early-maturing varieties and early seeding techniques, Iloilo farmers grow more crops each year on both the rainfed and irrigated land. Cropping intensity rose 72% on an average farm because of multiple cropping technology and increased irrigation (from 5 to 25% of land). b. A 72% increase in cropping intensity and 42% increase in crop yields per farm resulted in a 140% increase in crop value on Iloilo village farms. Source: (36).

environment, usually dictated by water and soil regimes, is the principal determinant.

MVs had two major impacts in irrigated and favorable rainfed areas. First, they produced higher monsoon-season rice yields than did traditional varieties. Yield increases from 1.5 to 2.5 t/ha are frequently reported (29). Second, because MVs are earlier maturing and photoperiod insensitive, they provide the opportunity to plant a second wet season crop or a dry season rice crop as well. Therefore, the major impact of MVs in irrigated and favorable rainfed areas is increased rice supply, as opposed to increased dryland crop production which would increase diet diversity. For example, in Iloilo, Philippines, the adoption of early-maturing varieties and early seeding techniques derived from IRRI research now allows farmers to grow more crops each year on their rainfed and wet-season irrigated land than was previously the case (Fig. 6a). In Iloilo, cropping intensity increased 72% and rice yields 42%. The introduction of early-maturing MVs and associated technology increased the total income per hectare of crops grown in these villages 140% (Fig. 6b) without reducing labor use and with only small increases in variable costs (Table 15).

IRRI's objective of developing early-maturing varieties and techniques to allow earlier crop establishment was primarily intended to facilitate double-cropping of rice in rainfed areas. Another advantage has been the opportunity to increase dryland crop production, notably grain legumes, in rainfed rice-based farming systems. However, more important advantages of increased cropping intensity are more frequent harvests, regular supply of food and income, reduced price fluctuations, and increased employment opportunities. In combination, these help reduce seasonal malnutrition and associated ill health, a common problem in regions where only one or two major harvests a year are possible (9).

Increasing cropping intensity frequently increases rice supplies. It also provides a more favorable total food balance if dryland crops, such as grain legumes and other cereals, are introduced or their productivity is increased. A major constraint here is the lack of dryland crop cultivars suited to pre- and postrice environments. Therefore, in collaboration with IDRC and the Institute of Plant Breeding in Los Baños, a varietal improvement program for dryland crops grown in rice-based systems has been established (36). Mungbean, soybean, peanut, maize, and sorghum are the principal crops. The dominant breeding objectives are high and stable yields, early maturity, and drought and waterlogging tolerance.

IRRI collaborates with other international centers to facilitate increases in the overall productivity of rice-based cropping systems. For example, an IITA scientist based at IRRI provides liaison for cowpea improvement in Asia. Emphasis is on cowpea productivity in rice-based farming systems. A project between IRRI and CIMMYT is designed to increase productivity of rice- and wheat-based cropping systems dominant over vast areas of South Asia. Introducing

Table 15. Costs of production and rate of returns of new rice technology on 45 farms in Iloilo, 1975-80 (36).

Management regime	Cost ($/ha) Labor	Material	Variable	Return-to-cost ratio
		Transplanted		
Rainfed				
Local	194	29	223	1.7
Modern variety	191	36	227	2.1
Irrigated				
Local	172	41	213	1.8
Modern variety	212	56	268	2.6
		Direct-seeded		
Rainfed				
Local	134	36	170	2.0
Modern variety	151	62	213	2.1
Irrigated				
Local	155	69	224	2.1
Modern variety	178	101	279	2.6

early-maturing rice varieties into these patterns can help improve the yields of associated grain legumes (e.g., mungbean, black gram, chick-pea), fodder, or green manure crops.

Cultivars identified from the rice and dryland crop improvement programs are evaluated for local suitability throughout Asia under the Asian Rice-Based Farming Systems Network. In the 1982-83 cropping year, 47 trials tested dryland crops before rice and 152 dryland crops after rice (Table 16), the more common sequence in rice-dryland crop patterns.

However, cropping patterns based on nutritional criteria have little chance of being adopted when relative prices demonstrate that other crops or production practices are more profitable to the farmer. Also the evidence is mixed whether the increased production of nutritionally superior crops improves the nutritional status of the household producing that crop. FAO (20) has developed a manual to assist in the design and evaluation of agricultural and rural development projects from a nutritional perspective.

Artificial drying of paddy

Modern rice varieties allow farmers to grow more than one rice crop each year. With two crops, the first one is generally harvested during the wet season rather than at the beginning of the dry season. Therefore, the traditional method of sun drying is frequently delayed or becomes impractical because of rain or cloudy weather. Much of this wet season rice crop is harvested at more than 25% moisture, and delays in drying lead to deterioration of the grain (2). This wet environment may also produce fungi as *Aspergelles* which in some crops (e.g., peanut) produce mycotoxins reported to lead to jaundice and other forms of liver ailments if digested.

The problems of storing wet paddy led IRRI to develop prototype dryers for village or farmer cooperative use. Conventionally fueled dryers were built as were ones using local materials as the heat source and vortex wind machines to

Table 16. Crops tested before and after wetland rice in the Asian Cropping Systems Network (1982-83 cropping pattern year) (8).

Country	Crops and number of sites						
	Mungbean	Cowpea	Bush sitao	Soybean	Peanut	Sorghum	Maize
I. Dryland crop before rice							
Vietnam	2	1	1	2	2	–	1
Burma	1	–	1	1	1	–	1
Pakistan	1	1	–	–	1	–	–
Nepal	3	–	–	2	2	2	1
Thailand	3	3	–	–	1	–	–
Philippines	4	1	3	–	–	–	–
Indonesia	1	–	–	1	1	–	2
Total	15	7	5	6	8	2	5
II. Dryland crop after rice							
Malaysia	1	–	–	–	1	–	–
Thailand	2	2	–	2	2	2	2
Vietnam	2	–	–	2	–	1	2
Sri Lanka	2	2	2	2	2	2	2
Bangladesh	2	1	–	3	3	1	4
Burma	1	1	–	1	1	–	1
Indonesia	3	2	1	4	4	2	4
Philippines	14	10	14	11	7	8	14
Total	27	18	17	25	20	16	29

provide draft for the dryer (26). A constraint to the adoption of rice dryers, in the Philippines at least, is the low price margin offered for high-quality, dried grain. It has proven difficult to reduce artificial drying costs to the point of economic return to farmers.

IMPACT OF MV RESEARCH ON NUTRITION

Benefits from new technology

Technical progress, as embodied in modern rice varieties, lowers production costs and increases supply. Whether this changes prices and incomes depends on government policies and market conditions. In general an increased supply lowers market prices, benefiting purchasing consumers at the expense of producers who sell their output. Small farmers who retain much of their production for home consumption also gain, because they can produce their food with a lower real expenditure of resources (27). The improved productivity of MVs also increases returns to production factors and hence improves the income of landowners, farmers, and laborers.

The impact of MVs on nutrition depends on the size and distribution of the price and income effects, and on whether the malnourished tend to be urban consumers or rural laborers. There is little hard evidence on the latter. We follow convention and assume that falling prices improve nutrition by making food cheaper for both the urban poor and small farmers. Furthermore, absolute increases in hired labor income are also assumed to improve nutrition by increasing purchasing power of the rural landless. This section examines the available evidence regarding production, price, and income effects of MVs.

The impact of MVs on rice production and availability

In the 8 Asian countries that produce 85% of the world's rice, the principal source of increased rice production from 1955 to 1965 (prior to MVs) was the addition of new land to production (Table 17). As the potential for adding land declined, high yielding varieties allowed intensified production in the 1970s. Yields per hectare in the past decade increased through greater use of modern varieties and complementary inputs such as fertilizer and irrigation.

The most dramatic increases in per hectare yields occurred in Burma, the Philippines, and Indonesia, where aggressive government programs extended modern rice technology to irrigated and favorable shallow rainfed areas. In the Philippines and Indonesia, governments also invested heavily in irrigation infrastructure. The smallest yield in-

Table 17. Growth rates of rice production, area, and yield in South and Southeast Asian countries, 1955-65 and 1971-80 (28, 44).[a]

	Annual compound growth rate (%)					
	1955-65			1971-81		
	Production	Area	Yield	Production	Area	Yield
Bangladesh	3.08	1.10	1.98	2.90	0.82	2.07
Burma	2.87	1.93	0.94	5.90	0.56	5.32
India	2.56	1.26	1.30	-1.53	-3.04	1.56
Indonesia	1.41	0.90	0.51	5.02	1.36	3.62
Malaysia	5.38	3.41	1.97	1.35	0.00	1.36
Nepal	6.53	-1.71	8.24	0.40	1.28	-0.75
Pakistan	4.46	3.25	1.21	3.37	2.46	0.95
Philippines	2.35	1.15	1.20	5.01	1.28	3.67
Sri Lanka	4.98	2.88	2.10	3.96	2.01	1.98
Thailand	3.46	1.73	1.73	2.84	2.32	0.51

[a]Growth rates estimated from 3-yr averages centered on the years specified.

creases in this period were in Thailand where lack of water control limited the impact of technology. New land continued to contribute to production increases in Pakistan and Sri Lanka where dry areas were brought under irrigation, and in Thailand which still has an arable land frontier for expanding cultivation.

MVs have contributed directly to global food availability. Herdt and Capule (29) estimate that MVs have contributed 27 million t (23%) or about $4.5 billion annually to the increase in Asian rice output over the past 15 yr (Table 18). MVs have also indirectly contributed to increased rice output because fertilizer-responsive varieties increase the profitability of investing in fertilizer and irrigation.

MVs have contributed about a quarter or more to the growth rate in rice output in most Asian countries (Table 19). They have not contributed as much in the deep water or dryland areas of Bangladesh, Thailand, and Eastern india. Production growth has been most rapid in those countries where MVs are most widely adopted. In both Indonesia and the Philippines, production growth has accelerated since the introduction of IR36 in 1976, the first early-maturing, multiple pest-resistant variety.

Production growth due to intensified land use has increased per capita rice availability in 7 of the major rice-producing countries. In Bangladesh, with the least benefit from MVs, production growth lagged behind population growth. The very rapid growth of availability in Indonesia reflects large rice imports in the 1970s, but because domestic production also grew rapidly, imports declined as a percent of total supply after 1977. Imports also declined sharply in Sri Lanka, the Philippines, and India due to domestic production growth in the 1970s.

Rice availability grew faster than total food availability in most major rice-producing countries, reflecting greater technological change for rice than for other crops in insular Asia. In Indonesia, for example, rice contributed 56% of total calories in 1975 as compared to 49% in the early 1960s.

Price effects

MVs have increased global rice supply. In real terms, world rice prices in the late 1970s were the same as in the 1960s (Fig. 7). The 1973-74 price increase reflected the bad

Table 18. Contribution of specified factors to rice production increases (29).

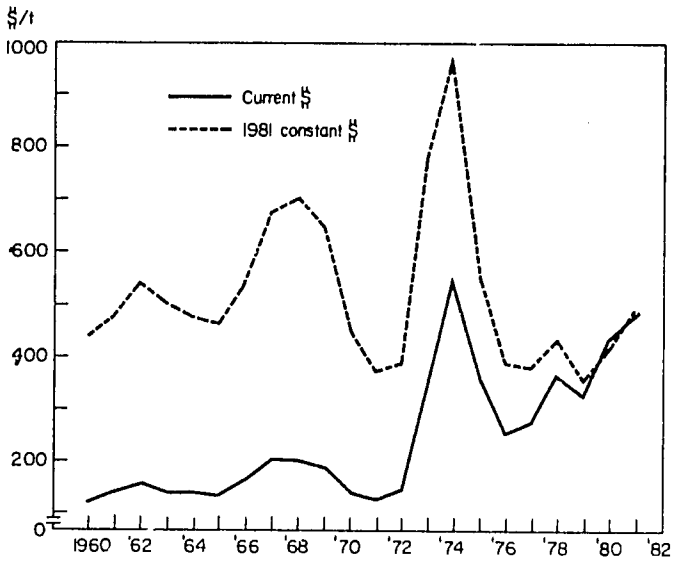
	Contribution of factors				
	MV effect	Fertilizer effect	Irrigation effect	Other factors (residual)	Total observed growth in output[a]
			Output increases (000 t paddy)		
Bangladesh	420	1,284	1,091	2,759	5,554
Burma	647	353	685	167	1,852
China	13,231	11,507	16,153	9,609	50,500
India	7,998	10,867	11,209	5,078	35,152
Indonesia	3,162	2,630	2,773	4,998	13,613
Philippines	849	1,009	801	615	3,274
Sri Lanka	241	215	262	316	1,034[b]
Thailand	822	682	865	4,031	6,400
Total	27,370	28,597	33,839	27,573	117,379
			Value (US$ million)[c]		
	4,615	4,718	5,583	4,549	19,367

[a]Difference between 1980 and 1965 production. [b]A 3-yr av was used for 1965 because 1965 yields were unusually low. [c]Paddy was valued at $165/t.

Table 19. Contribution of modern varieties to growth in rice production and availability.

	Growth rate of rice 1965-80[a]	MV contribution[b]	Area (%) grown to MVs, 1975-79[a]	Growth rate of all foods per capita/day 1965-80[c]	Growth rate of rice per capita/day 1965-80[d]	Growth rate of population 1965-80[a]
Sri Lanka	7.00	23.21	56	0.29	0.67	2.23
Indonesia	4.62	23.23	55	1.76	3.35	2.65
Philippines	4.36	25.93	70	1.42	1.05	3.32
India	3.76	22.75	37	-0.33	0.70	2.56
Thailand	3.54	12.84	10	0.59	1.20	3.31
China	3.13	26.20	66	1.97	2.31	2.24
Burma	3.07	34.94	12	1.14	2.78	2.68
Bangladesh	1.88	7.56	16	-0.05	-0.11	3.09

[a]Source: (44). [b]Source (29). [c]Sources of basic data: (1, 19). [d]Sources of basic data: (19, 61).

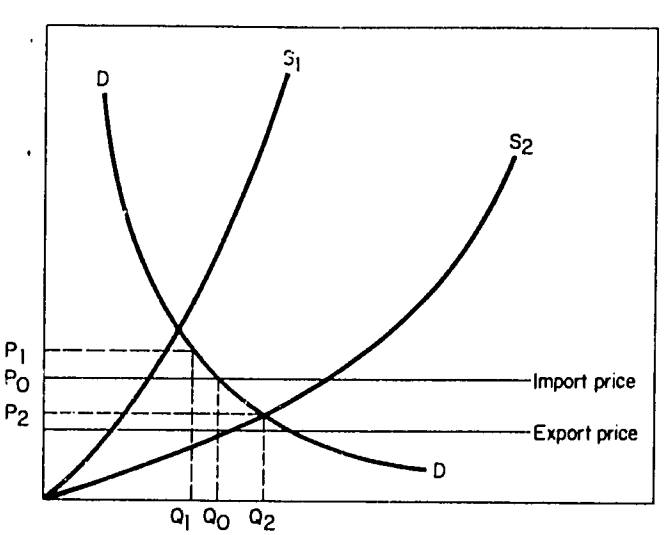


7. Current and constant world rice prices (Thai FOB 5%), 1960-81 (63).

weather and global shortfalls in grain production, as well as reduced productivity of early MVs due to pest susceptibility. The second-generation MVs, released in the mid-1970s, have allowed steady growth of production and contributed substantially to the current situation of stable to declining prices.

The supply impact of MVs has been concentrated in the traditional rice importing countries of Sri Lanka, Indonesia, Philippines, and to lesser extent, India (54). These countries have made substantial investments in irrigation infrastructure in pursuit of self-sufficiency. Because MVs are best suited to irrigated environments, they have been more widely adopted in these countries.

Increased domestic supplies within importing countries lead to price reductions even when world prices remain the same. Figure 8 illustrates domestic price formation for a small importer. Before MVs are introduced, domestic supply cannot meet domestic demand at the import price. With no government intervention, imports provide a total supply of Q_0, and domestic price, P_0, equals the import price. For various reasons governments frequently intervene to limit imports. Total supply may only be Q_1 then, and domestic price is P_1.



8. Technological change lowers domestic prices in an importing country.

Technological change causes supply to shift rightward to S_2. Domestic price then falls below the import price level. Without government intervention, domestic prices can only fall to the export price level. The difference between the import and export price is caused by transportation costs on international markets. If government intervention discourages exports and supply shifts further beyond S_2, then domestic prices fall below the export price level.

Increasing self-sufficiency in an importing country can cause prices to fall for two reasons. First, prices decline from import parity to export parity. Second, prices decline because intervention to reduce international trade will now reduce domestic prices rather than increase them. These effects are further reinforced with rice by the decline in world price levels.

In three importing countries, the Philippines, Indonesia, and India, falling real world prices and growth in domestic supply led to declining real domestic rice prices and declining nominal protection for rice.

In the Philippines, the ratio of domestic to world prices declined to less than 1 as domestic supply grew in the 1970s (Table 20). Domestic prices in the Philippines in importing years were frequently above world prices, because of the difficulty of obtaining funds to import (6). As domestic supply grew large enough to meet demand at

Table 20. Rice trade, nominal protection and real rice prices in Philippines, 1960-80 (44).

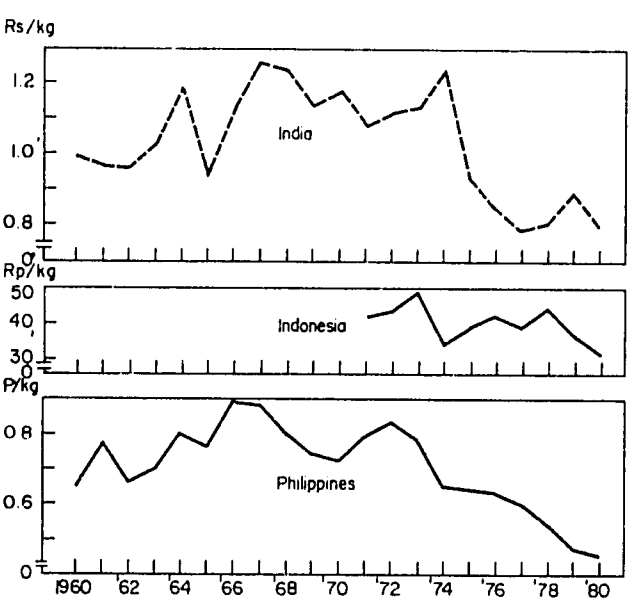
Year	Net imports (000 t)	Ratio domestic price to Thai FOB	Real domestic price (₱/kg)
1960		1.83	.65
1961	186.4	2.28	.77
1962	–	1.13	.66
1963	256.3	1.23	.69
1964	299.9	1.43	.80
1965	569.2	1.35	.76
1966	108.2	1.39	.89
1967	238.6	1.37	.88
1968	–40.3	1.11	.80
1969	–0.5	1.19	.74
1970	–	1.09	.72
1971	369.3	1.75	.79
1972	440.1	1.62	.83
1973	308.1	0.78	78
1974	169.3	0.56	.65
1975	145.3	0.90	.64
1976	55.2	1.21	.63
1977	15.6	1.17	.60
1978	–13.4	0.81	.54
1979	–38.0	0.90	.47
1980	–236.0	0.79	.45
1981	–	0.75	–

world prices, the government was hesitant to export due to a desire to build up large buffer stocks and the low quality of domestic rice by international market standards (58). Thus, domestic rice prices in the Philippines have been below world levels since 1977. In real terms domestic rice prices have declined substantially: from ₱0.70/kg in the late 1960s to ₱0.50/kg in the late 1970s (Fig. 9).

Indonesian price policy sought to buffer domestic rice prices against world price instability. Oil export revenues in the 1970s allowed the government to finance large rice imports – up to 2.0 million t/yr. As domestic production grew after 1977, imports became a declining share of domestic consumption. Domestic rice prices were usually below world prices in the 1970s (Table 21) and real domestic prices have been stable or declining since 1974 (Fig. 9). Domestic production growth and falling international prices made it cheaper and easier for Indonesia to lower domestic rice prices.

In India, nominal protection shifted from high domestic prices relative to world prices in the 1960s to low prices in the 1970s, as imports declined from around 500,000 t to zero. Real rice prices also declined in the late 1970s (Table 22, Fig. 9). Again, domestic production growth reduced the need for imports and hence the cost of domestic prices.

Consumption by the poor. What impact have increased availability and decline in real rice prices had on consumption by the poor? Unfortunately, few recent data exist to quantify this relationship. A number of extensive cross-section household expenditure surveys are reported from India, Indonesia, and the Philippines. However, the latest available surveys in India and the Philippines were conducted in the mid-1970s before the decline in rice prices. In India, rice consumption appeared to fall from the early 1960s to 1973-74 for all income groups (Table 23). This may largely reflect the high food prices which prevailed at



9. Real domestic wholesale rice prices in India, Indonesia, and Philippines, 1960-80 (44).

Table 21. Rice trade, nominal protection, and real rice prices in Indonesia, 1960-80 (44).

Year	Net imports (000 t)	Ratio domestic price to Thai FOB price	Real domestic rice price (Rs/kg)
1960	962.0	1.47	
1961	1,063.8	2.46	
1962	1,024.8	3.17	
1963	1,022.8	1.89	
1964	1,009.7	2.27	
1965	203.2	0.71	
1966	308.5	0.64	
1967	353.8	0.68	
1968	628.4	0.99	
1969	604.2	0.88	
1970	955.6	1.15	
1971	502.9	1.25	41.94
1972	748.0	1.23	43.24
1973	1,663.8	0.79	48.83
1974	1,074.0	0.42	34.00
1975	675.4	0.87	39.28
1976	1,296.1	1.35	42.14
1977	1,964.1	1.34	39.35
1978	1,838.3	0.79	44.46
1979	1,930.0	1.07	36.46
1980	2,000.0	0.95	31.39
1981	500.0	0.96	

Table 22. Rice trade, nominal protection, and real rice prices in India, 1960-80 (44).

Year	Net imports (000 t)	Ratio domestic price to Thai FOB price	Real domestic rice price (Rs/kg)
1960	699	1.31	.99
1961	384	1.26	.96
1962	390	1.27	.96
1963	483	1.32	1.03
1964	645	1.61	1.19
1965	783	1.44	.94
1966	773	1.03	1.13
1967	743	1.28	1.26
1968	446	1.09	1.24
1969	487	1.18	1.14
1970	206	1.54	1.18
1971	240	2.01	1.08
1972	131	1.73	1.12
1973	0	0.84	1.14
1974	0	0.61	1.24
1975	130	0.71	.94
1976	117	0.91	.85
1977		0.96	.79
1978		0.63	.81
1979		0.85	.90
1980		0.68	.80
1981		0.63	

the end of that period (see Fig. 9). In the Philippines, per capita rice consumption by the poor did not increase significantly between 1970 and 1976 (3) even though real price per kilogram fell from ₱0.72 to ₱0.63.

In Indonesia, household expenditure survey data give consumption estimates for 1970, 1976, 1978, and 1980. Interpreting these data is difficult. First, it is not possible to divide the income groups on a strictly comparable basis

because the distribution of population by group varies in the different years. Second, the 1979 data give rice consumption figures considerably below food balance sheet estimates (13). As real price declines were greatest after 1978 (Table 21), the 1980 data should show consumption increases by the poor. A comparison of 1976 and 1980 data shows a slight increase in rice consumption by the bottom quarter of the population, but this difference may only reflect the larger population percentage average for 1980 (Table 24). Thus, survey evidence is inconclusive.

Table 23. Average per capita rates of use in kg, by income group, India (22).[a]

India	1961-62	1964-65	1973-74	% population
Rural				
Bottom quartile	67.44	69.84	59.16	25
Top quartile	137.76	122.76	106.44	25
All consumers	105.24	97.56	82.80	
Urban				
Bottom quartile	55.20	52.68	53.76	25
Top quartile	86.64	71.04	67.68	25
All consumers	73.68	67.32	64.56	

[a]The bottom quartile is the 25% of consumers who spend least, the top quartile, the 25% who spend most.

Table 24. Rice consumption in rural Java, 1976 and 1980 (30, 31).

Expenditure group	1976		1980	
	% population	kg/capita per yr	% population	kg/capita per yr
I	22.3	59.0	28.8	63.4
II	30.7	93.1	32.8	100.2
III	47.0	129.1	38.4	129.5
Av		102.4		100.0

Table 25. Estimated own-price and income elasticities for rice by income group for Indonesia and the Philippines.

Income group	Own-price elasticities	Expenditure elasticities	% population
	Indonesia[a]		
Low	-1.28	0.78	53
Medium	-0.45	0.49	38
High	n.s.	0.16	9
	Philippines[b]		
1	-0.73	0.1	32
2	-0.69	0.1	31
3	-0.68	0.2	26
4	-0.43	0.0	11

[a]Source: (13). n.s. = not significant, based on 1976 data. [b]Source: (5). Based on 1970-75 data.

Table 27. Price effect on rice consumption by the poor.

	Indonesia	Philippines
Own rice elasticity	-1.3	-0.7
Average consumption	70	92
% change real price, 1975-80	-20	-30
Estimated % change in consumption	26	21
Estimated total consumption of the poor in 1980	88	113

The effect of declining real rice prices on the poor's consumption in the late 1970s may be inferred from price elasticity estimates. Income group specific price elasticities have been estimated for the Philippines (5) based on 1970-76 survey data and for Indonesia (13) based on 1976 survey data. These estimates imply that the poor's consumption of rice is extremely sensitive to price changes (Table 25). In part this is due to the large income effect of price changes for poor households, as rice expenditure is a large proportion of total expenditure (Table 26).

Gonzales and Regalado (24) estimated that a 7-18% rice price decline would allow the lowest income group in the Philippines to satisfy their minimum calorie intake. Between 1975 and 1980 real prices declined 20% in Indonesia and 30% in the Philippines. Other things being equal, this should have increased rice consumption by the poor 26% in Indonesia and 21% in the Philippines (Table 27). Indonesian data show these estimates probably overstate changes in consumption perhaps because the poor have received a smaller than average share of income growth. Pinstrup-Andersen et al (46) found that shifts in the food supply curve are less effective in improving nutrition than increased income for the poor, because both the rich and the poor increase consumption when prices fall.

Income effects

Although the link between increased income and better nutrition is controversial, the expenditure elasticities for rice (Table 26) imply that much of the poor's increased income is used to increase calorie intake.

Table 26. Rice consumption and food expenditure by income group in the Philippines and Indonesia.

Income group	Indonesia, 1976[a]			Philippines, 1970-76[b]		
	Rice (kg)/ capita per yr	% of population	Budget share of rice	Rice (kg)/ capita per yr	% of population	Budget share of rice
I	58.35	15	.36	91.8	32	.31
II	92.56	23	.38	100.2	31	.23
III	116.64	33	.33	100.7	26	.19
IV	136.29	28	.24	105.0	100	.14
All groups	113.62	100	.33	101.9	100	.23

[a]Source: (13). [b]Source: (24). Computation of percent of population was based on the 1975 distribution of households by income class.

Table 28. Changes in share of income from rice production per ha, Laguna Survey, 1966-81 wet season (42).

	1966	1970	1975	1978	1981
Gross value added[a]	2,098	2,791	2,854	2,958	3,874
Income in paddy (kg/ha):					
Farmer	716	873	1,148	1,191	1,779
(Family labor)	(324)	(276)	(334)	(377)	(519)
(Capital)[b]	(141)	(119)	(91)	(253)	(450)
(Operator's surplus)	(251)	(478)	(723)	(561)	(810)
Hired labor	473	769	734	888	1,027
(Preharvest work)	(162)	(350)	(241)	(374)	(433)
(Harvest work)	(311)	(419)	(493)	(514)	(594)
Landowner	851	1,035	834	673	751
Capital owner	58	114	138	201	317
Income shares (%):					
Farmer	34.1	31.3	40.2	40.3	45.9
(Family labor)	(15.4)	(9.9)	(11.7)	(12.7)	(13.4)
(Capital)	(6.7)	(4.3)	(3.2)	(8.6)	(11.6)
(Operator's surplus)	(12.0)	(17.1)	(25.3)	(19.0)	(20.9)
Hired labor	22.5	27.5	25.7	30.0	26.5
(Preharvest work)	(7.7)	(12.5)	(8.4)	(12.6)	(11.2)
(Harvest work)	(14.8)	(15.0)	(17.3)	(17.4)	(15.3)
Landowner	40.6	37.1	29.2	22.9	19.4
Capital owner	2.8	4.1	4.9	6.8	8.2

[a]Output value less current input cost. [b]Includes imputed land rent.

Herdt and Capule (29) and Barker and Herdt (4) reviewed studies from many Asian countries concerning the distribution of benefits from new rice technology. They concluded that in most cases, low-resource farmers adopted MVs as rapidly as richer farmers and use comparable levels of cash inputs per hectare. Furthermore, labor use (days/ha) and labor productivity (kg/day) increased in most cases after the adoption of MVs. They conclude that "most studies show that new rice technology has had rather broad benefits to laborers and farm operators as well as landowners." Technological changes in rice have in general been neutral (49) so that benefits from new technology are distributed in proportion to the ownership of resources. Therefore, the existing distribution of assets will be the biggest determinant of distribution of gains but the absolute gains for labor can be large.

An example of the changing benefits from rice production in Laguna, Philippines, is shown in Table 28. Rice output in the wet season more than doubled between 1977 and 1981 from 2.2 to 4.6 t paddy/ha. Hired labor's share remained about the same but labor's absolute income more than doubled because both wages and employment increased. Farm operator's income grew faster and at the expense of landowner's income because of the imposition of land reform during the period. These results demonstrate that although ownership of assets may determine income shares, the new technology can greatly increase absolute income for laborers and small operators.

Implications

Little specific evidence is available regarding changes in nutritional status following the introduction of MVs. The indirect evidence indicates that MVs should have improved nutritional status by improving rice and total food availability, lowering consumer prices, and providing greater rural income. Improved availability of rice means increased calories to meet the most pressing nutritional need in Asia. MVs, in particular the insect- and disease-resistant varieties released since 1976, have contributed to the current situation of stable or declining rice prices in world markets in many Asian countries. Lower prices should make possible greater rice consumption by the poor, who are particularly sensitive to price changes. Lower production cost due to MVs has also generated increased income for farmers and laborers, although the direct impact has been greatest in irrigated and favored rainfed environments. If prices and income affect the nutritional status of the poor, then MVs should have contributed to better nutrition.

Incorporating nutrition into IRRI's research goals

The dominant nutritional problem in rice-eating Asia is inadequate quantity of food, which stems from the linked issues of rice supplies, rice prices, and low consumer purchasing power. The principal goal of IRRI research is to increase rice yields and reduce unit production costs for small farmers. Thus, IRRI's goals and programs serve both to increase the quantity of rice available in the market and to increase farm incomes. These objectives, therefore, are generally suited to solve the major nutrition problems caused by a lack of rice supply and poverty.

However, the main source of income for rural landless populations is rice production. IRRI recognizes that its production-oriented goals may not necessarily improve the income or nutrition of this less advantaged group; technologies that maximize yields or farm incomes are not necessarily those that maximize wage income. Therefore, whether innovations are labor saving or labor using and under what prices they are adopted are becoming more important considerations in IRRI's ex-ante evaluation of technological options.

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REFERENCES CITED

1. ADB (Asian Development Bank), Economics Office. 1983. Key indicators of developing member countries of ADB. Vol. 14. Manila, Philippines. p. 1-13.
2. Araullo, E. V., D. B. De Padua, and M. Graham. 1976. Rice postharvest technology. International Development Research Centre, Ottawa, Canada.
3. Aviguetero, E. F., F. V. San Antonio, I. S. Valiente, H. A. del Castillo, and E. L. San Jose. 1978. Income and food consumption (summary of 19 economic surveys). Special Studies Division, Department of Agriculture, Diliman, Quezon City, Philippines.
4. Barker, R., and R. W. Herdt. 1985. Rice economy in Asia. Johns Hopkins Press, Baltimore, Maryland. (in press)
5. Bouis, H. E. 1982. Demand for cereal staples in the Philippines. International Food Policy Research Institute, Washington, D. C.
6. Bouis, H. E. 1982. Rice policy in the Philippines. Ph D dissertation, Food Research Institute, Stanford University.
7. Calabio, J. C., and S. K. De Datta. 1985. Increasing productivity and protein content by using early-maturing rices and efficient nitrogen management. Fert. Res. (in press)
8. Carangal, V. R. 1983. Collaborative research on rice-based cropping systems in Asia. Paper presented at an IRRI Saturday Seminar, 21 May 1983, International Rice Research Institute, Los Baños, Philippines.
9. Chen, L. C., A. K. M. A. Chowdhury, and S. L. Huffman. 1979. Seasonal dimensions of energy-protein malnutrition in rural Bangladesh: the role of agriculture, dietary practices and infection. The Johns Hopkins Press, Baltimore, Maryland.
10. Chong, Y. H. 1979. Malnutrition, food patterns, and nutritional requirements in Southeast Asia. Pages 1-17 *in* the Proceedings of a 1977 workshop held on the interfaces between agriculture, nutrition, and food science. International Rice Research Institute, Los Baños, Philippines.
11. Davidson, S., R. Passmore, J. F. Brock and A. S. Truswell. 1979. Human nutrition and dietetics. 7th ed. Churchill Livingstone, Edinburgh.
12. De Datta, S. K., W. N. Obcemea, and R. K. Jana. 1972. Protein content of rice grain as affected by nitrogen fertilizer and some triazines and substituted ureas. Agron. J. 64:785-788.
13. Dixon, J. A. 1982. Food consumption patterns and related demand parameters in Indonesia: a review of available evidence. Rice Policies in Southeast Asia Project, Working Pap. 6. 51 p.
14. Dowling, J. M., and D. Soo. 1983. Income distribution and economic growth in developing Asian countries. Asian Development Bank Economic Staff Paper 15. Manila, Philippines. 54 p.
15. Eggum, B. O., and B. O. Juliano. 1975. Higher protein content from nitrogen fertilizer application and nutritive value of milled-rice protein. J. Food Sci. Agric. 26:425-427.
16. Eggum, B. O., A. P. Resurreccion, and B. O. Juliano. 1977. Effect of cooking on nutritional value of milled rice in rats. Nutr. Rep. Int. 16(5):649-655.
17. Food and Agriculture Organization. 1972. Food composition tables for use in East Asia. U. S. Department of Health, Education and Welfare and FAO, Maryland.
18. Food and Agriculture Organization. 1977. The fourth world food survey. Rome, Italy.
19. Food and Agriculture Organization. 1980. Food balance sheets 1975-77 average and per caput food supplies 1961-65 average 1967 to 1977. Rome, Italy.
20. Food and Agriculture Organization. 1982. Integrating nutrition into agricultural and rural development projects. Nutr. Agric. 1.
21. Food and Nutrition Research Institute. 1981. First nationwide nutrition survey-Philippines, 1978 (Summary report). National Science Development Board, Philippines.
22. George, P. S. 1979. Aspects of the structure of consumer foodgrain demand in India, 1961/62 to 1973/74. Pages 53-81 *in* Two analyses of Indian foodgrain production and consumption data. International Food Policy Research Institute. Res. Pap. 12, Washington.
23. Gomez, K. A. 1979. Effect of environment on protein and amylose content of rice. Pages 59-68 *in* the Proceedings of the workshop on chemical aspects of rice grain quality. International Rice Research Institute, Los Baños, Philippines.
24. Gonzales, L. A., and B. M. Regalado. 1983. The distributional impact of food policies to nutritional intakes: a first approximation for the Philippines. Agric. Econ. Dep., International Rice Research Institute, Los Baños, Philippines.
25. Guiting, H., A. Te, Z. Xigang, S. L. Travers, L. Xuifang, and R. W. Herdt. 1985. The economics of hybrid rice production in China. IRRI Res. Pap. Ser. 101.
26. Halos, L. S., Y. W. Jeon, and C. W. Bockhop. 1983. Design and performance of a multi-purpose dryer using non-conventional energy sources. A paper presented at the 33rd annual convention of the Philippine Society of Agricultural Engineers, 28-29 April 1983. IRRI, Los Baños, Philippines.
27. Hayami, Y., and R. W. Herdt. 1978. Market price effects of new rice technology on income distribution. Pages 283-302 *in* Economic consequences of the new rice technology. International Rice Research Institute. Los Baños, Philippines.
28. Herdt, R. W., and R. Barker. 1979. Sources of growth in Asian food production and an approach to identification of constraining factors. Pages 21-43 *in* the Proceedings of a 1977 workshop held on the interfaces between agriculture, nutrition, and food science. International Rice Research Institute, Los Baños, Philippines.
29. 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.
30. Indonesia, Central Bureau of Statistics. 1976. National income and consumption survey.
31. Indonesia, Central Bureau of Statistics. 1980. National income and consumption survey.
32. International Food Policy Research Institute. 1977. Food needs of developing countries. projections of production and consumption to 1990. Res. Rep. 3. Washington.
33. International Rice Research Institute. 1974. Research highlights for 1973. Los Baños, Philippines. 62 p.
34. International Rice Research Institute. 1979. Proceedings of the workshop on chemical aspects of rice grain quality. Los Baños. Philippines.
35. International Rice Research Institute. 1982. A plan for IRRI's third decade. Los Baños, Philippines.
36. International Rice Research Institute. 1983. Research highlights for 1982. Los Baños, Philippines. 157 p.
37. Juliano, B. O. 1979. The chemical basis of rice grain quality. Pages 69-90 *in* the Proceedings of the workshop on chemical aspects of rice grain quality. International Rice Research Institute, Los Baños, Philippines.
38. Juliano, B. O., and H. M. Beachell. 1975. Status of rice protein improvement. Pages 457-69 *in* High-quality protein maize. CIMMYT/Purdue Univ., Dowden, Hutchinson and Ross, Inc., USA.
39. Khush, G. S. 1983. Improved rice varieties in restrospect and prospect. Paper presented at the Conference on Women in Rice Farming Systems, 26-30 September, International Rice Research Institute. Los Baños, Philippines.
40. Khush, G. S., and B. O. Juliano. 1982. Status of rice varietal improvement for protein content at IRRI. International Rice Research Institute, Los Baños, Philippines.
41. Khush, G. S., C. M. Paule, and N. M. de la Cruz. 1979. Rice grain quality evaluation and improvement at IRRI. Pages 21-31 *in* Proceedings of the workshop on chemical aspects of rice grain quality. International Rice Research Institute, Los Baños, Philippines.

42. Kikuchi, M., F. B. Gascon, L. M. Bambo, and R. W. Herdt. 1982. Changes in technology and institutions for rice farming in Laguna, Philippines. 1966-1981: a summary of five Laguna surveys. Paper presented at an IRRI Saturday Seminar, 30 October 1982, International Rice Research Institute, Los Baños, Philippines.
43. Padua, A. B., and B. O. Juliano. 1974. Effect of parboiling on thiamin, protein and fat of rice. J. Food Sci. Agric. 25:697-701.
44. Palacpac, A. C. 1982. World rice statistics. International Rice Research Institute, Los Baños, Philippines.
45. Pellett, P. L., and V. R. Young. 1980. Nutritional evaluation of protein foods. The UNU World Hunger Programme. Food and Nutrition Bulletin. United Nations University.
46. Pinstrup-Andersen, P., N. Ruiz de Londoño, E. Hoover. 1976. The impact of increasing food supply on nutrition: implications for commodity priorities in agricultural research policy. Am. J. Agric. Econ. 58(2):131-142.
47. Poleman, T. T. 1981. Quantifying the nutrition situation in developing countries. Food Res. Inst. Stud. 18(1):1-58.
48. Price, E. C. 1982. Developing more productive farming systems. Paper presented at the Workshop on Conquest of Hunger Program Review, May 20, 1982. The Rockefeller Foundation, USA.
49. Ranade, C. G., and R. W. Herdt. 1978. Shares of farm earnings from rice production. Pages 87-104 *in* Economic consequences of the new rice technology. International Rice Research Institute, Los Baños, Philippines.
50. Resurreccion, A. P., B. O. Juliano, and Y. Tanaka. 1979. Nutrient content and distribution in milling fractions of rice grain. J. Sci. Food Agric. 30:475-481.
51. Reutlinger, S., and H. Alderman. 1980. The prevalence of calorie-deficient diets in developing countries. World Dev. 8:399-411.
52. Roxas, B. V., C. L. Intengan, and B. O. Juliano. 1979. Protein quality of high-protein and low-protein milled rices in preschool children. J. Nutr. 109(5):832-839.
53. Seetanum, W., and S. K. De Datta. 1973. Grain yield, milling quality, and seed viability of rice as influenced by time of nitrogen application and time of harvest. Agron. J. 65:390-394.
54. Siamwalla, A., and S. Haykin. 1983. The world rice market: structure, conduct and performance. International Food Policy Research Institute, Res. Rep. 39, Washington.
55. Srinivasan, T. N. 1983. Measuring malnutrition. Pages 23-27 *in* CERES, FAO Review on Agriculture and Development.
56. Swaminathan, M. S. 1983. Utilization of the rice biomass: an opportunity for income generation and training-by doing. Pages 194-197 *in* New frontiers in technology application. Tycooly International Publishing Ltd., Dublin.
57. Tanaka, Y., A. P. Resurreccion, B. O. Juliano, and D. B. Bichtil. 1978. Properties of whole and undigested fraction of protein bodies of milled rice. Agric. Biol. Chem. 42(11):2015-2023.
58. Unnevehr, L. J. 1983. The hidden costs of Philippine government intervention in rice markets. A working paper for the project on Assessment of Food Demand and Supply Prospects and Related Strategies for Developing Member Countries of ADB. International Rice Research Institute, Los Baños, Philippines.
59. Unnevehr, L. J., B. O. Juliano, C. M. Perez, and E. Marciano. 1985. Consumer demand for grain quality in Southeast Asia. IRRI Res. Pap. Ser. (forthcoming).
60. UNU (United Nations University). 1979. Protein-energy requirements under conditions prevailing in developing countries: current knowledge and research needs. The UNU World Hunger Programme. Food and Nutrition Bull. Suppl. 1.
61. USDA (United States Department of Agriculture). 1982. Foreign agriculture circular grains. Foreign Agricultural Service, Washington, D. C.
62. Virmani, S. S., R. C. Aquino, and G. S. Khush. 1982. Heterosis breeding in rice (Oryza sativa L.). Theor. Appl. Genet. 63:373-380.
63. World Bank. 1982. Price prospects for major primary commodities: summary and implications 1. Rep. 814/82.
64. World Bank. 1982. World development report 1982. Oxford University Press.
65. WHO/FAO (World Health Organization/Food and Agriculture Organization). 1973. Energy and protein requirements. World Health Organization. Tech. Rep. Ser. Geneva, Switzerland.

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