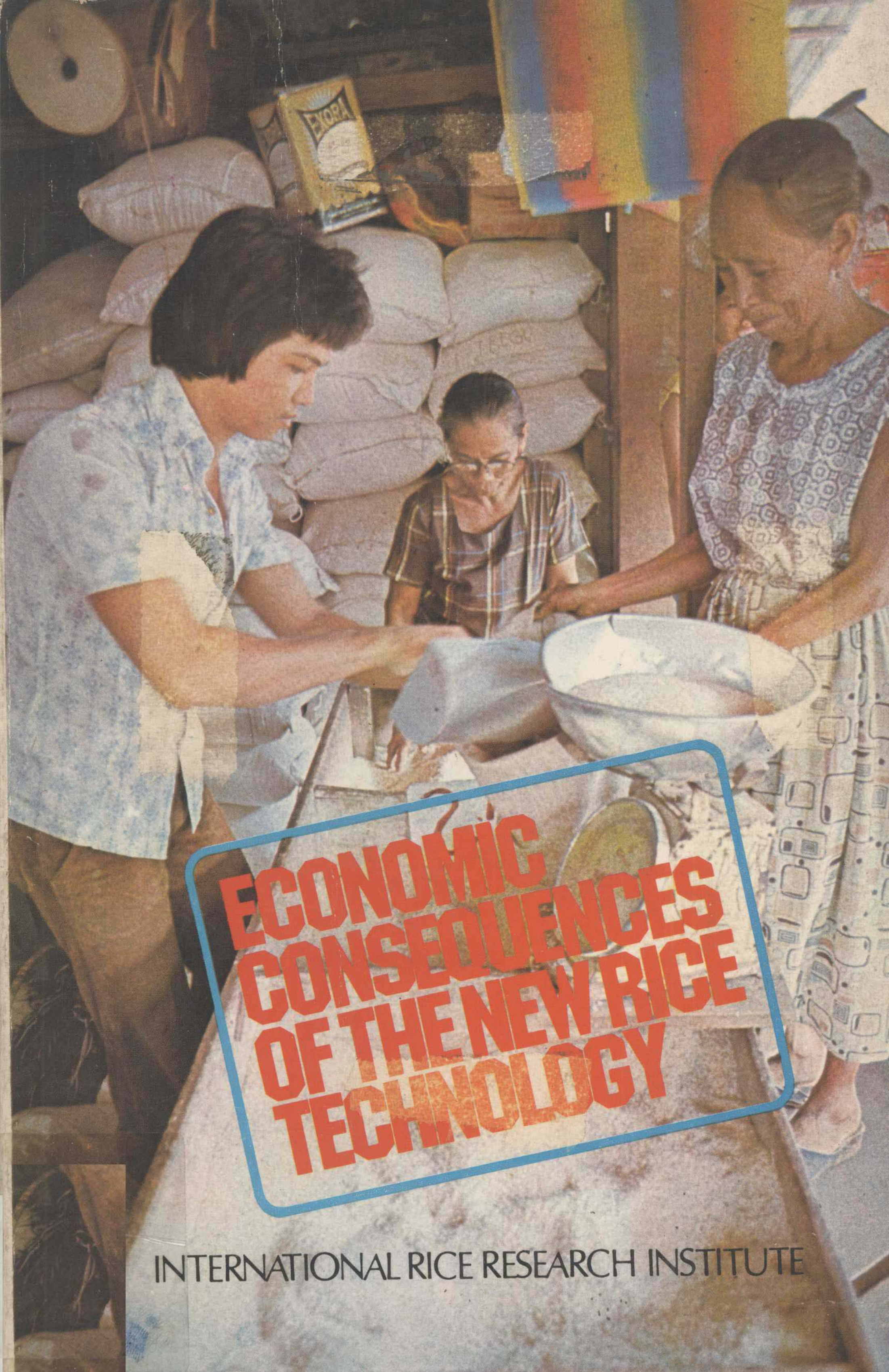

ECONOMIC CONSEQUENCES OF THE NEW RICE TECHNOLOGY

INTERNATIONAL RICE RESEARCH INSTITUTE

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LOS BAÑOS, LAGUNA, PHILIPPINES, P.O. BOX 933, MANILA, PHILIPPINES

Foreword

SCIENTISTS AT the International Rice Research Institute (IRRI) are keenly aware that new technology, although an essential element of agricultural development, can have harmful as well as beneficial effects. Research to identify socioeconomic consequences of the introduction of the new rice technology provides important information for the strategy and design of biological science and engineering research. IRRI's modest efforts in examining the consequences of the new technology have paid high dividends as the contents of this volume will attest.

The conference on the "Economic Consequences of the New Rice Technology" held at IRRI 13–16 December 1976 brought together a number of eminent social scientists 1) to exchange views on research procedures and findings, 2) to appraise the past efforts in *consequences* research at IRRI, and 3) to help set the goals and priorities for future work. Drs. R. Barker and Y. Hayami acted as convenors of the conference and assumed most of the responsibility for technical editing of the papers presented.

These published proceedings reflect the high degree of complementarity between research efforts in the biological and the social sciences.

N.C. Brady
Director General

Preface

THE DEVELOPMENT AND DIFFUSION of modern rice varieties since the mid-1960's have had a profound impact on the economies in tropical and subtropical Asia. Discussions of the socioeconomic consequences of the new rice varieties generated a large mass of literature, both scientific and popular. In many cases, however, the discussions have been impressionistic, not based on solid empirical evidence, as reflected in the sudden shift in the public mood from the initial enthusiasm on the *green revolution* to the current worry about a *world food crisis*.

Since the establishment of the International Rice Research Institute, its economists have engaged primarily in production-oriented micro research to maximize interactions with their colleagues in the biological sciences and in engineering. The objective was to achieve IRRI's primary mission to develop technology for the increase of rice production on farms in developing countries.

That the technology developed must improve the welfare of rural people engaged in rice production has always been kept in mind, however. Likewise, national policies on prices, trade, and provision of infrastructure such as irrigation were clearly recognized as the basic factors either constraining or promoting the realization of the potential of new rice technology. Thus, efforts were made to analyze broader social and economic problems, such as the impact of new rice technology on employment and income distribution, and the interactions between policy and technology.

Until recently, such research was ad hoc, primarily a by-product of direct production-oriented research. The analysis was limited mostly to problems in the backyard of IRRI, namely the Philippines. The trend toward wider use of the modern rice technology has, however, increased the need to assess its broad impact on the various aspects of economy and society in all of rice-growing Asia. In consideration of that need, IRRI organized in 1975 the major program area of *Economic Consequences of New Rice Technology*.

Because the problems to be examined by the *consequences* program are broad and versatile, analyzing them comprehensively is clearly beyond the capacity of IRRI or any other single agency. The need for collaborative research among national and international agencies thus became obvious. For that reason, IRRI organized this conference on the present state of knowledge and the future research need inherent in the socioeconomic consequences of new rice technology.

As bases for the discussion, resource papers based on accumulated empirical research findings during the past 10 years were prepared by IRRI economists. Discussants selected from among the specialists studying the socioeconomic impact of new rice technology in various parts of the world developed positive arguments to either support or refute the conclusions in the resource papers. The conference thus served as an overall critical review of IRRI's *consequences* research. At the same time, it identified the present state of knowledge through the discussions on whether — and how much — the findings at IRRI with respect to the Philippine case have anything in common with those in other countries.

The resource papers and the discussion papers presented at the conference are compiled in this volume. Although the problems covered are far from comprehensive, the materials add significantly to solid empirical evidence and can serve as the basis for future research to resolve controversial issues concerning the development and diffusion of new rice technology in Asia.

Randolph Barker and Yujiro Hayami

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Exploring the gap between potential and actual rice yields: the Philippine case[1]

R.W. HERDT AND T.H. WICKHAM

IN THE INITIAL FLUSH of enthusiasm that followed the release of the first tropical, semidwarf rice varieties that are highly responsive to fertilizers, predictions of imminent self-sufficiency for many of the developing countries were common. The Philippines was mentioned prominently among those expected to achieve self-sufficiency. But after a brief period in 1970 without rice imports, demand in the Philippines regularly exceeded production between 1971 and 1975, with self-sufficiency again proclaimed in 1976. Apparently some problems or constraining factors were not appreciated when the seed-fertilizer revolution started. We now explore some of the possible constraints to Philippine rice production to understand better why rice yields, and therefore rice production, have not increased more rapidly.

In this paper, constraints to rice production include the main factors that keep rice yields low. We briefly review constraints to the adoption of yield-increasing technology and explore in detail the constraints to increasing yields on existing rice land. We are primarily concerned with production constraints that affect farmers and that can be modified, not with those that presently appear to be outside the scope of man's influence.

The objective is to understand why on-farm yields are, on the average, so much lower than those under experimental conditions. The approach is to focus on farm-level constraints with the use of Philippine data.

The first section of the paper briefly discusses some issues relevant to the spread of new technology, the second section examines the possible constraints responsible for the gap between potential and actual yields, and the third section examines the results from a number of multifactor experiments to determine the possible effect of economic forces.

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[1] An earlier version of this paper was published in Food Research Institute Studies, Vol. 14, No. 2 (1975).

CONSTRAINTS TO THE SPREAD OF IMPROVED TECHNOLOGY

The flow of new rice technology from experiment stations must overcome physical, economic, and social constraints before that improved technology is adopted by farmers.

- To be adopted, the new technology must result in greater production per unit of inputs used than that from the previously existing technology.
- Given the costs, prices, tenure, and possible market discrimination that exist for particular individuals or locations, the technology must result in higher returns to family-owned resources than existing technology produces.
- The inputs, credit, markets, and the "social technology"[2] consisting of education, information, and decision-makers willing to take risks must be available for adoption to take place. Variability in yields and net returns must not be greater than that with the old technology.
- The social and personal changes as well as the output increases that result from accepting the new technology must be positively valued by both society and the individual.

There is no particular hierarchy in these requirements, but if any one is not fulfilled for a particular innovation or component of improved technology, then that innovation will not be adopted.

It appears that these conditions have been largely fulfilled for the modern varieties (MV) of rice in the Philippines. The varieties were first released in 1965. In 1966–67, they were planted in 2.7% of the rice area, and by 1969–70 they covered 44% of the area (Dalrymple, 1976). The proportion increased to 56% in 1971–72 and to 62% in 1974–75. Despite rapid adoption of new varieties, however, increases in Philippine rice production were disappointing.

PHYSICAL AND BIOLOGICAL CONSTRAINTS TO YIELDS

The data on actual yields of the MV on farms in the Philippines show why total rice production increases have been disappointing. On the average, MV grown with irrigation yielded 0.3 t/ha, or about 16% more than traditional varieties (TV); in rainfed fields they gave 0.1, or about 8% more than TV (Table 1). The yields are consistent with crop-cut yields in pilot studies. Such studies conducted in 1969–70 on 300 irrigated farms in Central Luzon and Laguna, revealed a 14% yield difference between TV and MV (Wickham, 1973). Absolute yield levels of the irrigated MV averaged 2.1 t/ha, far below the 6, 8, or 10 t/ha that was expected during the early days of IR8 (IRRI, 1967).

REASONS FOR THE YIELD GAP

Why is there such a difference between the expected and the actual? We hypothesize five possible reasons:

[2] We are indebted to Dr. Gelia T. Castillo of the University of the Philippines at Los Baños for this concept.

Table 1. Area and yield of modern [a] and traditional rice varieties under irrigated and rainfed conditions. Philippines, 1968–76 (Bureau of Agricultural Economics, Department of Agriculture and Natural Resources).

Year	Area (thousand ha)		Yield (t/ha)[b]	
	Modern	Traditional	Modern	Traditional
		Irrigated		
1968	447	862	2.0	1.6
1969	913	570	1.8	1.6
1970	827	519	2.2	1.9
1971	985	486	2.0	1.9
1972	977	355	2.1	1.7
1973	873	368	2.0	1.7
1974	1,194	299	2.1	1.9
1975	1,109	303	2.2	1.9
1976	1,207	287	2.3	2.0
Av.	948	450	2.1	1.8
		Rainfed[c]		
1968	254	1,260	1.3	1.2
1969	439	968	1.1	1.1
1970	527	828	1.5	1.5
1971	580	697	1.6	1.6
1972	850	698	1.4	1.4
1973	807	629	1.3	1.1
1974	982	552	1.5	1.2
1975	1,066	608	1.4	1.2
1976	1,092	602	1.5	1.3
Av.	733	760	1.4	1.3

[a]Includes IR-, BPI, and C-series. [b]Yield data converted from sacks of 44 kg. [c]Only lowland rainfed rice.

1. The reporting of yields by farmers is biased.
2. Expectations for the MV were unrealistically high; the *true potential yield* is considerably lower.
3. Potential yields of the MV are not fully expressed under conditions of poor environment.
4. Farmers strive for economic optimum, not maximum yields.
5. The supply of certain production inputs is less than is needed to achieve the economically optimum yield.

Bias in reporting yields. Three factors may bias reported yields:

1. Farmers count only what they actually recover after threshing, and may report their yields after deducting shares paid for harvesting (although care is taken to eliminate this source of error).
2. Errors arise because farmers tend to report the area of their farms to the nearest hectare or half hectare. Because yield is computed by dividing area into production, yields are miscalculated. A consistent direction of bias is serious, but there is no evidence on this point.
3. There is an obvious temptation to underreport for farmers who pay their land rentals as a percentage of harvest. The official data are therefore likely to understate actual yields and even careful survey techniques are likely to have the same problem (IRRI, 1974).

Each of these errors should bias reports of yields from TV and MV in the same way so that relative yields of the two types would be little affected. But even if bias led to underestimation of yields, it is not obvious that this alone would be enough to account for the difference between potential and actual yields of the MV.

High yield expectations. Undoubtedly, the original yield expectations for MV are high. Typical of the enthusiastic optimism was this comment by M. Yudelman(1972): "Where the new varieties of wheat, rice, and corn have been used with appropriate complementary inputs, the yields per acre have risen by as much as 100% . . ."

Those associated with the technological developments were only slightly more cautious. They reported yields 100 to 150% higher than prevailing averages, implying if not explicitly stating the widespread possibility of such yields. Others were somewhat more circumspect. In his 1969 discussion of prospects, Abel (1969) indicated that it was likely that the Philippines "could maintain physical self-sufficiency or have an exportable net surplus in rice for a number of years." Clearly, these expectations were too optimistic, but the question of the actual potential of the MV still remains.

Yields of 8 to 10 t/ha, repeatedly observed at IRRI, have been frequently mentioned and so provide a beginning, although admittedly arbitrary, estimate of the yield potential. The difference between 8 t/ha and the present Philippine national yield of about 1.8 t/ha is assumed as the gap between potential yield and actual yields.

Poor environment. Examining the environmental conditions where yields of 8 t /ha or more have been obtained, one soon wonders if that yield is typical of maximum yields even under those conditions. Is it only possible in dry seasons with exceptional weather even with the ideal water control that exists at IRRI?

To determine the maximum yields possible, considering year-to-year variability, we assembled data from the nitrogen response experiments on IR20, conducted cooperatively by IRRI and the Philippine Bureau of Plant Industry (BPI), during three to six dry seasons at four sites. The experiments were in four different regions of the country, and cannot represent the entire range of diversity in a country with as much climatic and soil variability as the Philippines.

Maximum dry season yields of IR20 averaged 6.4 t/ha for all sites and years with 120 kg N/ha (Table 2). Average yields of IR8 were higher, but IR8 is not presently grown by farmers and no longer appears to be a practical component of imporved rice technology. Newer varieties, such as IR26, have a yield potential close to that of IR8.

The data indicated that with present technology, the average maximum potential yield is 6.4 t/ha. That, however, is only true for the dry season, when the high solar radiation clearly has a favorable influence on rice yields (De Datta and Zarate, 1970). In the Philippines, most of the rice is grown during

Table 2. Average yields of IR20 by season and amount of nitrogen applied at four Philippine sites, 1968-75 (Agronomy Department, IRRI).

Nitrogen (kg/ha)	Average yields (t/ha)				
	IRRI	Maligaya, Nueva Ecija	Pili, Camarines Sur	La Granja, Negros	Av.[a]
			Dry season		
	1969–75	*1970–75*	*1970–75*	*1970–73*	
0	4.5	3.6	3.9	4.1	4.0
60	6.1	4.9	5.6	5.7	5.6
90	6.6	5.2	6.0	6.1	6.0
120	6.9	5.5	6.2	6.9	6.4
150	7.0	5.6	6.1	6.6	6.3
180	6.8	5.5	5.8	5.9	6.0
Seasons (no.)	7	6	6	4	
			Wet season		
	1969–75	*1968–75*	*1968–75*	*1968–73*	
0	3.8	3.4	3.1	3.8	3.5
30	4.2	4.2	3.8	4.7	4.2
60	4.4	4.6	4.2	5.5	4.6
90	4.4	4.8	4.4	6.1	4.9
120	4.0	4.6	4.2	5.8	4.6
150	3.4	4.2	3.7	5.4	4.1
Seasons (no.)	7	8	8	6	

[a]Weighted by the number of seasons.

the wet season, when water is more readily available. About two-thirds is harvested between July and December, after maturing during periods of low solar intensity. One-third matures during the dry season and is harvested between January and June. Many parts of the country do not have a true dry season — there is considerable rain between January and June. But for our purposes the approximation of one-third in the dry and two-thirds in the wet season will be used.

Maximum wet-season yields at IRRI and the three BPI locations were generally obtained from 90 kg N/ha on IR20; the average at that level (four to six seasons and four locations) was 4.9 t/ha (Table 2). Calculating a weighted average of wet- and dry-season maximum yields results in an average maximum potential yield of 5.6 t/ha (a gap of 3.8 t/ha between actual and potential yields).

These data reflect average maximum yields with irrigation, but less than half of the rice area in the Philippines is irrigated. About 45% is rainfed lowland and 13% is upland. To determine the maximum potential yields for rainfed rice, yield data from several experiments by the IRRI Agronomy Department and the Rice Production Training and Research Department between 1972 and 1975 were examined. All the experiments were rainfed lowland with IR20, IR22, or the experimental line IR1529-280-3. Most of the trials were grown at sites in Central Luzon. In all, inputs — except the specified variables being

Table 3. Reported rainfed yields for IRRI varieties in various trials, 1972–1975 (IRRI annual reports, 1972–75).

Location	Year of trial	Main treatments in trial	Levels (no./ treat-ment)	Av. yield (t/ha) of treatments with Maximum yield	Av. yield (t/ha) of treatments with Minimum yield
IRRI	1972	Land preparation	3	4.8	3.2
	1973	Planting method	2		
		Water availability	2		
	1973	Nitrogen	5	4.7	3.5
		Variety	16		
	1973	Nitrogen	3	5.8	3.5
		Water availability	2		
		Variety	2		
		Time of application	2		
	1974	Nitrogen	5	3.1	2.4
		Variety	16		
Central Luzon	1972	Variety	2	5.0	2.0
		Location	2		
		Elevation	13		
	1972	Soil type	5	3.9	3.4
		Nitrogen	4		
		Phosphorus	3		
		Potash	3		
	1972	Package of fertilizer insecticide, herbicide	5	5.5	3.6
	1973	Nitrogen	3	3.7	1.9
		Insecticide & herbicide	2		
		Soil type	4		
	1973	Nitrogen	4	4.7	4.0
		Soil type	5		
	1973	Insecticide	8	4.1	3.5
		Location	9		
	1974	Soil type	3	5.3	1.8
		Location	2		
		Direct-seeding method	2		
Nueva Ecija	1973	Source of nitrogen	3	4.5	2.6
		Variety	2		
		Time of application	2		
	1974	Management package	5	4.6	2.2
	1975	Management package	5	3.6	2.2
		Av.		4.6	2.8

tested — were supplied to obtain maximum yield levels. The treatment giving the maximum yield at most sites was selected, and yields were averaged over all sites. The average maximums ranged from 3.1 to 6.9 t/ha (Table 3). The average over years and trials of the entries in the table gave an estimated potential maximum yield of 4.6 t/ha for rainfed lowland rice.

There are few data on maximum yields with MV as an upland crop, but some show the fertilizer response of upland IR5 (Table 4). Data from three sites, two seasons, and a number of planting dates show that maximum yields generally occurred with 120 kg N/ha, and that such yields ranged from 0.8 to 6.4 t/ha, with an average of 2.8 t/ha.

Having recognized the influence of irrigated, rainfed, and upland water

Table 4. Response to nitrogen of IR5 as an upland crop at three experiment stations in the Philippines. 1970–74 (IRRI Agronomy Department).

Site	Year	Grain yield (t/ha)[a] at kg N/ha		
		0	60	120
IRRI	1970	2.1	2.7	3.5
	1972	2.1	3.0	3.5
	1973	2.4	3.3	3.4
	1974	2.4	2.6	2.0
Maligaya, Nueva Ecija	1970	4.6	6.0	6.4
	1971	2.2	3.5	4.2
	1972	1.5	4.1	4.4
	1973	2.0	2.6	2.0
	1974	1.3	1.6	1.2
La Granja, Negros	1971	0.6	1.2	1.7
	1972	1.5	1.9	2.4
	1973	0.5	0.9	0.7
	1974	0.2	0.5	0.8

[a]Yields are averages over several seeding dates for each year.

regimes on maximum yields, we ask how realistic it is to expect farmers to obtain these maximum yields. Farmers may not find such yields within their reach, because they frequently have neither the control over water that an experiment station does nor the favorable rainfall and moisture conditions represented by the rainfed and upland maximum yield trials.

In recent years, much of the work of IRRI's Agricultural Economics Department has been on the adequacy or inadequacy of irrigation and its implications.

The data shown in Table 5 document some results for a 5,000-ha area within the Peñaranda River Irrigation System in Central Luzon. The area was classified into quarters, and the mean water availability for each quarter was determined as of a certain date during the dry season. Crop-cut yields were taken at the end of the season. All measures were most favorable for the first quarter, and decreased with distance along the canal.

In a 1969–70 study, 11 irrigated sites in Luzon were classified as to location along the first, second, or last third of the distribution canal (IRRI, 1974). Yield losses in the dry season, calculated on the basis of moisture-stress days, were 7% in the first third of the canal, 20% in the second third, and 25% in the last third. The average loss was 17%. Since the 11-site study is more broadly representative than the Peñaranda study, we assume that the average dry-season yields will be 17% lower than the maximum attainable under good water conditions. This conservative estimate of yield reduction due to moisture stress gives an average maximum attainable dry-season yield of 5.3 t/ha.

Yield reduction due to moisture stress in the wet season was considerably less than that in the dry season. At the 11 sites, the reduction was 4% in the first third of the canal system, 4% in the second third, and 8% in the last third, for an