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NEW VARIETIES IN ASIA

THE IMPACT OF NEW VARIETIES OF RICE AND WHEAT IN ASIA

By Joseph W. Willett

SUMMARY

i. In the last two years the rapid spread of highly productive new varieties of rice and wheat in several of the less-developed countries of Asia has helped to change the outlook for the race between food and population in favor of the former. 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 over the low levels of two or three years ago.

ii. The new grain varieties which have spread most rapidly in recent years are wheat, developed in the late 1950's in Mexico and rice varieties developed in the early 1960's at the International Rice Research Institute in the Philippines. The new varieties of both types of grains have short, stiff straw and are able to produce much higher yields of grain than traditional varieties without lodging or falling over. They are adaptable to wide differences in latitude, which has helped their rapid spread.

iii. The new varieties can make better use of larger amounts of fertilizer than can traditional varieties, but they must have adequate irrigation to do so. It appears that the shortage of irrigation systems with adequate water supplies may turn out to be the most critical factor limiting the further spread of the new grain varieties.

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

v. Wet grain has been a problem with the new varieties and investment in artificial drying equipment is sometimes necessary. The new grains have been introduced rapidly with little testing or adaptive research, a risky procedure, and pests and diseases could turn out to be serious drawbacks. Consumers do not rate the new grains highly, and they have sold at considerable discounts in the markets.

vi. The rapid spread of the new varieties has generally been due to vigorous programs by the governments. United States aid programs have assisted in a variety of ways. The rapid spread has clearly demonstrated that farmers in the less-developed countries will rapidly adopt new practices when the inputs are available and returns are substantial.

vii. The improved wheat is used on all of Mexico's wheat areas. Both the new wheat and new rice varieties spread rapidly in Asia, and in 1968/69 they occupied about 7 percent of the rice land and about 16 percent of the wheat land in the less-developed areas of Asia (excluding Communist China). A rough estimate is that they will contribute an additional 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.

viii. The future spread and production of the new varieties is uncertain. It will depend on prices of grain and inputs, extension and improvement of irrigation systems, and damage from pests, among other factors.

ix. The farmers in a position to quickly adopt the new varieties can benefit substantially. Farmers not in such a position may be harmed by increased competition. The effects on farm labor are uncertain. In some situations they increase the demand and thus (at least temporarily) may bring a raise in the

wages of farm labor. However, mechanization is also stimulated and it may displace labor.

x. The evaluation of the effects of the increases in production on consumers requires judgments as to whether or not the increases will be net additions to supplies, will replace food aid, replace commercial imports, or perhaps, to some extent, be exported. The actual situations will depend upon government decisions as well as market forces.

xi. 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 may be impossible to maintain. The poor countries generally cannot afford to subsidize the production of grain, either to give to consumers at low prices or to export. Already some surplus problems have arisen. It seems possible that the less-developed countries of Asia can generally become self-sufficient in grain before many years. However, after reaching self-sufficiency, if supplies grow faster than demand, prices will be depressed, unless international markets can absorb additional increases.

xii. The longer-run outlook for grain exporters does not look promising. Surpluses of, or surplus capacity to produce grain, expecially 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 very important in determining the economic framework in which further increases in production of grain will take place.

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THE IMPACT OF NEW VARIETIES OF RICE AND WHEAT IN ASIA 1/

by

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I. The Setting

1. Less than two 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 a number of predictions of impending mass starvation.

2. Such apocalyptic predictions are still being made, but in the past year and a half views have been expressed that the world food situation and outlook has changed radically. Evidence cited to support the view of a changed world food outlook include falling grain prices, increased grain stocks, and the rapid spread of new varieties of grain in Asia. Dramatic increases in the production of grain have occured in India, Pakistan and the Philippines.

1/ Paper presented at The Spring Review of the Agency for International Development, Washington, D.C., May 14, 1969. This paper was prepared as part of the research done by the Economic Research Service under an agreement with the Agency for International Development on the outlook for the demand for agricultural products produced by the less-developed countries.

2/ Deputy Director, Foreign Regional Analysis Division.

3. Much attention has been focused on the development and rapid spread of more productive varieties of grain. In several of the less developed countries of Asia new varieties of rice and wheat have become important in a very short time. This paper estimates the contribution of the new varieties of rice and wheat to the production of grain in Asia in 1968-69. The estimate is necessarily very rough and is presented as a broad range of possibilities. The paper includes a discussion of various limiting factors which probably will tend to slow the spread of the new varieties in Asia and also comments on some of the probable economic and social effects of the use of these new varieties.

4. For several reasons it is not possible to estimate accurately either the actual accomplishments thus far or the potential of the new varieties. 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 varieties 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 large year-to-year variations in yield, which complicates the analytical problem of isolating the effects of the new varieties. Also the exceptionally high grain prices in recent years have been important in the generally enthusiastic reception given the new varieties.

II. How the New Varieties Were Developed

5. 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. The development of these grains are outstanding examples of effective research accomplished in a remarkably short time. However, the breeders of the new varieties had much solidly-based earlier work on which to draw.

The "Mexican" wheat varieties

6. 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 had been a major factor limiting the yields of wheat in Mexico, and early breeding efforts were directed to developing resistant varieties. (3, p. 3, 19, p. 239) Later the breeders concentrated on producing wheats with short, stiff straw and a high response to fertilizer. (19, p. 239)

7. Norin 10, a variety of wheat with stiff, short straw, which was first registered in 1935, was developed by the Japanese by crossing two varieties from the United States with several

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1/ Underscored numbers in parentheses refer to items in the Bibliography, p. .

Japanese varieties. S. C. Salmon, who had been working with the Japanese after World War II brought Norin 10 to the United States and is was distributed to wheat breeders in this country in 1947-48. Orville A. Vogel, a USDA scientist working in the state of Washington used Norin 10 in developing the Gaines wheat variety, which has set world yield records in the U.S. Northwest. In 1953 Norman E. Borlaug, 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. (19, p. 236-238)

The IRRI rice varieties

8. 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 them from spreading into the tropical areas. They have generally been more prone to diseases than the native Indicas. The Japonicas do not have a period of dormancy of the seed; in those areas where the harvest takes place during a rainy period, a dormant period after harvest is necessary to prevent germination. Also the Japonicas do not thresh well using the methods which are common in the Asian tropics. Furthermore, consumers in tropical Asia generally do not care for the Japonica varieties. (3, p. 17)

9. The International Rice Research Institute, which is supported by the Ford and Rockefeller Foundations, was dedicated in 1962. During 1962, its rice breeders made a number of crosses involving tall, tropical Indica varieties, the Ponlai Japonica

variety from Taiwan and several semi-dwarf Indica varieties from Taiwan. By 1965 IR-8 had been developed and given it's 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. (7, p. 252-253)

III. Some Characteristics of the New Varieties

10. Because of the genetic characteristics which have been assembled by the plant breeders into the new varieties of rice and wheat, under suitable conditions they produce much higher yields than traditional varieties. The shorter, stiff stems are important in achieving the 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, or buckled over, does not develop properly and is harder to harvest; photosynthesis is interfered with and yields are reduced. Generally short stature goes with a shorter growing period. (3, p. 16) The new varieties accomplish much more photosynthesis during the period when the grain is produced; the ratio of grain to straw is greatly increased in comparison with older varieties.

11. In developing IR-8, thus far the most important of the new rice varieties, breeders reduced the height to 100 centimeters, as contrasted with a height of perhaps 180 centimeters of traditional varieties. The leaves of IR-8 are short and upright. This permits water to run off quickly and allows 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. (7, pp.254-255) The short, stiff stems of the new varieties may under some circumstances, be a disadvantage. For example, in East Pakistan much of the rice is planted on land which is flooded after some growth, and the native varieties apparently are better able to withstand such conditions.

12. The Mexican wheats, and IR-8 have proved to be productive in areas with wide variation in the length of day, which is dependent upon latitude. (7, p. 255) This has been important in their rapid spread to regions of different latitudes. (19, p. 239) The breeders have also incorporated into the new rice varieties the ability to produce many stems on a single plant (tillering) (7, p. 252) which lowers seed requirements. In addition, the new rice varieties especially have a significantly shorter growing season than traditional varieties, which increases the possibilities of producing more crops per year. (5, p. 692) The new varieties of rice ripen in 120 to 125 days rather than the 180 days required by traditional varieties (22, p. 2)

13. The new varieties of rice, with their shorter growing periods, sometimes mature during the wet season in the tropics. Thus the customary method of drying, by spreading rice on the road, may be inadequate and artificial drying may be required. (5, p. 693)

14. 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, also, consumers generally do not rate them very highly. Although these characteristics rated undesirable by consumers probably can be bred out, both the new rice varieties and the new wheat varieties often have sold at considerable discounts from the prices of traditional grains. (8, p. 44)

IV. Area Planted to the New Varieties

15. The rapidity of the spread of the new grain varieties in the last few years in some areas has indeed been extraordinary. Where they have spread very rapidly it has been due to a well-established institutional base (as in India's Intensive Agricultural Districts Program), vigorous Government action, and the availability of a combination or "package" of inputs which are usually subsidized and provided at incentive prices in relation to the farmer price of grain. The role of AID in the programs has been substantial, but has varied according to the circumstances in the individual countries. 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.

16. The improved wheat varieties spread rapidly on the irrigated acreage of the wheat farmers of Mexico. (3, p. 3) At present the improved seed is used in all of Mexico's wheat area, of which nearly 90 percent is irrigated and more than two-thirds is fertilizer. (9, p. 14)

17. The Mexican wheats were introduced into Pakistan and India in small quantities during 1963/64. A number of tests were made and in 1966 India made a large purchase of seed from Mexico. The seed was planted in the fall of that year. In 1967 Pakistan made an even larger purchase. (6, p. 90)

18. 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, although they did affect production in certain regions and in certain countries. 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.

19. In the 1968/69 crop season the new rice varieties were planted on perhaps 13 million acres or nearly 7 percent of the total rice land in South and Southeast Asia. The new wheat varieties were scheduled for planting on 14-15 million acres or about 16 percent of the total wheat area in West and South Asia.

V. Yields and Production Increases

Yields

20. It is impossible at present to make reliable estimates of the impact of the new varieties on total grain availability in Asia because of a lack of adequate data to permit comparing yields of new and traditional varieties by region, while accounting for the influence of such factors as weather, acreage changes, fertilizer, prices, credit availability, irrigation, availability of extension services, etc. The new varieties are generally produced under the best conditions and therefore it would be misleading to compare their yields with average yields of traditional varieties, and then assign all the differences to the genetic characteristics.

21. Some aspects of the problem of evaluation are indicated below:

(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 two years of drought. In 1967/68, about 5 percent of India's total grain area was in high-yielding varieties of grain. It has been estimated that it added about 6 percent to India's total grain production in 1967/68 relative to average production during 1959/60-1961/62, and that good weather added about 7 percent. (23, 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. (17) Turkey also experienced good weather in 1967/68.

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 acres					
Turkey				.42 2/	(20.0)	1.48
Iran					(10.4)	
Afghanistan				.06	(5.8)	
Nepal				.02	.06	(.3)
West Pakistan		.01	(3.5) 3/ .70	.26	1.80	(14.8) 3.00
East Pakistan		.16	(24.4) .20		.03 2/	(.2) .05
India	2.14	4.41	(90.7) 9.32	1.28	7.27	(36.9) 10.00 4/
Burma		.01	(12.8) .55			
Thailand			(15.0)			
South Vietnam			(5.7) .11			
Philippines	.18	.59	(7.5) 1.11			
Indonesia			(18.2) .94			
Total above countries	2.32	5.17	(177.8) 12.93	1.56	9.64	(88.4) 14.53
Other countries			(13.2)			(1.6)
Total rice area, South and Southeast Asia			(191)			
Total wheat area, West and South Asia						(90.0)

1/ Adapted from Dana G. Dalrymple's, Imports and Plantings of High-yielding Varieties of Wheat and Rice in the Less Developed Nations (unpublished), U.S. Dept. Agr., IADS December 17, 1968.
2/ Target or projection.
3/ Parenthetic figures are total area.
4/ Given as 6.5 in India Program Memorandum, FY 1970, State/AID, Sept. 1968, p. D-55.

(2) The total acreages planted (including both new and traditional varieties) increased as follows in 1967/68: wheat in India, 10 percent; wheat in Pakistan, almost 10 percent (irrigated wheat acreage expanded 20 percent) (17); rice in Pakistan, almost 10 percent. Rice acreage remained unchanged in India and, perhaps, in the Philippines. 4/ Turkey's wheat area did not change.

(3) There have been frequent references to planting the best land to new varieties. In Turkey, Mexican wheat was distributed in "areas of low latitude and high rainfall." (24, p. 5) In the Philippines, IR-8 was planted on the "most productive rice growing area." (20, p. 4) All of the new wheat varieties used in Pakistan were planted on irrigated land, and this apparently was also the case in India. In India the Mexican wheats are said to have been planted 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 in fertilizer was used on new varieties, but detailed information is not available.

22. With adequate and controlled irrigation and other improved practices the increased response to fertilizer of the new varieties can be large. The actual yield advantage will, of course, depend upon the level of fertilization, which will depend upon the farmers' incentives to use fertilizer, which in turn will be a function of

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

the price of fertilizer and the price of grain. The yield advantages of the new varieties generally seem to be greater at high levels of fertilizer use. When no fertilizer is used they seem to have little if any advantage over traditional varieties. Thus, it will be only when the economic situation provides an incentive to use fertilizer that the yield advantages of the new varieties will be relevant. For example, one analysis has concluded that with the 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 maximum yield increase, but Sonora Wheat 63 can use more fertilizer effectively (116 kilograms per hectare) and gives promise of 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 fertilizer dosage applied to the 1963 varieties to achieve this yield. (1, 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. (8, p. 45)

23. Farmers' yield experience with the new grain varieties has varied greatly. However, a number of experiments, and one farmer survey, suggest that average yield advantages of the new rice and wheat varieties fall generally in the range of 30 to 100 percent, when planted under conditions of adequate irrigation and a high level of fertilization and compared with traditional varieties grown under similar conditions.

24. Table 2 assembles some results from a number of experiments and farm performance. In each comparison the last indicated is a traditional variety.

Table 2.--Data on Average Yield Advantages of New Varieties

Variety	Yield (MT/Ha.)	Remarks
Rice		
Dwarf Indica	4.1	Both at 100 kilograms of nitrogen per hectare uniform variety trials, Kharif 1966, India. (10, 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. (4, p. 4)
IR-5	4.9	
Peta	2.7	
IR-8	6.2	Same conditions as above, Maligaya, Philippines. (4, p. 4)
Peta	4.2	
IR-8	6.8	Same conditions as above except dry season, Maligaya, Philippines. (4, p. 4)
IR-5	7.1	
Peta	4.0	
IR-8	NA	IR-8 showed 30 percent yield advantage over Peta. (4, p. 11)
Peta	NA	
Wheat		
Sonora Wheat 63	NA	Sonora 63 has a 30-35 percent yield advantage over local varieties, both at optimum levels of fertilization, based on experimental results in India. (1, p. 695)
Local Varieties	NA	
Mexican Wheat	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. (10, p. 9)
Indian Wheat	2.4	

Table 2 continued--

Variety	Yield (MT/Ha.)	Remarks
Lerma Rojo Wheat 64 A Local Varieties	 3.7-5.0 1.9-2.5	Tests and demonstrations, 1966/67-1967/68, India. (2, p. 121)
Semi-dwarf Wheat Local Varieties	2.8 1.6	Both varieties grown on same farm, India. (12)
New Varieties Local Varieties	1.8 1.0	Both irrigated, West Pakistan. (12)

Production increases

25. As shown in table 1, in 1968/69 the new rice varieties occupied about 7 percent ($\frac{12.9}{191}$) of the total rice area in South and Southeast Asia. As shown in table 2, the yield advantage of the new varieties seems to fall within the wide range of 30 to 100 percent. However, this yield advantage is in relation to rice raised under some of the better conditions (better irrigation, farmer skills, etc.) 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 yields under some of the better conditions may have been twice that. Thus the 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 x 14 percent). An average of this range would be about 9 percent ($\frac{14 + 4}{2}$), a very rough estimate of the addition to production.

26. Wheat is a much less important crop than rice in the less developed Asian countries, but as shown in table 1, about 16 percent (14.5/90) of the area was scheduled to be planted to new varieties in 1968/69. Wheat yields in the region averaged about 1 metric ton per hectare before the introduction of the new varieties. Again, table 2 suggests that yields under better conditions may have been twice that. Using the procedure followed above for rice, a rough estimate is that the new varieties would add from about 9.6 to 32 percent to wheat production in the region in 1968/69 compared to what production would be without them. The average of this range is about 20 percent.

27. This paper includes no forecast of additional increases of production from the new varieties. The expansion of their area will slow as the adequately-irrigated area is more fully occupied by them. Expansion on poorer land will tend to lower yields, but experience should tend to raise them. Farmer prices for grains, for competing products and for inputs will affect both acreage and yields, but their is little information available for making estimates.

VI. Multiple Cropping

28. 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 co-ordinate a series of complex activities, and it is unlikely that it

will spread quickly to areas where it is not already practiced. 5/ 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. (2, p. 65) As irrigation systems are improved and farmers gain experience, the area double-cropped could be expanded.

29. In India, about 13 percent (46 million acres) of the net area sown to all crops (342 million acres) was double-cropped in 1967/68. However, the bulk of the double-cropped area (31 million acres) is unirrigated and thus unsuitable for high-yielding grain varieties. It is expected that the irrigated double-cropped area will increase by only about 5 million acres--less than 2 percent of the new sown area--by 1969/70. (23, p. D-5, D-23)

VII. Limitations to Spread in Individual Countries

Irrigation

30. A shortage of good irrigation appears to be the most important input limitation to the spread of the new varieties. Unless water can be carefully controlled, the advantage of new varieties decreases rapidly. Many of the irrigation systems in South

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5/ Malaysia, a small producer of rice, seems to be an exception: Less than five years ago, an insignificant area was double-cropped in Malaysia. In the 1968/69 season, 210,000 acres were planted with a second crop of rice compared to 100,000 acres two years before. The area single-cropped to rice amounts to about 800,000 acres. Thus, more than 20 percent of the rice area is now double-cropped. (Kuala Lumpur, AGR-73, October 1, 1968).

and Southeast Asia are not of the proper type 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 chemcials are carried off in the flowing water. Also it sometimes is 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.

31. 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, and therefore, it would seem that there is ample room for expansion. However, the 22.6 million acres planned for high-yielding varieties represents 27 percent of the total irrigated grain area and a very much higher, although undetermined, percent of the land with reliable water control during the dry season. The data shown in table 5 seem to support the view that inadequacy of the irrigation system is limiting the spread of the new varieties in India; the last column shows an almost equal increment in the planned acreage under high-yielding varieties and the planned increase in irrigated grain acreage. The irrigated area projected for traditional varieties remains very large and virtually stable, implying that water control on this area is not sufficiently reliable to risk the high cash costs of fertilizer and insecticides required by the new varieties. There is not expected to be a shortage of seed of the new varieties or of fertilizer (in fact some of the fertilizer requirement for 1969/70 is projected for use on traditional varieties).

32. West Pakistan has a good environment for the new wheat varieties--adequate irrigation, low rainfall, high solar energy, and few insect problems. (3, p. 34) Long-standing problems of poor drainage and salinity are now being attacked effectively. (6, p. 19) About 20 percent of West Pakistan's wheat land was planted to new varieties in the fall of 1968.

33. The potential for new varieties of rice in Pakistan is much 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. (9, p. 19) In addition, insect and disease problems complicate the growing of new varieties in East Pakistan. West Pakistan, which has a better natural environment, 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. (18, p. 5) However, exports of basmati rice have declined rapidly in the last few years.

34. 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 and, in 1967/68, many farmers had

Table 3.--Grain Production and Inputs in India, 1967/68 - 1969/70

	1967/68	1968/69 1/	1969/70 1/	Change 1967/68 to 1969/70
Grain production (million tons)	100 2/	98	103	+10 3/
Total grain area (million acres	300 2/	293	295	+ 3 3/
Irrigated grain area (million acres)	76.6	82.4	88.6	+12.0
High yielding varieties of grain on irrigated land (million acres)	16.0	22.6 4/	27.0 4/	+11.0
Traditional varieties of grain on irrigated land (million acres)	60.6	59.8	61.6	+ 1.0
Fertilizer applied to grain (million nutrient tons) 5/	1.18	1.53 6/	1.90 6/	+ .72

1/ Projections.
2/ "Normal weather" estimate is 93.1 million tons and 292 million acres.
3/ Relative to "normal weather" estimate.
4/ Plan.
5/ Fertilizer applied to both high-yielding and traditional grain varieties.
6/ Requirements.

Source: India Program Memorandum, Fy 1970, State/AID, September 1968, pp. D-2, D-16, D-17, D-20, D-22, D-24, D-26, D-55, E-1.

to sell new type rice wet in the fields at a 20 percent discount because of a shortage of drying facilities and the inferior quality of the rice. (3, p. 31)

In Turkey, Mexican wheat seems to be well adapted to the warmer coastal areas, especially on irrigated fields. In 1968/69, Mexican wheat was planted on about 7 percent of the total wheat land and it is likely that within a few years the Mexican seed will be successfully grown on much of the southern and western coastal

wheat lands, or on about 15 percent of Turkey's total wheat acreage. The Turkish government has also undertaken a program to promote U.S. wheat varieties on the dry central plateau.

35. New dry-land 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 dry-land 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 sub-surface plowing and deep planting. For such methods to be introduced 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

36. The new varieties of wheat and rice are exotic to most of the regions where they are being introduced and, in time, may become susceptible to local diseases and insect damage. In most countries little adaptive research and testing was done before the new varieties were introduced. It is possible that new micro-organisms, previously unimportant, will become major causes of disease as field microclimates are altered by heavy fertilization and the denser plant population of the new varieties. Plant protection services, which require a high level of technical skill, are primitive in many of the less developed countries. (2) Some

problems with diseases and pests have developed. In India the new rice varieties, which have spread much more slowly than the new wheats have faced more such problems than have the new wheats.

Prices and incentives

37. Consumers generally do not give the new varieties a high rating and they sell at substantially lower prices than do traditional varieties. (8, p. 43) The new rice generally is considered inferior to traditional varieties in milling qualities and taste. These characteristics, however, may be bred out in a few more years. (3, p. 31) As indicated earlier, wet grain may often be a problem with the new rice varieties, but presumably can be overcome with investment in driers. Strains will be put on facilities for storage, processing and transportation as output increases.

38. The new varieties are exceptionally productive only when combined with fertilizer and pesticides, which must be purchased by farmers. Thus, farmers using them will of necessity be integrated into the markets and, when prices for grain decline, they will tend to buy less fertilizer and pesticides. Of course, the prices of inputs are important, and the cost of fertilizer has declined. However, as the immediate food crisis abates, pressure for government investment in new irrigation and marketing facilities may lessen. In some cases the margins of prices over costs seem to be so large that considerable price declines could be absorbed without forcing farmers out of production and perhaps without even forcing much cut-back in fertilization. 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. It is likely that farmers located close to rapidly growing cities will shift to the production of fresh fruits and vegetables. It also is possible that more low quality rice and wheat will be fed in the less developed countries, especially to poultry.

VIII. The Beneficiaries - the People Left Behind

Technological innovations

39. The development of more productive varieties of grain is a technological change which permits input factors to produce more grain, thus lowering the costs of production and increasing 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 the heart of the economic development, and are an important reason why Malthus' predictions about population have not, and probably never will, come true. On the other hand, technological developments often create major economic, social, and political problems of adjustment.

40. 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. The latter may be reflected in lower labor costs and thus have pervasive effects on overall economic development. The increased production also may substitute for costly imports. However, in evaluating the effects of the new grain varieties in the poor countries even these conclusions must be qualified. One must judge whether or not he expects the increased output to result in increased total supplies to consumers or whether they may be a considerable exten displace grain obtained cheaply under concessional arrangements. In some countries the prices of grains have been quite high and subsidies substantial, which may have stimulated some high-cost, uneconomic production.

The people left behind

41. The effects on inputs may not all be desirable. The owners of some inputs will find that the demand for their services are lessened, at least in their present uses.

42. The development of the new grain varieties implies a shift in the comparative advantage between 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 beneffited. To a considerable extent, unless taxed away, the benefits of these developments will tend to 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 lower 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 positions will find that the increased competition reduces their market opportunities and thus causes them additional difficulties.

43. The tendency for certain groups to be especially benefitted may be accentuated in the adoption of new varieties in some countries because under Government programs resources are concentrated in subsidized "packages." There has been a tendency for the packages to be made available to those regions or farmers where the production response it likely to be greatest.

44. Generally, in the less developed countries, there probably are not good alternative opportunities in agriculture to which the disadvantaged resources can turn. Such considerations suggest the necessity for research to increase the productivity of resources not just on one, or a few products, but on many products. They also indicate the necessity of policies to improve the productivity of labor and the operation of the labor market. 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.

45. 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 the land leveling equipment has held down yields. (12, p. 13, 14) In most developing countries the labor force in agriculture will continue to increase

for some decades and 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." (11, p. 2)

46. The implications of the above arguments are not that technological development is undesirable. They are rather that a few, very limited technological changes cannot be expected by themselves to give a great impetus to economic development, while a particular technological change may generate considerable social dislocation and even discord. Some such difficulties have apparently already been associated with the use of the new grain varieties. (14, p. 12)

47. The developed countries now have serious problems arising from the displacement of farm people by technological developments. However, the developed countries have been able to afford high welfare costs for some of such people and have had rapid growth in the nonfarm sectors to absorb most of them. They have also had relatively good labor markets and a high level of education which tends to make labor transferable. Technological changes are inevitable and essential for economic development. However, the poor countries do not have all the options of the developed countries to solve the problems caused by the uneven impacts of technological changes.

Research to evaluate these problems and develop policies to solve them should have a high priority.

IX. The Outlook for World Supply and Demand

Short-run outlook for LDC grain exports

48. Current world supplies of grain are large relative to demand. In the short run this relationship probably will continue, barring widespread drought or radical changes in policy. It seems likely that actual grain surpluses or surplus capacity to produce grain will continue to bear down on export prices. 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. Can the less developed countries of Asia enter into large-scale competition in this market?

49. 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, with associated high cash costs of inputs and high producer prices relative to export prices, have already encountered surplus-disposal problems.

50. Relatively high producer prices have been incentives to the adoption of the new grain technology which, in turn, has been partly responsible for the accumulation of exportable surpluses in

several Asian countries. An alternative to disincentive prices, would be to keep producer prices relatively high and subsidize exports. But it appears that the present gap between producer and export prices in many Asian countries is so large that even some lowering of producer prices would still require large outlays for export subsidies. Here, the experience in Mexico may be relevant. The 1968 support prices for wheat in India, Pakistan, and Turkey were substantially above the 1959-65 support price of wheat in Mexico, which remained stable at about $73 per metric ton during that period.

51. Mexico was the pioneer in adoption of the wheat varieties now being introduced in Asia and in 1963/64 became a substantial net exporter of wheat. In 1963/64, world wheat prices were at a peak because of the short crop in the USSR, and 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 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 make exports economic.

Demand - self-sufficiency

52. Several recent studies suggest that production of food grains in the countries considered in this report may increase at a rate of 4 to 6 percent per year. (9, p. 19, 23, 27-28; 10, 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 per year. (Less than 3 percent for population growth and perhaps 1 percent from rising per capita incomes.)

53. An increase in effective demand is an essential stimulant for increased supplies. Thus, after reaching self-sufficiency, if supplies of grain in the poor countries grow faster than domestic demand prices will be depressed, unless the international market can absorb additional increases. 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". (13, p. 76) This conclusion may not be correct in the case of large increases of particular products in concentrated areas in poorly-organized markets, which description fits many of the situations wherein the increases of the new varieties have occured. Already there have been price declines which in some cases have been countered by government purchases. (8, p. 44-45)

54. As a percent of total consumption, imports of grain in most less developed countries are relatively small. Supplies growing faster 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 too many years. Turkey and the Philippines are nearly self-sufficient in food grains. Both Pakistan and India plan to be self-sufficient within a very 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, their 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 provides an additional stimulus to the recipients to decrease it.

The outlook for international grain markets

55. The higher 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 surplus capacity to produce wheat, will be bearing down on prices for some time to come. In world markets, food grains have tended to be at higher prices than 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.

56. There are many uncertainties in trying to look very far into the future of world grain markets but there is evidence to suggest that 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.

57. Standards of living and consumption of grain probably will rise throughout most of the world including most of the less-developed countries. In the latter, 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 the next decade, apart from possible natural disaster, there will be tendencies for worsening food situations. On the other hand, there will still be many undernourished people in the world, people who are too poor to pay for adequate nutrition.

58. 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, food aid, etc. Such government policies have major effects 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 fall back on "assumptions", which often are of very doubtful validity. As the world's biggest grain producer and grain exporter, and the largest giver of food aid and other kinds of aid, the policy decisions of the United States will be important in determining how world grain trade will actually develop.

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