THE IMPACT OF NEW GRAIN VARIETIES IN ASIA

ERS-FOREIGN 275

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PREFACE

This report on the impact of new varieties of grain in Asia was prepared by the Economic Research Service under an agreement with the Agency for International Development. It is part of a larger study on the outlook for demand of agricultural products produced by the less developed countries. An earlier version was presented at The Spring Review conference of the Agency for International Development, Washington, D.C., May 13-15, 1969. This report benefited from the many excellent studies prepared for that conference, as well as from discussions by the participants; but the analysis and conclusions contained herein are entirely the responsibility of the author.

This report estimates the contribution of the new varieties of rice and wheat to the production of grain in Asia in 1968-69. Since the estimate is necessarily rough, it is presented as a broad range of possibilities. The paper includes a discussion of various factors which may tend to slow the spread of the new varieties in Asia and also comments on some of the probable economic and social effects associated with these new varieties.

Special thanks are due Donald Chrisler and Dana G. Dalrymple who rendered invaluable service in many ways in preparing the report.

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SUMMARY

In the last 2 years, the rapid spread of highly productive new varieties of rice and wheat in several less developed countries of Asia has increased the likelihood that these countries will improve the diets of their rapidly growing populations. These new varieties of grain, along with better weather, more fertilizer, higher prices to farmers, and other factors, have helped to bring about dramatic increases in grain production in India, Pakistan, and the Philippines.

The new wheat was developed in the late 1950's in Mexico. The rice varieties were developed in the early 1960's at the International Rice Research Institute in the Philippines. Both types of grains have short, stiff straw and produce much higher yields than traditional varieties without lodging. Their adaptability to wide differences in latitude has contributed to their rapid spread.

The new grains can make better use of larger amounts of fertilizer than traditional varieties, but their water requirements are high. The shortage of irrigation systems with adequate water supplies may be the most critical physical factor limiting the further spread of the new grain varieties.

The new seeds produce crops in shorter time periods than most traditional varieties, and thus sometimes make it possible to raise additional crops.

The new varieties have several disadvantages. Wet grain has been a problem, necessitating investment in artificial drying equipment in some instances. Moreover, since consumers rate the new grains rather low on palatability, they have been marketed at considerable discounts. Because of their rapid introduction, these grains may yet prove to be susceptible to native pests and diseases.

The rapid spread of the new varieties has generally been due to vigorous government programs. U.S. aid programs have assisted in a variety of ways. The swift adoption of these grains has clearly demonstrated that farmers in the less developed countries will readily accept new practices when the inputs are available and returns are substantial.

The improved wheat is used on almost all of Mexico's wheat areas. Both the new wheat and new rice varieties have spread rapidly in Asia. In 1968/69, they occupied about 7 percent of the riceland and about 16 percent of the wheatland in the less developed areas of Asia (excluding Communist China). It is estimated that, under average weather conditions, they would add about 9 percent to rice production and 20 percent to wheat production in the area, based on the judgment that their yields are from 30 to 100 percent greater than traditional varieties raised under similar irrigated conditions.

The future spread and production of the new varieties is uncertain. Factors which will influence their adoption include prices of grain and inputs, extension and improvement of irrigation systems, and damage from pests.

Farmers in a position to adopt the new varieties quickly can benefit substantially. Others may be harmed by the increased competition. The effects on farm labor are uncertain. In some situations the new grains may increase demand and thus (at least temporarily) bring about a rise in the wages of farm labor. On the other hand, the corresponding stimulus to mechanization may displace some labor.

The evaluation of the effects of the increased production on consumers requires judgments as to whether the increases will add to net supplies, replace food aid, displace commercial imports, or perhaps, to some extent, be exported. The actual situations will depend upon government decisions as well as market forces.

It seems possible that the less developed countries of Asia can become nearly self-sufficient in grain before many years. However, if supplies continue to grow faster than demand after self-sufficiency is attained, prices will be depressed, unless international markets can absorb additional increases. World supplies of grain have been growing relative to demand. The high producer prices which have been incentives to the rapid adoption of the new technology probably will be impossible to maintain. The poorer countries generally cannot afford to subsidize the production of grain, either to sell domestically at low prices or to export. Already some surpluses have arisen.

The longer run outlook for grain exporters does not appear promising. Surpluses of grain, or the capacity to produce surpluses, especially wheat, seem likely to grow. Government policies in both the developed and less developed countries, with respect to domestic agricultural programs, trade, and aid, will be vital in determining the economic framework in which further increases in production of grain will take place.

THE IMPACT OF NEW GRAIN VARIETIES IN ASIA

by

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THE SETTING

Less than 2 years ago, concern was expressed by a number of commentators that the world was losing the race between population and food production. The evidence usually cited was a comparison between ‘‘recent trends’’ in population and food production, shifts in patterns of grain trade, and a decline in surplus grain stocks, especially those held by the United States. There were even predictions of impending mass starvation.

These pessimistic views about the longrun outlook for food and agriculture were reinforced by shortrun developments. By 1966, world grain stocks were rapidly drawn down, mainly as a result of expanded imports by India and the Soviet Union. India had suffered two droughts in succession, and the Soviet Union had two crop failures in 3 years. Australia also had a poor crop. U.S. stocks were greatly reduced, the outlook for wheat yields was unfavorable, and the acreage allotment for the 1967 U.S. wheat crop was increased considerably.

As a result, the United States made considerable changes in its aid policy. In addition to lending support for population control, more emphasis was placed on agricultural development. Countries receiving assistance were strongly encouraged to place a higher priority on agricultural production.

This crisis atmosphere was an important factor in the rapid adoption of new varieties of grain in Asia. The governments of some Asian countries became especially concerned over their food problems, and the availability of highly productive grains seemed to offer a solution. In some instances, governments mounted high-priority programs to ensure that farmers would quickly adopt the new seed. These programs helped to make the essential inputs available to farmers to grow the new grains. The availability of the inputs together with the incentive of high grain prices quickly spread the new seed over substantial acreages.

Apocalyptic predictions of food shortages are still being made, but in the past year and a half opinions have been expressed that the world food outlook has changed radically. Evidence cited to support this view includes falling grain prices, increased grain stocks, and the rapid spread of the new grains.

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Dramatic increases in production have occurred in India, Pakistan, and the Philippines. In these and several other of the less developed countries of Asia, new varieties of rice and wheat have become significant in a very short time.

For several reasons, it is not possible to estimate accurately either the actual impact of the new grains thus far or their potential. In most less developed countries, statistics on acreage, production, and yields of crops, including grain, are not reliable. The term ''new varieties'' is used to include varying groups of grains. The new grain varieties have not yet been widely tested in most countries, and little information on farm experience is available. In many of the less developed countries, the weather causes wide year-to-year variations in yield. These variations complicate the analytical problem of isolating the effects of the new varieties. Exceptionally high grain prices in recent years have also been influential in the generally enthusiastic reception given the new varieties.

HOW THE NEW VARIETIES WERE DEVELOPED

The new grain varieties which have received the most publicity in the last few years, and which are already making a substantial contribution to increased production in Asia, are the so-called ''Mexican'' wheats, and rice varieties developed and disseminated by the International Rice Research Institute (IRRI), especially those designated as IR-5 and IR-8. These grains were developed in a remarkably short time. However, the breeders of the new varieties had much firmly established earlier work on which to draw.

The Mexican Wheat Varieties

In the early 1940's, a program was initiated in Mexico which concentrated first on improving varieties and increasing production of corn and wheat and was later expanded to cover other commodities. Rust was a major factor limiting the yields of wheat in Mexico, and early breeding efforts were directed to developing resistant varieties (4, p. 3, 26, p. 239). 2/ Later, the breeders concentrated on producing wheat with short, stiff straw and a high response to fertilizer (26, p. 239).

Norin 10, a variety of wheat with short, stiff straw, which was first registered in 1935, was developed by the Japanese by crossing two U.S. varieties with several Japanese varieties. S. C. Salmon, who worked with the Japanese after World War II, brought Norin 10 to the United States where it was distributed to wheat breeders in 1947-48. Orville A. Vogel, a USDA scientist working in the State of Washington, used Norin 10 in developing Gaines wheat, a variety which has set world yield records in the northwest region of the United States. In 1953, Norman E. Bourlaug, a Rockefeller scientist working in Mexico, obtained some wheat varieties with short straw from Vogel. Norin 10 made a major contribution of germ plasm to the new Mexican wheats (26, pp. 236-238).

2/ Underscored numbers in parentheses refer to items in the Bibliography, page 24.

The IRRI Rice Varieties

The new varieties of rice are Indicas. The Indicas have long been predominant in tropical Asia, although their yields have been much lower than the Japonicas of Japan and Taiwan. Despite their higher yields, several characteristics of the Japonicas have prevented their spread into the tropical areas. They are more prone to disease than the native Indicas; they do not thresh well using the methods commonly employed in the Asian tropics; consumers generally do not care for their taste; and they lack a period of seed dormancy. The latter is especially important to prevent germination in areas where the harvest takes place during a rainy period (4, p. 17).

The International Rice Research Institute, which is supported by the Ford and Rockefeller Foundations, was dedicated in 1962 at Los Banos in the Philippines. During 1962, IRRI rice breeders made a number of crosses involving tall, tropical Indica varieties, the Ponlai Japonica variety from Taiwan, and several semidwarf Indica varieties from Taiwan. By 1965, IR-8 had been developed and given its first yield trial. IR-8 was obtained by crossing Peta, a tall rice from Indonesia, with Dee-geo-woo-gen, a short rice from China (8, pp. 252-253).

SOME CHARACTERISTICS OF THE NEW VARIETIES

Because of the genetic characteristics which have been bred into the new varieties of rice and wheat, these grains produce much higher yields than traditional varieties when conditions are favorable. The short, stiff stems are important in achieving increased productivity under heavy fertilization, because the plants do not lodge, or fall over, when heavy applications of fertilizer produce a heavy seed head. Grain which has lodged does not develop properly and is harder to harvest; photosynthesis is interfered with, yields are reduced, and growth of molds is stimulated. Generally, height is reduced when the growing period is shortened (4, p. 16). The new varieties accomplish far more photosynthesis then traditional varieties during the period when the grain is produced. Also, the ratio of grain to straw is greatly increased in comparison with older varieties.

In developing IR-8, thus far the most important of the new rice varieties, breeders reduced the height to 100 centimeters, compared with a height of perhaps 180 centimeters for traditional varieties. The short, upright leaves of IR-8 permit water to run off quickly and allow sunlight to penetrate to the lower leaves. The straw of the plant is not only reduced in length, but it is also exceptionally stiff because the breeders selected plants which had thick stems wrapped with leaf sheaves (8, pp. 254-255). Under some circumstances, the short, stiff stems of the new varieties may be a disadvantage. In East Pakistan, for example, plantings are made on land which is subject to uncontrolled flooding; the native varieties are better able to withstand such conditions.

The Mexican wheats and IR-8 have proved to be productive in areas with wide variations in the length of day. This adaptability has been important in their rapid spread to different latitudes (26, p. 239). The breeders have also incorporated into the new rice varieties the ability to produce many stems on a single plant, which lowers seed requirements (8, p. 252).

The new varieties of rice ripen in 120-125 days, rather than the 180 days required by most traditional varieties (30, p. 2). The shorter growing season increases the possibilities of producing more crops per year on the same land. However, a shorter growing period also sometimes brings the grains to maturity during the wet season. Thus, the customary method of spreading rice on the ground to dry may be inadequate and artificial drying may be required (6, p. 693).

The new rice varieties have some characteristics which make them relatively undesirable for processors and consumers. They do not mill as satisfactorily as older varieties, and consumers generally rate them lower on palatability. Although these disadvantages probably can be bred out, both the new rice and wheat varieties have often sold considerably below the prices of traditional grains (10, p. 44).

AREA PLANTED TO THE NEW VARIETIES

In some areas, the new grain varieties have spread with extraordinary rapidity. This rapid dissemination has been built on a well-established institutional base (as in India's Intensive Agricultural Districts Program), vigorous government action (as in Turkey), or both. Although the existence of an institutional base seems to have been important, many ad hoc arrangements have been employed. In some cases, institutions were used to perform jobs other than their traditional ones (27, p. 28). The availability of a combination or ''package'' of inputs at subsidized prices has greatly stimulated farmer acceptance of the programs. The rapid spread has clearly demonstrated that farmers in less developed countries will quickly and enthusiastically adopt new methods if the inputs are available and the benefits are substantial. AID's role in the programs has been substantial, but has varied according to circumstances in the individual countries.

The improved wheat varieties spread rapidly on the irrigated acreage of the wheat farmers of Mexico from 1949 to 1956. At present, the improved seed is used on nearly all of Mexico's wheat area, of which nearly 90 percent is irrigated and more than two-thirds is fertilized (11, p. 14).

The Mexican wheats were introduced into Pakistan and India in small quantities during 1963/64 and tests were conducted. In 1966, India made a large purchase of seed from Mexico for planting in the fall of that year. In 1967, Pakistan made an even larger purchase (7, p. 90).

Despite their rapid spread, the new varieties were not planted on a large enough share of the grain acreage in Asia in 1967/68 to have had a major impact on production in the less developed countries as a whole. They did affect production in certain regions and in certain countries, however. As indicated in table 1, less than 3 percent of the rice area in South and Southeast Asia was planted to new varieties in 1967/68. Wheat occupies a far smaller share of crop acreage than does rice in the less developed Asian countries, but about 11 percent of the wheat area in West and South Asia was planted to new varieties in 1967/68. The country-to-country variation in the rate of adoption is great. The share of the total wheat area seeded to new varieties in 1967/68 was insignificant in Turkey and Afghanistan but amounted to about 12 percent in Pakistan and nearly 20 percent in India.

Table 1.--Estimated area planted to new varieties of rice and wheat in West, South, and Southeast Asia, 1966/67-1968/69 1/

Country or region	Rice			Wheat		
	1966/67	1967/68	1968/69 2/	1966/67	1967/68	1968/69 2/
	Million hectares					
Turkey					2/0.17 (8.1)	0.60
Iran					(4.2)	
Afghanistan					.02 (2.3)	
Nepal				0.01	.02 (.1)	
West Pakistan		3/(1.4)	0.28	.11	.73 (6.0)	1.21
East Pakistan		0.06 (9.9)	.08		2/ .01 (.1)	.02
India	0.87	1.78 (36.7)	3.77	.52	2.94 (14.9)	4/4.05
Burma		(5.2)	.22			
Thailand		(6.1)				
South Vietnam		(2.3)	.04			
Philippines	.07	.24 (3.0)	.45			
Indonesia		(7.4)	.38			
Total	.94	2.08 (72.0)	5.22	.64	3.89 (35.7)	5.88
Other countries		(5.3)			(.6)	
Total rice area, South and Southeast Asia		(77.3)				
Total wheat area, West and South Asia					(36.3)	

1/ Adapted from Dalrymple, Dana G., Imports and Plantings of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations (unpublished), U.S. Dept. Agr., IADS, Dec. 17, 1968.
2/ Target or projection.
3/ Figures in parentheses are total area.
4/ Given as 2.63 in India Program Memorandum, FY 1970, US/AID Mission, New Delhi, Sept. 1968, p. D-55.

In the 1968/69 crop season, about 5 million hectares were planted to the new rice varieties in South and Southeast Asia, or nearly 7 percent of the total riceland in the region. The new wheat varieties were scheduled for planting on 6 million hectares, or about 16 percent of the total wheat area in West and South Asia.

YIELDS AND PRODUCTION INCREASES

Yields

Reliable estimates of the impact of the new varieties on grain availability in Asia would require the comparison of yields of new and traditional varieties by region, while accounting for the influence of such factors as weather, acreage changes, fertilizer, prices, and availability of credit, irrigation, and extension services. The new varieties are generally produced under the best possible conditions. Therefore, it would be misleading to compare their yields with yields of traditional varieties grown under a variety of conditions and then assign all the differences to the genetic characteristics.

Following are some aspects of the problem of evaluating yields of the new grains:

(1) The new varieties were first planted on substantial acreages in Asia in 1967/68, a year of generally good weather in the region. In India and Pakistan, the large increases in area planted to new varieties in that year coincided with excellent weather, following 2 years of drought. It has been estimated that good weather contributed more than did the new varieties to India's increase in grain production in 1967/68 (33, p. D-20). During the 1967/68 wheat growing season in West Pakistan, average monthly rainfall was 135 percent above that of the previous two seasons (14). Turkey also experienced good weather in 1967/68 and correspondingly high yields.

(2) In 1967/68, the total acreages planted to both new and traditional varieties increased as follows: wheat in India, 10 percent; wheat in Pakistan, almost 10 percent (irrigated wheat acreage expanded 20 percent) (14); and rice in Pakistan, almost 10 percent. Rice acreage remained unchanged in India and, perhaps, in the Philippines. 3/ Turkey's wheat area did not change.

(3) There have been frequent references to planting the best land to new varieties. In Turkey, Mexican wheats were distributed in ''areas of low altitude and high rainfall'' (35, p. 5). In the Philippines, IR-8 was planted on the ''most productive rice growing area'' (28, p. 4). All of the new wheat varieties in Pakistan were planted on irrigated land. This apparently was also the case in India where the Mexican wheats are reported to have been cultivated by better-than-average farmers.

(4) Fertilizer consumption increased 50 percent in India and 30 percent in Pakistan in 1967/68. It is reasonable to assume that much of that increment was used on new varieties, but detailed information is not available.

3/ Estimates of 1967/68 Philippine rice acreage vary by 10 percent.

With adequate water, controlled irrigation, and other improved practices, the increased response of the new varieties to fertilizer can be substantial. The actual yield advantage will depend upon the level of fertilization, which, in turn, will depend upon the farmers' incentives to use fertilizer. The latter will be a function of the price of fertilizer and the price of grain. The yield advantages of the new varieties are generally greater at high levels of fertilizer use; when no fertilizer is used, they seem to have little if any advantage over traditional varieties. Thus, the yield advantages of the new varieties will be relevant only when the economic situation provides an incentive to use fertilizer. For example, one analysis has concluded that with the traditional wheat varieties used in India in 1963, fertilizer (with an ''optimum'' application of 58 kilograms per hectare) holds a promise of only a 50-percent yield increase. But Sonora Wheat 63 can use more fertilizer effectively and (with the application of 116 kilograms per hectare) will give a doubling of yields. Thus, it may be said that Sonora 63 has a 30-35 percent yield advantage over the traditional 1963 varieties (200 percent divided by 150 percent); however, Sonora required twice the dosage of fertilizer applied to the traditional varieties to achieve this yield (32, p. 695). Although there have been a few farm management studies of costs and returns, there is insufficient basis to generalize to aggregate supply functions which would predict the overall response of output to price changes (10, p. 45).

Yield experiences with the new grains have varied greatly, according to farmers' reports (18, p. 7). Numerous experiments and one farmer survey suggest that the new rice and wheat varieties have a yield advantage of 30-100 percent, when planted with adequate irrigation and a high level of fertilization and compared with traditional varieties grown under similar conditions. Data from these field trials are shown in table 2. The last item in each comparison is the traditional variety.

Production Increases

In 1968/69, the new rice varieties occupied about 7 percent ($5.22 \div 77.3$) of the total rice area in South and Southeast Asia (table 1). As shown in table 2, the yield advantage of the new varieties seems to fall within the wide range of 30-100 percent. However, this advantage is in relation to rice raised under some of the best conditions--better irrigation and farmer skills--of the region. Average rice yields in the region before the introduction of the new varieties were about 1.6 metric tons per hectare. Table 2 suggests that under some of the better conditions yields may have been double the average. Thus, 7 percent of the area may have already been producing 14 percent of the rice. A doubling of yields (100-percent yield advantage) by use of new varieties would add another 14 percent to the output. On the other hand, a 30-percent yield advantage would add only 4.2 percent (30 percent times 14 percent). An average of this range would be about 9 percent, a rough estimate of the contribution of the new varieties to rice production, under normal weather conditions, on the area planted to these varieties in 1968/69. This is not an estimate of a growth rate.

Wheat is not nearly as important as rice in the less developed Asian countries, but as shown in table 1, about 16 percent ($5.88 \div 36.3$) of the area was scheduled to be planted to new varieties of wheat in 1968/69. Wheat yields in the region averaged about 1 metric ton per hectare before the introduction of

Table 2.--Yield advantages of new varieties of rice and wheat, compared with traditional varieties, Asia, selected years

Variety	Yield per hectare	Remarks
Rice:	Metric tons	
Dwarf Indica	4.1	Both at 100 kilograms of nitrogen per hectare uniform variety trials, kharif, 1966, India (15, p. 8).
Local Indica	3.2	
IR-8	5.1	All at optimum marginal benefit-cost fertilizer application, experimental, wet season 1966 and 1967, IRRI, Los Banos, Philippines (5, p. 4).
IR-5	4.9	
Peta	2.7	
IR-8	6.2	Same conditions as above, Maligaya, Philippines (5, p. 4).
Peta	4.2	
IR-8	6.8	Same conditions as above except dry season, Maligaya, Philippines (5, p. 4).
IR-5	7.1	
Peta	4.0	
IR-8	n.a.	IR-8 showed 30 percent yield advantage over Peta (5, p. 11).
Peta	n.a.	
Wheat:		
Sonora 63	n.a.	Sonora 63 has a 30-35 percent yield advantage over local varieties, both at optimum levels of fertilization, based on experimental results in India (32, p. 695).
Local	n.a.	
Mexican	4.7	The 1966/67 crop in Ludhiana District, Punjab State, India. Mexican wheat was planted on only 11 percent of the wheat area in the district, probably by the best farmers on the best land (15, p. 9).
Indian	2.4	
Lerma Rojo		Tests and demonstrations, 1966/67-1967/68, India (3, p. 121).
Wheat 64 A	3.7-5.0	
Local	1.9-2.5	
Semi-dwarf	2.8	Both varieties grown on same farm, India (18).
Local	1.6	
''New''	1.8	Both irrigated, West Pakistan (18).
Local	1.0	

n.a. - not available

the new varieties. Again, table 2 suggests that yields under better conditions may have been twice that amount. Using the procedure followed above for rice, it can be roughly estimated that the new varieties would add from about 9.6 to 32 percent to normal wheat production in the region in 1968/69. The average of this range is about 20 percent.

This paper includes no forecast of future increases in production from the new varieties. Unless irrigation systems are extended, plantings will tend to be limited to the areas now adequately irrigated. Expansion on poorer land will tend to lower yields, but experience and adaptive research should help to overcome this problem. Farmer prices for grains, for competing products, and for inputs will affect both acreage and yields, but there is little information available on these factors for making estimates.

MULTIPLE CROPPING

The above estimates do not include the contribution from multiple cropping. An important characteristic of the new varieties is their shorter growing period and consequent potential for multiple cropping. However, even with good irrigation systems, multiple cropping requires a high level of managerial skill to coordinate a series of complex activities; hence, it is unlikely that it will spread quickly to areas where it is not already practiced. 4/ Multiple cropping may also create new problems. For example, in Thailand, in an area where year-round cropping has expanded, ''the presence of lush young plants throughout the year has not permitted the normal insect depletion common when the land was barren six months annually.'' This contributed to the spread of insect-borne disease (13). According to a recent survey, the potential land for double cropping of rice under existing irrigation is less than 10 percent of the total rice area in South and Southeast Asia, where the present double-cropped area amounts to 5 percent of the land in rice (3, p. 65). As irrigation systems are improved and extended and farmers gain experience, the area that is double cropped should be expanded.

In India, about 13 percent (18.6 million hectares) of the net area sown to all crops (138 million hectares) was double cropped in 1967/68. However, the bulk of the double-cropped area (12.5 million hectares) is unirrigated and thus unsuitable for high-yielding grain varieties. By 1969/70, it is expected that the irrigated double-cropped area will increase by only about 2 million hectares --less than 2 percent of the new sown area (33, p. D-5, D-23).

4/ Malaysia, a small producer of rice, seems to be an exception. Less than 5 years ago, an insignificant area was double cropped in Malaysia. In the 1968/69 season, 85,000 hectares were planted with a second crop of rice, compared with 40,000 hectares 2 years before. The area single cropped to rice amounts to about 325,000 hectares. Thus, more than 20 percent of the rice area is now double cropped (12).

LIMITATIONS TO SPREAD IN INDIVIDUAL COUNTRIES

Irrigation

A shortage of good irrigation systems appears to be the most important input limitation to the spread of the new varieties. Unless water can be carefully controlled, the advantage of the new varieties decreases rapidly. Many of the irrigation systems in South and Southeast Asia are not suitable for full realization of the potential of the new varieties. In many existing systems, the water flows by gravity from one field to the next, and fertilizer and plant protection chemicals are carried off in the water. Also, it is sometimes not possible to let the upper fields dry out in time for the harvest of the new varieties and thus the problem of wet grain at harvest is accentuated.

In much of Southeast Asia, the broad valleys will require large dams and long irrigation canals if additional irrigation systems are to be built (16, p. 339). Such systems cannot be built by local enterprise alone. Government action may be required to supply the initative, capital, and expertise, and new forms of cooperative organizations may be necessary to coordinate the use of the water.

In India and Pakistan, irrigation by pumps has grown rapidly. In West Pakistan, nearly 32,000 tube wells were installed by private enterprise in 5 years (3, p. 617). In many areas of Asia, there probably are large underground water resources which could be developed effectively. However, surveys and careful attention to water management will be necessary (3, p. 638).

As shown in table 3, only about 8 percent of India's grain area was planned to be under high-yielding varieties in 1968/69; therefore, it would seem that there is ample room for expansion. However, the 9.1 million hectares planned for high-yielding varieties represents 27 percent of the total irrigated grain area and a much higher, although undetermined, percentage of the land with reliable water control during the dry season. The data shown in table 3 support the view that inadequacy of irrigation is limiting the spread of the new grain varieties in India; the last column shows an almost equal increment in the planned acreage under high-yielding varieties and the planned increases in irrigated grain acreage. The irrigated area projected for traditional varieties remains very large and virtually stable. This suggests that water control on this area is not sufficiently reliable to risk the high costs of the fertilizer and insecticides required by the new varieties. No shortage of seed of the new varieties or of fertilizer is expected. In fact, some of the fertilizer available for 1969/70 will probably be used on traditional varieties.

West Pakistan has a good environment for the new wheat varieties--adequate irrigation, low rainfall, abundant sunshine, and few insects (5, p. 34). Longstanding problems of poor drainage and salinity are now being attacked. About 20 percent of West Pakistan's wheatland was planted to new varieties in the fall of 1968.

The potential for new varieties of rice in Pakistan is far more limited than for wheat. In East Pakistan, where 90 percent of Pakistan's rice is grown, the regular uncontrolled flooding of most of the producing areas lessens the value of the new short-stemmed varieties in the main spring and summer seasons

Table 3.--Grain production and inputs in India, 1967/68, and projections to 1968/69-1969/70

Item	Unit	1967/68	Projected 1968/69	Projected 1969/70	Change 1967/68-1969/70
Grain production..	Million tons	1/ 100	98	103	2/ +10
Total grain area..	Million ha.	1/ 121	119	119	2/ + 1
Irrigated grain area............	do.	31.0	33.3	35.8	+ 4.8
High-yielding varieties of grain on irrigated land	do.	6.5	3/ 9.1	3/ 10.9	+ 4.4
Traditional varieties of grain on irrigated land	do.	24.5	24.2	24.9	+ 0.4
Fertilizer applied to grain 4/	Million nutrient tons	1.18	5/ 1.53	5/ 1.90	+ .72

1/ ''Normal weather'' estimate is 93.1 million tons and 118 million hectares.
2/ Relative to ''normal weather'' estimate.
3/ Plan of the Indian Government.
4/ Fertilizer applied to both high-yielding and traditional grain varieties.
5/ Requirements.

Source: (33, pp. D-4, D-16, D-17, D-20, D-22, D-24, D-26, D-55, E-1.)

(11, p. 19). In addition, insect and disease problems complicate the growing of new varieties in East Pakistan. West Pakistan, which has better growing conditions, produces basmati rice, an extra-long-grain variety. A significant share of this rice is exported at premium prices, and the government has increased the minimum purchase price to deter basmati producers from shifting to other varieties (25, p. 5). However, exports of basmati rice have declined rapidly in recent years.

The main obstacles to a rapid increase in the production of high-yielding rice in the Philippines appear to be the lack of good irrigation, a shortage of rice-drying facilities, and problems of consumer acceptability. The new varieties mature early during the latter part of the wet season. In 1967/68, because of a shortage of drying facilities, many farmers had to sell the new type rice wet in the fields at a 20-percent discount (4, p. 31).

Lack of water control and the inferior quality of the new rice varieties relative to export grades are deterrents to their spread in Thailand and Burma. A shortage of fertilizer at the farm level is a handicap in Burma and Indonesia (4, p. 31).

In Turkey, Mexican wheats seem to be adapted to the warmer coastal areas. The Turkish program for the expansion of acreage in these wheats developed very rapidly with little preparation (2, p. 19). In 1968/69, Mexican wheats were planted on about 7 percent of the total wheatland. It is likely that within a few years the Mexican seed will be grown on much of the southern and western coastal wheatlands, or on about 15 percent of Turkey's total wheat acreage.

New dryland wheat varieties may hold promise for increased yields in Turkey. Varieties are available which, under the proper conditions, greatly increase production without the necessity of irrigation. However, efficient dryland wheat farming is complicated and requires mechanization for proper tillage. The stubble-mulch system, which has been developed in the U.S. Great Plains, requires heavy equipment for subsurface plowing and deep planting. Introduction of such methods in areas of peasant farming will require the development of institutions to obtain and coordinate the use of heavy equipment.

Risks of Diseases and Pests

The new varieties of wheat and rice are exotic to most of the regions where they are being introduced and may become susceptible to local diseases and insect damage. In some countries, little adaptive research and testing was done before the new varieties were introduced. It is possible that microorganisms that were previously unimportant will become major causes of disease as field micro-climates are altered by heavy fertilization and the denser plant population of the new varieties. In the past, the use of locally produced seed of many strains provided some protection against the spread of diseases, since some of the various strains were resistant. The rapid introduction of a single variety on large contiguous areas increases the danger of epidemics (34, p. 468). Plant protection services, which require a high level of technical skill, are primitive in many of the less developed countries. Some problems with diseases and pests have already arisen. In India, the new rice varieties, which have spread much slower than the new wheats, have nonetheless been troubled more by insects and disease (1, rice, pp. 26-31; wheat, p. 26).

Prices and Incentives

The new varieties of rice sell at substantially lower prices than the traditional ones, since consumers generally do not rate them very highly (10, p. 43). The new rice generally is also considered inferior in milling qualities (9, pp. 7, 36). These characteristics, however, may be bred out in a few more years (4, p. 31). As indicated earlier, wet grain may often be a problem with the new rice varieties, but this disadvantage can presumably be overcome with investment in driers. Facilities for storage, processing, and transportation will be taxed as output increases. However, the private trade probably has considerable capacity for expansion to handle the increased production of grain (20, pp. vi, 22, 23).

The new varieties are exceptionally productive only when combined with fertilizer and pesticides, which the farmers must purchase. Thus, farmers using these inputs will of necessity be integrated into the markets; when prices for grain decline, they will tend to buy less fertilizer and pesticides. Of course, the prices of inputs are important, and recently the cost of fertilizer has declined. In the poorer countries, the demand for food grains generally is more elastic than it is in the richer countries, and thus substantial increases in production may be absorbed with relatively small price declines, if the problems of distribution are solved (20, p. 37). However, as the immediate food crisis abates, pressure for government investment in marketing facilities as well as in new irrigation may lessen.

In some cases, the margin of price over cost seems to be so large that considerable price declines could be absorbed without forcing farmers out of production and perhaps without even requiring much cutback in fertilization. Lower wheat prices in India do not seem to have slowed the spread of the new varieties (20, p. 54). However, these effects will depend on the alternatives available to farmers. Some will undoubtedly shift from grain to the production of other products if grain prices decline. In the Philippines, after the price of IR-8 fell, some farmers shifted to Malagkit, a high-priced rice used for cakes and pastries.

There is a rapidly growing demand for fruits, vegetables, and livestock products in the poorer countries. A recent study of the outlook for farm commodities in India projects that demand for milk and milk products will grow faster than supply during the next decade (21, tables 37-39). It is likely that some farmers located close to rapidly growing cities will shift to the production of fresh fruits and vegetables as grain prices decline. If grain prices decline sufficiently, more low quality rice and wheat probably will be fed to livestock. Such changes would be facilitated by research and investment to make inputs more productive in raising fruits and vegetables and in feeding livestock (20, p. 39).

THE BENEFICIARIES—THE PEOPLE LEFT BEHIND

Technological Innovations

The development of more productive varieties of grain is a technological change which lowers the unit costs of production and increases supplies available to consumers. In economic terminology, the new varieties cause a shift in the supply function; that is, at each price a greater amount of grain can be profitably produced and offered for sale than formerly. Technological innovations are among the main factors in economic development, and are important reasons why Malthus' predictions about population have not, and probably never will, come true. On the other hand, technological developments are not magic, and while solving some problems or providing opportunities to solve them, they often create other major economic, social, and political problems of adjustment (31, pp. 77-87; 34, p. 475).

Technological developments affect both outputs and inputs. The effects on outputs are usually desirable; the production of increased amounts of socially desirable goods and the reduction in costs give rise to the possibilities of increased welfare and a lower cost of living. To a large extent the benefits of technological development in agriculture are soon widely distributed among consumers, at least among those consumers who have the purchasing power and the opportunity to take advantage of lower market prices. Lower costs of living may be reflected in lower labor costs and thus have pervasive effects on overall economic development (19, pp. 95, 96). The increased production also may substitute for costly imports. However, in evaluating the effects of the new grain varieties in the poorer countries, even these conclusions must be qualified. A judgment must be made whether the increased output can be expected to result in increased total supplies to consumers or whether it may to a considerable extent displace grain obtained cheaply under concessional arrangements. In some countries grain prices have been high and subsidies substantial, a condition which may have stimulated some high-cost, uneconomic production (20, pp. 55, 56).

The People Left Behind

Not all the effects of technological changes on inputs may be desirable. The owners of some inputs will find that the demand for their services is lessened, at least in their present uses.

The development of the new grain varieties implies a shift in the comparative advantage among areas producing grain. The irrigated areas most suitable for these new varieties gain an advantage relative to other grain-producing areas, and the owners of suitable resources will be benefited. To a considerable extent, unless taxed away, the benefits of these developments will go to owners of irrigated land. Those farmers who are early users of the new process will tend to benefit from increased production and extra income until competition lowers profits. Thus, those farmers who are in a position (because of irrigation, location, credit availabilities, knowledge, etc.) to take advantage of the new opportunities may do very well.

Those farmers who are not in such an advantageous position will find that the increased competition reduces their market opportunities and thus causes them additional difficulties. Opportunities for some of these farmers might be found by research directed at increasing the productivity of labor in dairying and in growing fruits and vegetables (20, p. vi). Policies to improve the operation of the labor market and increase the demand for agricultural labor should have high priority. It is almost universally true in the less developed countries that the nonfarm sector is not growing rapidly enough to absorb a large influx of displaced farm labor. In most of these countries, the labor force in agriculture will continue to increase for some decades. Thus, a strategy for agricultural development which will promote labor-absorbing activities will be important. It has been suggested that the labor-using, capital-saving approach to agricultural development followed in Japan and Taiwan provides a model which should be studied in relation to the ''seed-fertilizer revolution'' (17, p. 2).

The tendency for certain groups to be especially benefited may be accentuated in the adoption of new varieties in some countries because resources are concentrated in subsidized ''packages'' under government programs. There has been a tendency to make the packages available to those regions or farmers where the production response is likely to be greatest. Because of the complementarity between the various inputs required (seeds, chemicals, equipment, credit, information, storage, and processing), the ''package'' approach has been helpful in the rapid spread of the new varieties. However, these programs have been so profitable for the adopting farmers that some of the subsidies used may have been unnecessary. Even in cases where subsidies helped to obtain rapid initial adoption, they will be less necessary as farmers become aware of the potential of the new seed combined with fertilizer. Pakistan, for example, has reduced its fertilizer subsidy (20, p. 56).

In some areas, the success with the new grain varieties has already stimulated considerable investment in machinery, but a lack of machinery, especially drills, threshers, and land leveling equipment has held down yields (18, pp. 13, 14).

Many of the developed countries now have serious social and economic problems arising from the displacement of farm people by technological developments. However, the developed countries have had rapid growth in their nonfarm sectors to absorb most of such people and have been able to afford high welfare costs for some of the others. The developed countries have also had relatively good labor markets and high levels of education which tend to make labor transferable.

The implications of the above arguments are not that technological development is undesirable. Technological changes are inevitable and essential for economic development. However, a few, very limited technological changes cannot be expected by themselves to give a great impetus to economic development. On the other hand, a particular technological change may generate considerable social dislocation and even discord (22, p. 12). The poorer countries do not have all the options open to the developed countries in solving the problems caused by the uneven impact of technological changes. To ignore the existence of these problems might be disastrous. Therefore, it is imperative that close study be given to all alternatives. Research to evaluate these problems and develop policies to solve them should have a high priority.

THE OUTLOOK FOR WORLD SUPPLY AND DEMAND

Demand—Self-Sufficiency

Several recent studies suggest that production of food grains in some countries considered in this report may increase at a rate of 4 to 6 percent a year (11, pp. 19, 27-28; 15, p. 13). On the other hand, it is unlikely that effective economic demand for grain in any of these countries will increase faster than 4 percent a year (less than 3 percent for population growth and perhaps 1 percent from rising per capita income), unless the livestock industry can be developed fast enough to use substantial amounts for feed. Countries now importing grain may use increased domestic production to replace imports. As a precentage of total consumption, imports of grain in most less developed countries are relatively small. Thus, the growth of production at a faster rate than demand could soon eliminate the need for imports. It seems possible that the less developed countries of Asia can generally become self-sufficient in grain before many years, although imports may continue to supply some large coastal cities. Turkey and the Philippines are nearly self-sufficient in food grains. Both Pakistan and India plan to be self-sufficient within a few years.

Self-sufficiency is not necessarily a wise economic goal, however. To the extent that imports of grain are paid for with scarce foreign exchange, the concern for self-sufficiency is understandable. Of course, most of the imports of grain by these countries have been made as food aid with large price discounts. Still, there may be a desire to be free from the uncertainty and restrictions of large imports of food aid. The tightening of the conditions under which U.S. food aid is given undoubtedly reinforces this desire.

As indicated earlier, the demand for grains in the poorer countries probably is elastic enough so that prices need not decline greatly to bring substantial increases in consumption. It has been suggested that, because of the interrelations between agricultural output, income, and demand, ''. . . in early stages of development, increasing agricultural production will not have a strong effect upon prices'' (19, p. 76). However, this conclusion may not be correct in the case of large increases of production in concentrated areas and in poorly organized markets; a description which fits many of the situations wherein the increases of the new varieties have occurred. Despite surpluses of grain in West Pakistan, limited transportation and handling facilities restricted that country's ability to supply East Pakistan in the spring of 1969. In any case, after reaching self-sufficiency, if supplies of grain grow faster than domestic demand, prices will be depressed to some degree, unless the international market can absorb additional increases.

Shortrun Outlook for Grain Exports of the Less Developed Countries

Current world supplies of grain are large relative to demand. In the shortrun, this relationship probably will continue, barring widespread drought or radical changes in policy. In many countries, producer prices are well above export prices; the developed countries in this category are moving grain in world trade with the aid of subsidies. It is unlikely that the less developed countries of Asia will be able to afford to enter into large-scale competition in this market.

At present, Thailand stands almost alone among less developed Asian countries as a major world exporter of grain. The bulk of Thailand's grain is produced at relatively low cost with modest cash inputs and, consequently, is exported without subsidy. On the other hand, several Asian countries producing the new grain varieties have already encountered problems disposing of surpluses. High producer prices have been incentives to the adoption of the new grain technology. An alternative to disincentive prices would be to keep producer prices relatively high and subsidize exports. But the gap between producer and export prices in many Asian countries is wide, and large outlays might be required.

Here, the experience in Mexico may be relevant. Mexico pioneered in adoption of the wheat varieties now being introduced in Asia. In 1963/64, when Mexico became a substantial net exporter of wheat, world wheat prices were at a peak because of the short crop in the USSR. The f.o.b. export price of Mexican wheat was only about 5 percent below the Mexican producer price. In subsequent years, however, the gap widened substantially as export prices fell and Mexico was burdened with a large export subsidy. Since 1966, the Mexican Government has altered its price policy to favor a shift in acreage from surplus wheat to those crops in short supply (such as sorghum and oilseeds). However, the 1966 reduction in wheat support was not sufficient to bring domestic prices down to export price levels.

The Longer Run Outlook for International Grain Markets

The high prices which held in the international rice market in 1967-68 may well be things of the past, and it seems likely that actual surpluses of wheat, or the capacity to produce surplus wheat, will be bearing down on prices for some time to come. In world markets, prices of food grains have tended to be higher than those for feed grains, partly because of government programs specifically designed to benefit food grains. Increased supplies of food grains coming from the new developments will increase the pressure on prices of food grains relative to feed grains.

Even for rice and feed grains, the surplus problem, although less acute than for wheat, may also grow. Thus, market pressures will tend to depress the prices of grains (especially wheat) from recent levels unless offset by government actions. The actual balancing of supply and demand may be made by various combinations of government programs and market forces.

A major difficulty in forecasting future world grain markets is that the policies of governments affect the world grain economy in many and complex ways through price support programs, subsidies, taxes, trade agreements, and food aid. Such government policies have a profound effect on production, utilization, and trade in grains. Although theoretically the effects of changing policies may be analyzed by economic models, the changes in policies themselves cannot be predicted by economic analysis. The economist must rely on ''assumptions,'' which often are of doubtful validity. Since the United States is the world's leading producer and exporter of grain and the largest donor of food aid and other assistance, its policy decisions are of primary importance in determining how world grain trade will actually develop.

During the next decade, assuming general political stability, standards of living and consumption of grain probably will rise throughout the world. In the less developed countries, the per capita growth of consumption in general, and of grains in particular, will be slow. But there is little evidence to support the view that in this period, discounting possible natural disasters, the world food situation will tend to worsen. On the other hand, there will still be many undernourished people in the world, people who are too poor to pay for adequate nutrition.

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