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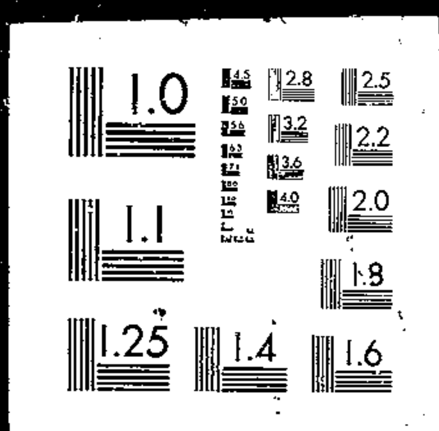

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High Yielding Varieties of Rice in the Philippines: Progress of the Seed Fertilizer Revolution

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About half the lowland rice area in the Philippines was planted to highyielding varieties (HYV's) in crop year 1969/70. The national average yield for all farmers was 1.7 metric tons per hectare. Yields average 20 percent higher for HYV's than for other varieties in the irrigated area and about 10 percent higher in the nonirrigated lowlands. However, one-fifth of the farmers growing HYV's in the irrigated area obtained high yields of more than 3.3 metric tons per hectare, averaging 4.3 tons per hectare. One-third of all HYV growers used no commercial fertilizer, and one-third used no chemicals for weed, pest, or disease control. Those using fertilizer applied an average of 32 kilograms per hectare of nitrogen plus phosphorus, about one-third the recommended rate.

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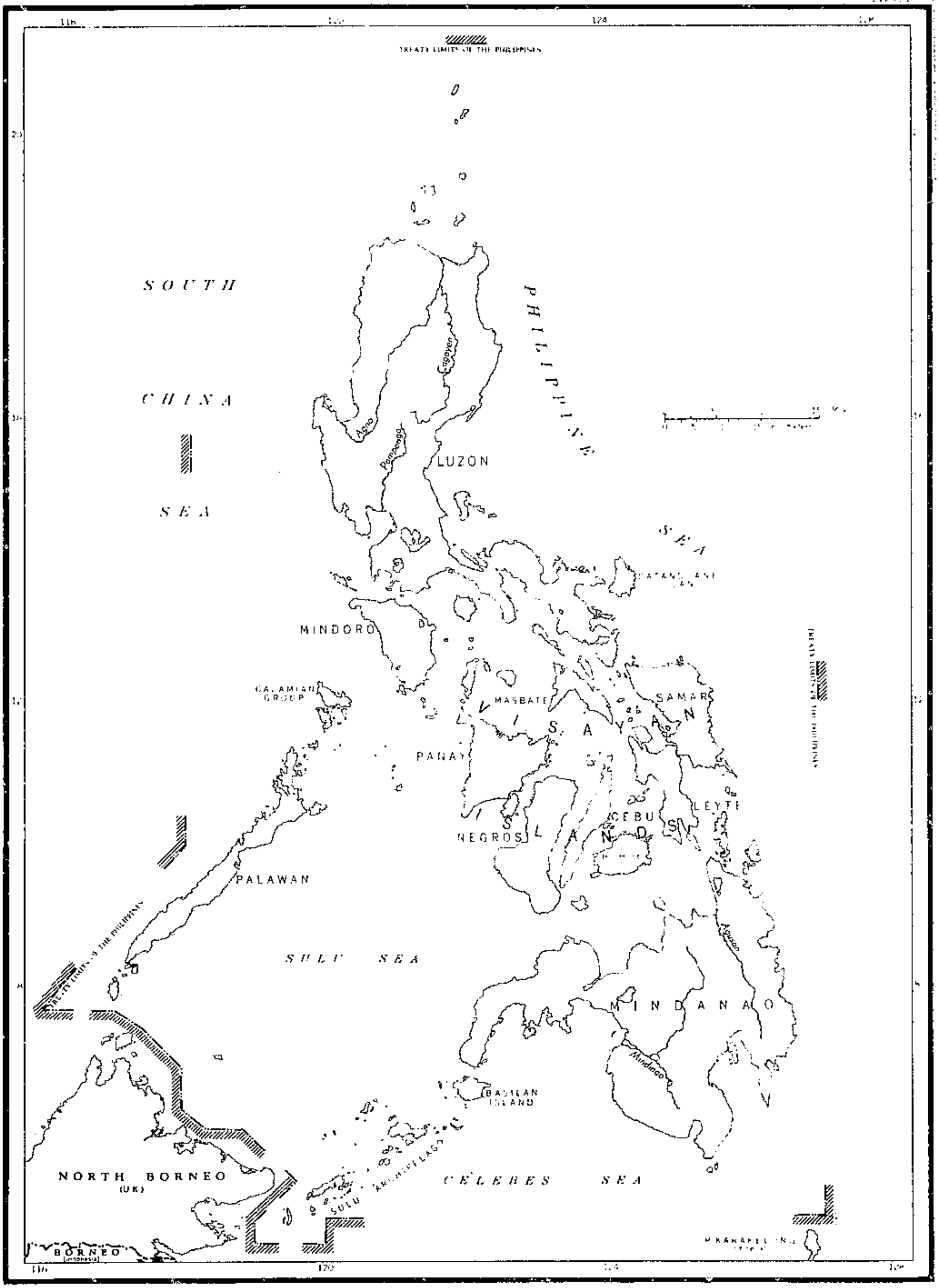
High-Yielding Varieties of Rice in the Philippines

Progress of the Seed-Fertilizer Revolution

L. Jay Atkinson and David E. Kunkel

Foreign Agricultural Economic Report No. 113

Economic Research Service • U.S. Department of Agriculture
in cooperation with the Philippines Department of Agriculture, Bureau of Agricultural Economics



U.S. DEPARTMENT OF AGRICULTURE NEG. FOREIGN AGRICULTURAL SERVICE

HIGH-YIELDING VARIETIES OF RICE IN THE PHILIPPINES, PROGRESS OF THE SEED-FERTILIZER REVOLUTION, by L. Jay Atkinson and David E. Kunkel. Economic Research Service, U.S. Department of Agriculture. Foreign Agricultural Economic Report No. 113.

ABSTRACT

About half the lowland rice area in the Philippines was planted to high-yielding varieties (HYV's) in crop year 1969/70. The national average yield for all farmers was 1.7 metric tons per hectare. Yields averaged 20 percent higher for HYV's than for other varieties in the irrigated area and about 10 percent higher in the nonirrigated lowlands. However, one-fifth of the farmers growing HYV's in the irrigated area obtained high yields of more than 3.3 metric tons per hectare, averaging 4.3 tons per hectare. One-third of all HYV growers used no commercial fertilizer, and one-third used no chemicals for weed, pest, or disease control. Those using fertilizer applied an average of 32 kilograms per hectare of nitrogen plus phosphorus, about one-third the recommended rate.

The calculated yield response for growers of HYV's was lower than the widely used United Nations-FAO fertilizer trial responses, but about the same as the International Rice Research Institute (IRRI) trials for the wet season, although the level of yields in the IRRI trials was about twice as high. The calculated profitability for fertilizer usage and the optimum rate were lower than most previous estimates. Differences in fertilizer usage accounted for little of the variation in rice yields.

Keywords: Philippines, rice, high-yielding varieties, fertilizer response, green revolution.

Conversion Factors

6 pesos = US$1.00
1 hectare = 2.471 acres
1 cavan = 44 kilograms rough rice, paddy, or palay

Washington, D. C. 20250

February 1976

FOREWORD

This analysis of the fertilizer response of high-yielding rice varieties (HYV's) in the Philippines carried out jointly by the Economic Research Service of the U.S. Department of Agriculture and the Bureau of Agricultural Economics of the Philippines Department of Agriculture is part of a larger AID-financed project dealing with agricultural diversification and trade, AID PASA 13-71. Rice is the primary food crop in the Philippines and is the basis of its agriculture. The work of the International Rice Research Institute (IRRI) and the Department of Agriculture of the Philippines, AID, and other international donors has made HYV's available to a large number of Philippine farmers.

Understanding the dominant role of rice in Philippine agriculture in general and in the activities of individual farmers in particular is necessary when evaluating the potential for diversifying the agricultural production base. Other reports produced by AID PASA project 13-71, completed and forthcoming, analyze the conditions needed to achieve this goal.

Leon F. Hesser
Acting Director
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ACKNOWLEDGMENTS

The Bureau of Agricultural Economics of the Philippines provided the principal data used in this analysis. The report was prepared as part of a joint project, AID-PASA 13-71, directed by Leonardo Paulino and Jesus Alix, Chief and Assistant Chief of the Bureau. The Department of Agricultural Economics of the University of the Philippines at Los Banos also participated in the direction of the AID-PASA project.

Considerable technical support in the area of agricultural economics, rice production techniques, and data processing was provided by Francis Sheppard, Reeshon Feuer, and Kenneth F. Smith, respectively, of the AID mission in the Philippines. Randolph Barker, R.W. Herdt, and Thomas Wickham of the International Rice Research Institute provided generous technical advice for this report concerning the interpretation of experimental and farm yield response data. J. Richard Foote, Economic Research Service, on leave with AID, assisted in the writing of certain sections.

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SUMMARY

About half the lowland rice area in the Philippines was planted to high-yielding varieties (HYV's) in the 1969/70 crop year. Yields averaged 20 percent higher for HYV's than for other varieties (OV's) in the irrigated area and about 10 percent higher in the nonirrigated lowlands. However, one-fifth of the farmers growing HYV's in the irrigated area obtained high yields of more than 75 cavans (3.3 metric tons) per hectare. Their yields averaged 97 cavans (4.3 tons) per hectare, or nearly twice the mean for the whole group.

In the irrigated areas in the principal season (wet), one-third of the farmers growing HYV's used no commercial fertilizer and one-third used no chemicals for weed, pest, or disease control. Farmers growing both HYV's and OV's who used fertilizer applied an average of 32 kilograms per hectare of nitrogen plus phosphorus, about one-third the recommended rate for irrigated HYV's.

The calculated response of HYV rice yields to increased applications of fertilizer obtained by growers was lower than the widely used trial responses obtained by the United Nations Development Programme-Food and Agriculture Organization (UNDP-FAO) in experiments in the Philippines. UNDP-FAO results averaged wet and dry se[illegible] trials. However, the calculated response for growers was about the same as responses obtained by the International Rice Research Institute (IRRI) wet-season trials, although the level of yields was only about half as high as the level in the IRRI trials. In the dry season, the level of yields and the response to fertilizer were about the same as in the wet season for all farmers growing HYV's on irrigated land, but both level of yield and the yield response to fertilizer reported for the IRRI trials were about twice as high as those for farmers.

IRRI trials for the dry season resulted in higher yields than the UNDP-FAO trials through most of the range of fertilizer application, as well as greater response to added increments of fertilizer. These high yields and high response to fertilizer during the dry season differ greatly from the yields and responses which average farmers have obtained--a difference which has been widely publicized. Farmers' average level of yields and response to fertilizer were similar, however, to IRRI-observed yields on farmers' fields with moderate water stress, a condition common, and perhaps typical, in the dry season.

Data on farmers' experience with HYV's were obtained from stratified random samples conducted by the Bureau of Agricultural Economics (BAECON) in the Philippines. These samples are the basis of a periodic crop production report, which is designated the Integrated Agricultural Survey (IAS). IAS data used for this analysis include: (1) a detailed analysis of 2,100 farms during the wet and dry seasons of the 1969/70 crop year, and (2) a summary analysis of 10,000 farms during the July to December wet season of 1971. The IRRI data are from a new comprehensive summary of variety trials to determine fertilizer response conducted by IRRI from 1966 to 1971.

Farmers reported paying appreciably more for fertilizer than published market prices. As a consequence, the calculated profitability for fertilizer usage and the optimum rate of application were lower than that previously estimated. The observed fact that most farmers did not follow Extension Service recommendations may reflect their feeling that they would get a lower fertilizer-yield response under farm conditions than under the conditions assumed when the recommendations were formulated.

In fact, recent analyses of IRRI experimental results indicate that based on return-cost considerations the optimum level of fertilizer usage during the wet season is lower than that previously assumed. These analyses, combined with the recent summary of IRRI data, suggest that, on the average, those farmers who used fertilizer came fairly close to an optimum usage. Differences in fertilizer usage accounted for little of the variation in rice yields. More research is needed to find out which constraints are preventing fuller exploitation of the yield potential of HYV's.

The most obvious explanation of the difference between yields obtained by IRRI and those obtained on farmers' fields is that farmers lack the control that the experimental plots have for pests and diseases, water, and timing of operations. IRRI, which has not had extension activities as a major aim, has not determined exactly why experimental results are not being duplicated in farmers' fields, but research on constraints holding down yields on farms is underway. Also, IRRI spares no cost to ensure controlled conditions, which may not be economical or even possible for farmers.

Findings of this research are of particular importance, given current worldwide shortages and very high prices of fertilizer and other petroleum-based chemicals. Factors other than fertilizer usage account for 50 to 80 percent of the variation in farm yields per hectare, and the combined factors other than fertilizer and other chemicals (pesticides and herbicides) accounted for 40 to 70 percent. If the more important "other" factors can be identified by new surveys or experimental results, then increased emphasis can be placed on these in farmer recommendations, so that yields can be maintained or increased despite the tight world supply-demand situation for fertilizer and certain other chemicals.

HIGH-YIELDING VARIETIES OF RICE IN THE PHILIPPINES,

Progress of the Seed-Fertilizer Revolution

by

L. Jay Atkinson and David E. Kunkel 1/

INTRODUCTION

The Republic of the Philippines has played an important role in the introduction of high-yielding varieties (HYV's) of rice in Southeast and South Asia. In summaries of international comparisons, the Philippines leads the list in the proportion of rice area in HYV's. In 1970/71, the Philippines had 50 percent of its area in HYV's, followed by Pakistan with 42 percent, and in total area in HYV's was second only to India. 2/ By 1972/73, high-yielding varieties accounted for 63 percent of all Philippine lowland paddy area planted to rice and 70 percent of the irrigated paddy lands. The location of the International Rice Research Institute (IRRI) in the Philippines has facilitated the introduction of HYV's and adoption of the appropriate technology.

This report is a comparative analysis of yields obtained from HYV's and other varieties (OV's) by farmers in the Philippines, especially those growing rice in the irrigated paddy lands, and as a result of experiments and farm trials. Data on yields obtained by farmers analyzed in this report were drawn principally from the 1969/70 and 1971/72 crop years. The 1969/70 year was a good "normal" year in which more detailed information than usual was collected. The 1971/72 crop year was the last year for which such information was available.

Major objectives are a description of the response of HYV's in the Philippines to fertilizer applications, a comparison of yields of HYV's and OV's, analysis of the contribution of HYV's to rice production, and a perspective on the exploitation of the potential of major technological advances.

We began this study by analyzing farmers' experiences and gains. Initial comparison and contrast with IRRI results were puzzling. Despite great differences in the level of yields obtained, similarities in response to fertilizer appeared--both in trials conducted during the wet season (the principal season) and in water-stress experiments conducted during the dry season. IRRI information on fertilizer response was combined with results of the Philippine Bureau of Agricultural Economics (BAECON) crop report, or Integrated Agricultural Survey (IAS), to trace development of HYV's in the Philippines.

RICE YIELDS (1968-73)--HIGH-YIELDING AND OTHER VARIETIES

Two questions are often asked about HYV's: How much do yields exceed those obtained for OV's? How much did adoption of HYV's affect total production?

Data from the IAS, based on large stratified samples, make possible calculations that provide reasonably good answers for the Philippines.

1/ Agricultural economists, Foreign Demand and Competition Division, Economic Research Service, U.S. Department of Agriculture.

2/ Dalrymple, Dana G., Imports and Plantings of HYV of Wheat and Rice in Less Developed Nations, Foreign Economic Development Report 14, Economic Research Service, U.S. Department of Agriculture, February 1972; p. 51.

Average yields per hectare of HYV's in the Philippines exceeded those of OV's by 30 to 35 percent during 1968-73, years for which IAS data were available. This gross difference is sometimes referred to as the yield gain attributable to the introduction of HYV's. But an adjustment for the varying proportions of HYV's and OV's on upland, irrigated lowland, and rainfed lowland provides a better basis for comparison. If upland rice is omitted from the calculation, since HYV's are of no consequence in upland areas, then the average difference in yield of HYV's and OV's drops to 19 percent for all lowland areas (app. table 3, last column).

Since HYV's are better adapted to irrigated land, and a higher proportion than that of OV's is grown under irrigation, comparative yields were calculated separately for irrigated and for rainfed lowland for 1968 through 1973. The average yield differential for the 6-year period was 14 percent for the irrigated area and 4 percent for rainfed lowland:

Land type	Area			Yield		
	Total	HYV's	OV's	HYV's	OV's	Ratio of HYV's to OV's
	1,000 hectares			Kilograms/hectare		Percent
Irrigated	1,364	837	527	1,990	1,753	114
Rainfed lowland ..	1,423	577	846	1,374	1,317	104
Upland	417			880		

If further adjustment is made for the higher proportion of HYV's on irrigated land, the actual yield differential for HYV's and OV's for all lowland was 11 percent for the 6-year period, with these annual average differences:

Year	Percent
1968 ...	17
1969 ...	8
1970 ...	8
1971 ...	4
1972 ...	14
1973 ...	13
1968-73 average	11

It is often said that differences in yields of HYV's and OV's have declined over the years. Although the difference in 1968 was greater than that in any other year, no subsequent trend is apparent; there are merely annual fluctuations.

The 11-percent greater yield for HYV's in 1968-73 is adjusted only for irrigation. Even this yield difference might be overstated because HYV's would be adopted in the more productive areas. However, some evidence showed that the yield difference of 11 percent might have been understated. A detailed regression analysis of a sample of the 1969-70 data showed differences of about 20 percent in favor of HYV's for the irrigated area, about 10 percent for the wet season rainfed lowland, and no difference for the dry season rainfed, or a weighted average of 13 percent. In any case, the 11- to 13-percent range difference in yields of HYV's and OV's is strikingly smaller than the usual estimates of 30 to 35 percent (app. tables 1-3).

How much has production been increased by the adoption of high-yielding varieties of rice in the Philippines? Again the result of using IAS data and multiplying the 30 to 35 percent higher average yield for all HYV's times the area planted to HYV's suggests that production was increased 12 percent over 1968-73. However, if the differences are calculated separately for irrigated lowland, rainfed lowland, and upland, the 6-year average difference is 5 percent; however, increases for the past 2 years have been above 7 percent (app. table 2).

HYV's were introduced in about 1967. Since then, yields of OV's also have shown some increase. Some rise may be attributable to a change in method of estimating yield introduced in 1970. Nevertheless, the considerably smaller yield differences of HYV's and OV's calculated above appear to be better estimates of the average differences in yield obtained by Philippine farmers adopting HYV's than those calculated from experimental data, most farm trials and demonstrations, and intuitive estimates not based on systematic farm surveys.

In order to obtain improved technology and higher yields, the Philippine Government launched an expanded extension program in 1973/74 called "Masagana 99." Special attention is being paid to providing delivery of purchased inputs. Credit is provided for fertilizer at subsidized prices and for other purchased inputs. Also, a stepped-up land reform program holds the promise of land ownership for tenants. Rice production rose to a new high in 1973/74, 5 percent above the previous high in 1970/71, and the preliminary estimate for 1974/75 was for a crop nearly as large as that the year before.

Data Description

Two types of data are analyzed in this report: The general samples of farmers collected by the BAECON for its survey, and fertilizer response experiments conducted by IRRI, including supervised trials in a farmer's field. These are compared with data from detailed observations by IRRI of HYV's on unsupervised farms with varying types of irrigation that produced a range of water-stress conditions common to Philippine farms.

IAS data are drawn from the 1969/70 and 1971/72 crop years. For 1969/70, a subsample of 2,100 farms was drawn from the IAS. This was a good "normal" year in the Philippines, and more input information was collected than in other years. More limited data from a larger sample in 1971/72 provide comparable IAS data only for the wet season.

IRRI fertilizer response experiments with HYV's and OV's were conducted in experiment stations located at Los Baños and elsewhere in the Philippines. Data shown in this report are from a comprehensive analysis (1966 through 1971) of all fertilizer response trials in various IRRI stations in the Philippines of varieties released for farm use. About 1,000 trials conducted at Los Baños were examined. 3/ The relationships developed in the analysis excluded trials that gave results contrary to theoretical expectations, such as those showing increasing returns throughout the range of fertilizer application.

The trials in a farmer's field in Laguna were rather closely supervised by the agronomy department of IRRI, so that results were not much different from IRRI experiments, although the management used may be within reach of many farmers who have access to good irrigation. Water-stress studies were of unsupervised farms, selected to include those with less than adequate irrigation.

The information obtained by a combination of experiments, farm trials, observations of selected farms, and general sample surveys selected for our analysis provided a broad range of yield-fertilizer response data. Interpretation of these data turned out to be surprisingly consistent. For those analyses that related to individual farms, error terms (i.e., unexplained variations) were much larger than the variation explained by the factors for which data were available from the surveys. For controlled experiments, error terms of about 20 percent were common. Research is currently underway to isolate factors now included in error terms, and further research and surveys in this area are needed urgently.

This report presents results of the IAS data in detail, makes summary comparisons of yields resulting from IRRI experiments and farm trials, and refers briefly to the water-stress results.

General Comments on Yields

IAS sample data for 1969/70 were broken down into data on HYV's and OV's during the first semester or wet season (July-December 1969) and second semester or dry season (January-June 1970) on irrigated and rainfed land. Enough farms were available in each of these groups, except rainfed in the second semester, to permit a statistical analysis. Rice yields for irrigated areas averaged 500 to 700 kilograms per hectare higher than those for rainfed areas. In the irrigated areas, the HYV yields averaged 350 to 400 kilograms higher than the OV yields, whereas in the rainfed areas, the HYV yields were about 190 kilograms higher than OV yields in the wet season and about equal to yields of OV's in the dry season. Table 1 shows average and median yields, and figure 1 illustrates yield distributions.

In contrast to the IRRI experience and some farm trials and demonstrations, wet season yields for varieties on irrigated land in the IAS sample averaged approximately 130 kilograms higher than yields during the dry season. Upland yields averaged 450 kilograms less than rainfed lowland yields.

3/ Pisithpun, Saowance, Fertilizer Response of Rice under Varying Environment and Management Practices, University of the Philippines, Los Baños Experiment Station, Philippines, Oct. 1973.

Table 1--Philippines: Average and median yields of HYV's and OV's, irrigated and rainfed lowland, and upland farms reported by IAS, 1969/70

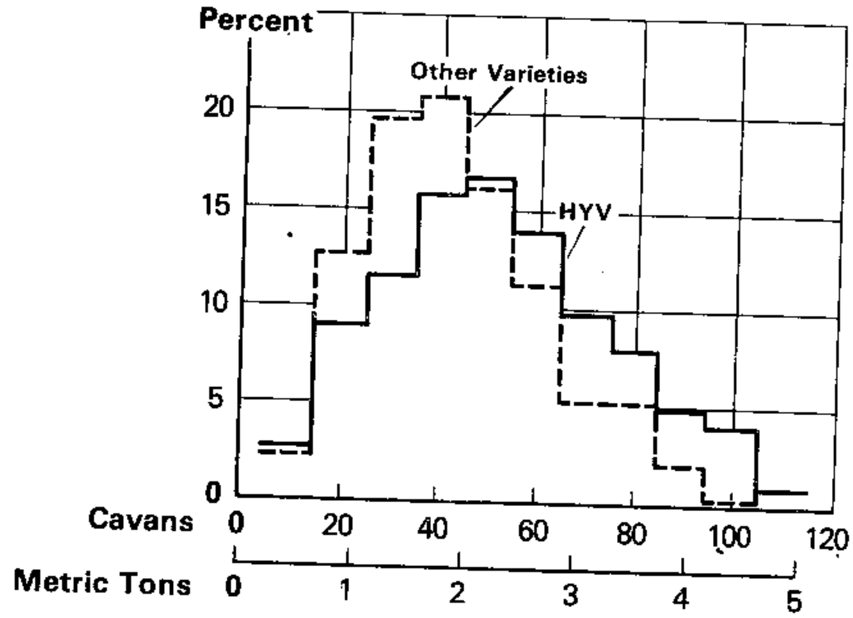
Season and type of farm	Mean	Median	Mean less median	Number of farms reported	Number of farms as share of total
	Kilograms	Kilograms	Kilograms	Number	Percent
Wet season:					
Irrigated lowland:					
HYV's	2,385	2,262	123	351	55
OV's	1,989	1,830	159	265	42
Difference	396	432	---	---	---
Total	---	---	---	1/634	100
Dry season:					
Irrigated lowland:					
HYV's	2,262	2,147	115	319	67
OV's	1,905	1,663	242	144	30
Difference	357	484	---	---	---
Total	---	---	---	1/479	100
Wet season:					
Rainfed lowland:					
HYV's	1,778	1,606	172	259	33
OV's	1,588	1,465	123	485	62
Difference	190	141	---	---	---
Total	---	---	---	1/778	100
Dry season:					
Rainfed lowland:					
HYV's	1,426	1,170	256	146	49
OV's	1,390	1,188	202	150	50
Difference	36	-18	---	---	---
Total	---	---	---	1/298	100
Upland:					
Wet season	1,140	968	172	338	---
Dry season	1,580	1,144	436	29	---
Total	1,307	---	---	367	---

1/ Includes a small number of mixed HYV's and OV's.

Source: Subsample of IAS, BAECON, crop year 1969/70.

Yield Distribution, Irrigated Paddy, 1969-70

First Semester



Yield Distribution, Nonirrigated Paddy, 1969-70

First Semester

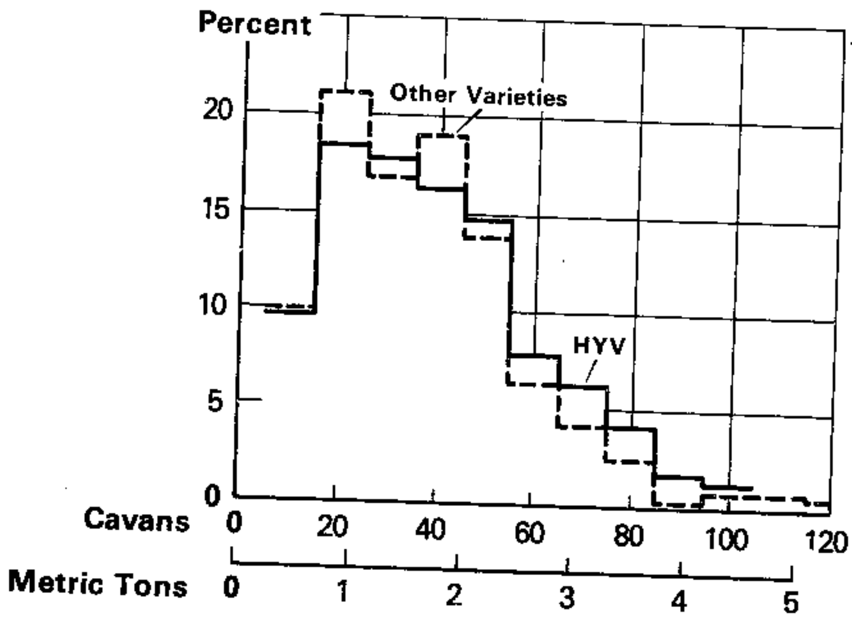


Figure 1

Other Yield Comparisons

The difference between yields of HYV's and other varieties reported in the IAS data were smaller than the differences reported in most published comparisons, especially those based on experiments or supervised farm trials. However, a few published comparisons based on data from farms show results similar to those reported here. In one study, small differences were found in yields of HYV's and OV's for the 1967/68 season in Laguna and Rizal Provinces, which lead in adoption of HYV's. 4/

BAECON researchers using IAS data for crop years 1968 and 1969 found that average yield on irrigated land for IRRI-developed HYV strains was 1,890 kilograms per hectare, compared with 1,630 kilograms for OV's--an advantage of 260 kilograms. 5/ Some IRRI comparisons of HYV and OV yields on farms have also shown small differences and poor response to fertilizer. 6/ 7/

Distribution Characteristics

In general, yield distributions, like incomes, are skewed to the right, with the median smaller than the mean (table 1). For irrigated paddy production, adoption of HYV's leads to a more normal distribution. For rainfed or nonirrigated lowland paddy, the shift is a further skewing to the right.

Rather wide variation in yields around the mean was reported, and size of farm and area harvested were small (figs. 1 and 2). There is a reporting problem for area of farm and area harvested which relates to the unit in which land is measured. Since most farms are less than 4 hectares in size, there is a tendency to report farm size at standard reference points such as 1/2, 1, 1-1/2, 2, 2-1/2, and 3 hectares. In the sample used, over two-thirds of the farmers reported harvested area on these points. Use of a smaller unit such as dekars (1/10 hectare) would permit more precise determination of yields. Rounding increases the variation in yields and possibly produces biases if systematic underreporting or overreporting occurs. 8/ In the regression analysis which follows, little can be done to account for this source of variation, which, if large, may tend to obscure any true relationships.

MULTIPLE REGRESSION ANALYSIS

A regression analysis was run, with yield as the dependent variable. Numerical independent variables were fertilizer (kilograms), chemicals (pesos), and irrigation fee (pesos). In addition, dummy variables were included for region, size of farm, tenure, and type of irrigation. The general form of the regression function was as follows:

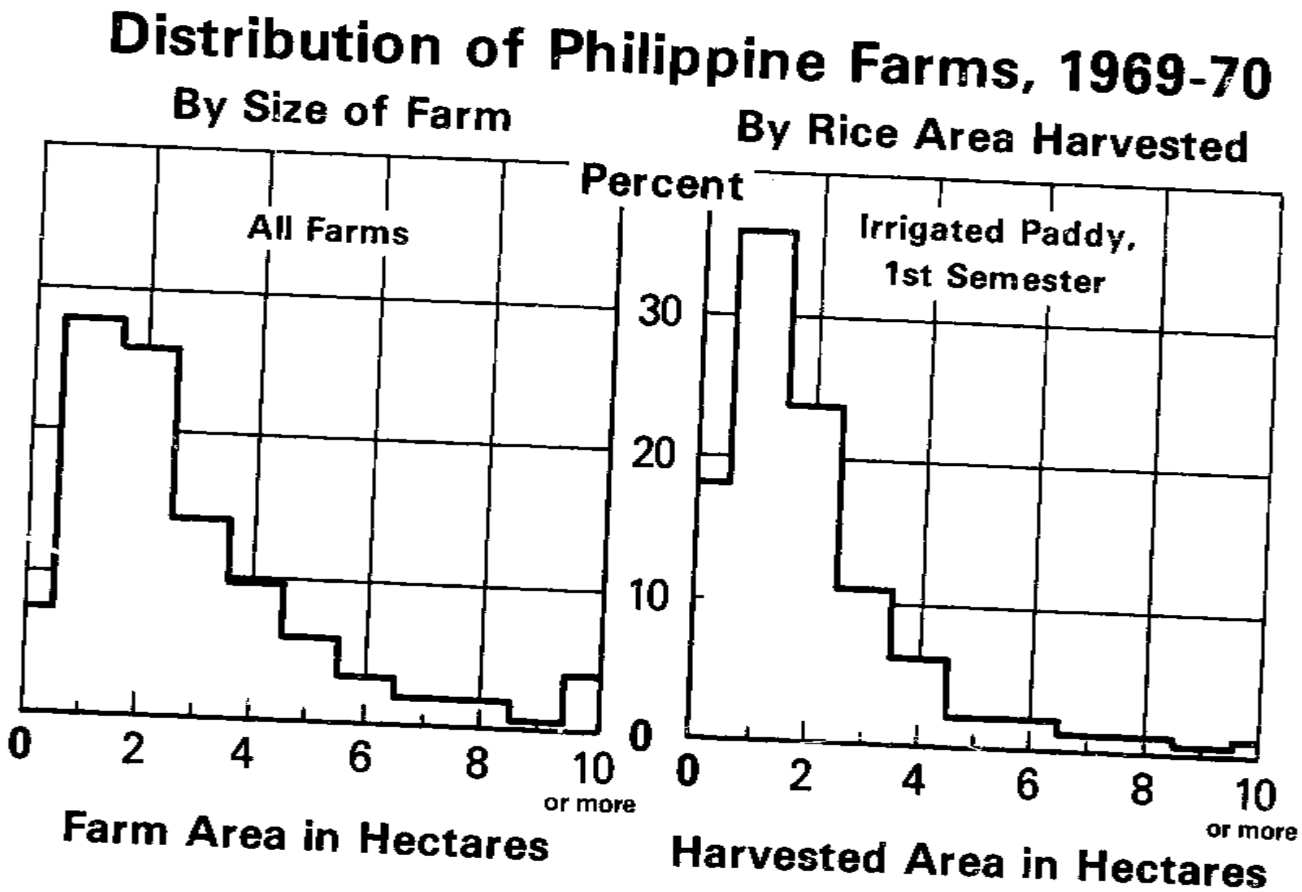
4/ Manuel, P.C. and Lopez, M.P., Productivity of Farms Using Traditional and Improved Rice Varieties in Rizal and Laguna, pp. 3-1 to 3-20, seminar on Economics of Rice Production in the Philippines, UPCA-IRRI, 1969.

5/ Paulino, L.A. and Trinidad, L.A., The Shift to New Rice Varieties in the Philippines, pp. 1-1 to 1-20, op. cit.

6/ R. Barker and associates, The Probable Impact of the Seed-Fertilizer Revolution on Grain Production and on Farm Labor Requirements, mimeo paper prepared for Stanford University Conference, Dec. 1971. (Preliminary paper is more explicit than published one.)

7/ Mandac, A.M., An Economic Analysis of Factors Affecting Yield of Rice in 1973-74 Central Luzon Farmers' Field Experiments, IRRI seminar paper, Dec. 7, 1974.

8/ Gomez, K.A. and Onate, B.T., "Response Bias in the Collection of Rice Statistics," The Philippine Agriculturalist, Vol. III, Feb.-Mar., 1969, pp. 602-613.



Distribution of Philippine Farms, 1969-70
By Size of Farm
By Rice Area Harvested
Percent
All Farms
Irrigated Paddy, 1st Semester
30
20
10
0
0 2 4 6 8 10 or more
Farm Area in Hectares
0 2 4 6 8 10 or more
Harvested Area in Hectares

Figure 2

$$\text{Yield paddy (Kg./ha.)} = F\left(\begin{array}{llll}\text{Fertilizer} & \text{Chemical} & \text{Irrigation} & \text{Dummy variables: region,} \\ \text{(Kg. N+P/ha.)} & \text{expendi-} & \text{fee} & \text{size of farm, tenure,} \\ & \text{tures} & \text{(Pesos/ha.)} & \text{type irrigation} \\ & \text{(Pesos/ha.)} & & \end{array}\right)$$

For fertilizer both a linear and a quadratic term are fitted:

$$Y = a + b_1 (X_F) - b_2 (X_F)^2 + b_3 (X_c) + \dots .$$

where Y = yield paddy in kgs./ha.
X_F = fertilizer in kgs./ha. of Nitrogen + Phosphorus
X_c = chemicals in pesos/ha.
a = constant
$b_1, b_2, \& \ b_3$ = coefficients to be fitted.

Quadratic terms were tried for chemicals and interaction terms for fertilizer and chemicals, but they were statistically insignificant and unstable. With the exception of fertilizer, the discussion that follows deals with coefficients in the final equation (see the first column of table 2).

A stepwise program was used, with variables entering the calculation if the standard error was no larger than the regression coefficient (t=1). Once entered, the variables were carried through subsequent steps even if the t-value fell below one.

Some constraints were introduced. The variables were partially ordered with the most relevant economic variables entering the calculations first, beginning with fertilizer and chemicals. Each of the components of a dummy variable group, such as the several regions, were kept together. For one equation, the OV alternate (no. 2.2) shown in table 2 but not discussed in detail, the stepwise regression was halted when intercorrelation between independent variables resulted in coefficients that were unstable and implausible.

The importance of fertilizer response of HYV's has been stressed in experiments and demonstrations. The simple relationship between yield and fertilizer application per hectare for HYV's irrigated in the first semester for the IAS sample is shown in the scatter diagram (fig. 3). Correlation between yield and fertilizer is not high (r^2=0.12), and only a small proportion of the variation in yield is explained by variation in fertilizer use, even with the addition of the quadratic term of fertilizer squared. Nevertheless, the fertilizer and fertilizer squared terms account for more than half the explained variation in yield.

The second input available from the sample is expenditure for chemicals to control weeds, pests, and diseases. Chemical expenditure may not be as satisfactory an independent variable affecting yield as fertilizer, since the use of more chemicals might reflect a more serious pest problem to be controlled instead of a higher level of pest control.

For herbicides there are specific recommendations, and relatively low cost herbicides are reported to give good control under good moisture conditions, if directions are followed. Nevertheless, herbicides are used little on Philippine farms. Because control of pests and diseases requires diagnosis and proper choice among many available pesticides, the situation is more complicated and no general recommendations are applicable. One of the major thrusts of IRRI is to produce resistant strains or seed varieties.

Table 2--Philippines: Regression results for irrigated rice production, first semester 1969/70 1/

Item	All farms using HYV's		Farms reporting OV's and use of fertilizer	
	Fertilizer use measured in:		Fertilizer use measured in:	
	Kilograms of N+P per hectare	Pesos per hectare	Kilograms of N+P per hectare	Pesos per hectare
Equation number	1.1	1.3	2.2	2.4
R^2	.1660	.1769	.2311	.3508
F	6.857	8.355	4.847	4.087
Number in sample	320	320	138	138
Dependent variable	Yield of rough rice, kilograms per hectare			
Constant	1,953	1,855	1,866	1,922
Independent variables:				
Fertilizer (X_f)	18.11	12.00	6.442	7.497
	(5.791)	(3.385)	(4.079)	(2.127)
Chemicals (X_c)	23.50	20.75	45.54	51.53
	(5.889)	(5.956)	(22.54)	(20.97)
Fertilizer squared $(X_f)^2$	-0.0858	-0.0316	---	---
	(0.0565)	(0.0199)	---	---
Interaction ($X_f \cdot X_c$) Fertilizer x chemical	---	---	.4534	---
	---	---	(.3996)	---
Chemicals squared $(X_c)^2$	---	---	-2.100	-1.588
	---	---	(.7208)	(.5806)
Region 2/				
Ilocos	---	---	-725.4	-786.0
	---	---	(213.2)	(245.4)
Cagayan	295.5	308.2	---	---
	(203.7)	(201.0)	---	---
Central Luzon	(Standard)	(Standard)	(Standard)	(Standard)
Southern Tagalog	---	---	---	250.6
	---	---	---	(192.0)
Bicol	186.3	204.6	---	---
	(164.1)	(166.7)	---	---
Eastern Visayas	---	---	-625.7	-623.4
	---	---	(336.2)	(355.2)
Western Visayas	---	---	---	---
Northern and Eastern Mindanao	197.6	209.4	499.3	559.8
	(185.4)	(179.7)	(394.1)	(431.2)
Southern and Western Mindanao	---	---	---	---
Size of farm:				
Lower fifth	---	---	---	---
Second fifth	---	---	---	---
Third fifth	(Standard)	(Standard)	(Standard)	(Standard)
Fourth fifth	---	---	---	-301.9
	---	---	---	(178.7)
Upper fifth	---	---	---	-270.6
	---	---	---	(207.7)
Tenure:				
Owner	123.2	---	---	421.1
	(135.7)	---	---	(209.0)
Part owner	---	---	---	213.7
	---	---	---	(198.9)
Lessee	---	---	---	---
Tenant	(Standard)	(Standard)	(Standard)	(Standard)
Irrigation:				
Fee	1.330	1.330	.8100	.71
	(1.07)	(1.06)	(1.500)	(1.51)
Water source:				
Stream diversion	(Standard)	(Standard)	(Standard)	(Standard)
Pump	---	---	---	501.5
	---	---	---	(280.4)
Water supply:				
Adequate	(Standard)	(Standard)	(Standard)	(Standard)
Inadequate	-192.6	-176.8	---	-352.1
	(130.8)	(129.7)	---	(155.2)
Ownership of irrigation system reported by farm:				
Government	(Standard)	(Standard)	(Standard)	(Standard)
Communal	---	---	---	-347.4
	---	---	---	(176.3)
Private	---	---	---	-263.0
	---	---	---	(252.4)

1/ In the stepwise program used, variables came into the equation if the t-ratio reached 1.0, and remained in the equation even though t-ratios subsequently dropped lower. Numbers in parenthesis below the regression coefficients are the standard errors.

2/ The coefficients shown for nonnumerical variables, e.g., region, in this table represent yield differences in kilograms of rough rice of the region from the region selected as the standard (Central Luzon) and the figure in parenthesis below each coefficient is the standard error. The same interpretation holds for the other dummy variable groups. For the size of farm group, size 3 is the standard from which yield differences are calculated for other size groups. For tenure, tenant is the standard; for type of irrigation ownership, government ownership is the standard; for water supply, adequate is the standard; and for source of water, stream diversion is the standard.

Source: BAECON, IAS.

These caveats notwithstanding, chemical expenditures were hypothesized as being an index of the attempt made to control weeds and pests other than control by cultivation, hand-weeding practices, and variety selection. After fertilizer, the expenditure for chemicals was the most important variable in explaining variations in yield, and the positive regression coefficient was statistically significant (t=4). However, the expenditures were rather small, averaging 6 pesos (about $1) per hectare, and hence represent a very slight control effort.

Since the use of HYV's and fertilizer ordinarily intensify weed, pest, and disease problems, and the humid, tropical conditions in the Philippines have a similar influence, weed, pest, and disease control are important for rice growers. IRRI is giving attention to what can be done about these problems on the basis of economically profitable practices for farmers.

Fertility and climatic conditions are important influences on yields. In the regression analysis these factors are represented only by the weak proxy of location by region. Although yields vary considerably by region, the independent effect of region, other than that associated with irrigation, variety type, and fertilizer, was rather limited in the irrigated HYV regression equation. Central Luzon was used as the standard. Three regions had higher yields (t-value greater than one)--Cagayan Valley, Bicol, and Northern and Eastern Mindanao--and the other five regions were not significantly different from Central Luzon.

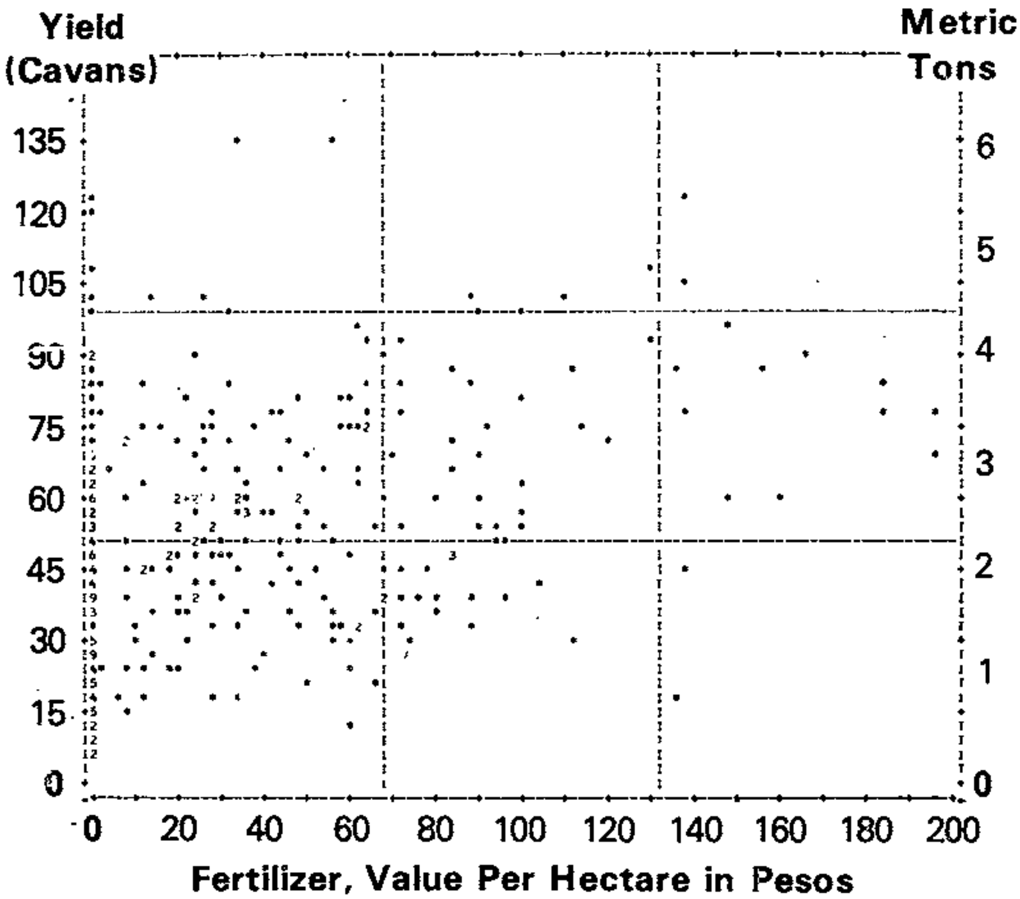
Of the several irrigation variables tried, the most significant was the adequacy of water reported by the farmer. Irrigation fees were also of some influence, and positively related to yield. Size of farm was an inconclusive variable. Tenancy was also of limited influence on yields.

Profitability Calculation

A common way to calculate how much fertilizer is profitable is to make use of a fertilizer response curve, and relate this to the price ratio, using 2 to 1 or 2.5 to 1 as the appropriate return and allowing for the harvesters' share. This report uses 2.5 to 1 and does not allow for the harvesters' share, which would reduce returns to 2.1 to 1. One side of the profit calculation is to determine what ratio of yield response will return 2.5 to 1 (table 2, equation 1.1). On the curve fitted for the wet season HYV, on irrigated land, this ratio is reached at a relatively low fertilizer application (35 kilograms/hectare of N+P) near the mean rate of usage in 1970 for those using fertilizer. Thus, the typical Philippine farmer using the HYV on irrigated land in the wet season was about in equilibrium (i.e., at his most profitable point) for fertilizer usage, given the relatively low yield response to fertilizer.

An additional influence restricting the optimum fertilizer application was the reported payment by farmers in this group of an average of 1.75 pesos per kilogram of fertilizer nutrient (N+P), about one-third higher than the published market price in Central Luzon. The national average price (reported by BAECON) received by farmers for rough rice (16 pesos per cavan or 0.36 pesos per kilogram) was used in the calculation, giving a fertilizer (N+P)-rice price ratio of 4.9 to 1. Except for those farmers benefiting from fertilizer subsidies from 1959 to 1963 and from 1973 to 1975, this is less favorable for the farmer than the 4 to 1 ratio which has been calculated for the Philippines for recent years for nitrogen rice.

Rice Yield - Fertilizer Value, HYV, Irrigated, 1st Semester, Philippines, 1969-70



STATISTICS:

CORRELATION (R) - 0.35287	*R SQUARED - 0.12451*	*SIGNIFICANCE - 0.00001*
STD ERR OF EST - 22.99591	*INTERCEPT (A) - 46.98979*	*SLOPE (B) - 0.205477*
PLOTTED VALUES - 318	*EXCLUDED VALUES - 2*	*MISSING VALUES - 0*

Figure 3

Other Varieties, Irrigated

For the OV's (equation 2.4 of table 2, column 4), the regression results for fertilizer users (54 percent of the total) showed a yield response that was about three-fourths as large as the response to the HYV's. No indication of diminishing response was noted as application increased, mainly because few observations were made for heavy fertilizer usage. For reasons not clear, several of the dummy variables that were insignificant for HYV's accounted for a significant part of the variation in the OV yield. In addition to the numerical variables of fertilizer and chemicals, two of the dummy location variables, Ilocos and Eastern Visayas, had lower yields than yields in Central Luzon. The larger size farms also had lower yields, especially the next to largest size group.

For the irrigation variables, those who reported inadequate water had yields averaging 352 kilograms per hectare lower than those reporting adequate water. This greater decline in yield due to inadequate water for OV's than for HYV's may reflect more severe shortages for OV's. Growers with better water control are more likely to plant HYV's. The community systems also had lower yields and pump systems had higher yield than gravity systems.

Finally, owners got significantly higher yields than tenants. With the contribution of these several variables, the variation in yield explained was twice as great as for the HYV group (R^2=0.35, compared with 0.17) (table 2, equation 2.4).

High-Yielding and Other Variety Comparison--Irrigated, Wet Season

In addition to a comparison of the regression equations for HYV's and OV's irrigated in the wet season, a comparison of yield levels obtained by fertilizer application can be made from cross section tabulation (table 3 and figure 4). By far the largest groups were those using no fertilizer--37 percent of HYV's and 46 percent of the OV's. For these two groups, the HYV yield exceeded the OV by 71 kilograms. However, the HYV group had a substantial reduction of one-third in the variation in yield.

Most of the HYV growers using fertilizer applied 10-65 pesos (5-35 kilograms N+P) of fertilizer with a reasonably good yield response of around 2,600 kilograms, well above the average of 2,055 kilograms for those using no fertilizer, and 350-900 kilograms higher than the traditional groups using the same quantity of fertilizer. Above 65 pesos per hectare of fertilizer, gains were erratic, although the HYV groups obtained higher yield than the OV groups.

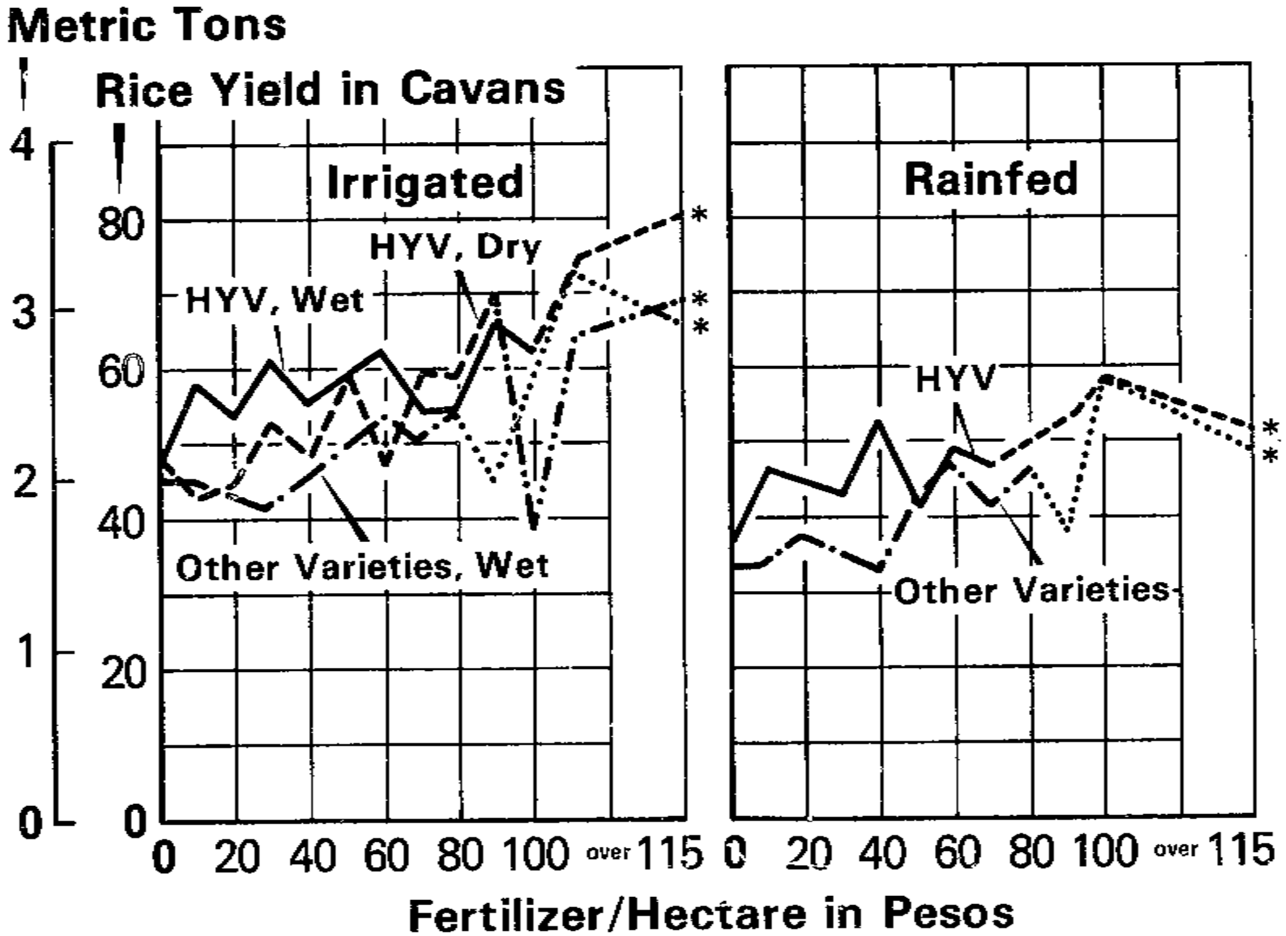
In the second semester--not all regions are dry--over two-fifths of the HYV growers used no fertilizer, obtained appreciably higher yields (6 cavans, or 264 kilograms) than the OV growers using no fertilizer, and also had lower variation in yields. Thus, this large group of adopters of HYV's reduced risks and obtained marginal gains from the revolutionary potential of high response varieties. For the fertilizer users, so few in the OV group are included in the sample that no comparison between the yield of the HYV and OV rice can be made. (See table 3 for fragmentary data.)

Table 3--Philippines: Rough rice yield on farms by rate of fertilization, for HYV and OV, irrigated, 1969/70

Value of fertilizer applied in pesos per hectare	Wet season					Dry season				
	HYV's		OV's		Yield of HYV's less OV's	HYV's		OV's		Yield of HYV's less OV's
	Yield	Farms in sample	Yield	Farms in sample		Yield	Farms in sample	Yield	Farms in sample	
	Kilograms	Number	Kilograms	Number	Kilograms	Kilograms	Number	Kilograms	Number	Kilograms
0	2,055	130	1,984	121	+71	2,165	138	1,901	89	+264
1-15	2,587	27	1,998	14	+589	1,866	19	1,958	5	-92
16-25	2,336	29	1,905	23	+431	1,962	23	1,584	11	+378
26-35	2,710	30	1,813	15	+897	2,306	17	2,477	9	-171
36-45	2 446	18	1,989	25	+457	2,160	14	1,967	4	+193
46-55	2,614	18	2,191	19	+423	2,596	21	1,786	6	+810
56-65	2,737	25	2,407	7	+330	2,046	13	2,116	4	-70
66-75	2,411	17	2,231	10	+180	2,636	15	2,116	5	+520
76-85	2,407	11	2,398	9	+9	2,592	15	---	1	---
86-95	2,939	11	1,980	7	+959	3,089	9	---	2	---
96-105	2,724	8	---	1	---	1,663	4	2,587	4	-924
106-115	3,291	4	3,181	3	---	2,825	5	---	0	---
116+	3,551	23	2,917	10	+634	3,049	25	2,451	4	+598

Source: Tabulations from sample of BAECON IAS.

Relationship of Rough Rice Yield to Fertilizer Value, Philippines, 1969-70



∗ Change in Line Pattern Denotes Fewer than 8 in Sample

Figure 4

Wet and Dry Seasons

For the dry season, the yield response to fertilizer for HYV's was about the same as in the wet season. In the lower range of fertilizer usage of up to 45 pesos (25 kilograms N+P), wet season yields averaged about 450 kilograms higher than in the dry season, but for those using more fertilizer, and for the large groups using none, the differences in yields were small and erratic (see fig. 4).

For the wet and dry seasons, the users' only curves are nearly straight lines and very similar with respect to fertilizer response:

$$\text{First semester--}Y = 1891.2 + \underset{(4.558)}{10.030}\, P_f + \underset{(6.019)}{22.854}\, P_c - \underset{(0.0233)}{.0223}\, (P_f)^2$$

$$\text{Second semester--}Y = 1806.3 + \underset{(5.000)}{10.940}\, P_f + \underset{(3.867)}{3.697}\, P_c - \underset{(.0270)}{.0262}\, (P_f)^2$$

where P_f = fertilizer per hectare in pesos; P_c = chemicals per hectare in pesos, and Y = yield in kilograms. Standard errors are in parentheses.

If the simple regression is used, or first step:

$$\text{First semester--}Y = 2{,}254.6 + \underset{(1.639)}{6.594}\, P_f$$

$$\text{Second semester--}Y = 1{,}958.5 + \underset{(1.657)}{6.573}\, P_f$$

again, very similar, and with lower slope.

For the wet season, inclusion of all the variables and adding nonusers raises the slope slightly, and adds some curvilinearity. For the dry season, the slope is reduced.

For OV's, first semester, the best curve has a slope for fertilizer three-fourths as steep as for HYV's (7.5 to 10), but has no curvilinearity.

High-Yield Variety and Other Variety Comparison, Rainfed Lowland

For rainfed lowland, first semester, the average yield increase for HYV's over OV's was 190 kilograms or 12 percent--from 1,588 to 1,778 kilograms, although the median increase was only 141 kilograms, or less than 10 percent (tables 1 and 4 and fig. 4). Partly, this reflected only a limited change in technology. Over half (54 percent) of the HYV group used no fertilizer, which was a small shift from the OV group, 46 percent of whom used no fertilizer.

For the large number in the HYV group using no fertilizer, the yield of 1,600 kilograms was only 124 kilograms higher than for the OV non-fertilizer group. For those using fertilizer, up to 45 pesos per hectare (about 30 kilograms N+P/ha.), the HYV group obtained an average of 2,000 kilograms, or about 420 kilograms more than the OV group using the same amount of fertilizer. Thus, this group of HYV growers, representing nearly half the fertilizer users, had good fertilizer response with yields more than 400 kilograms higher than the non-fertilizer HYV group, as well as a

Table 4--Philippines: Rough rice yields on farms by rate of fertilization for HYV and OV rainfed lowland, first semester, 1969/70

Value of applied fertilizer in pesos per hectare	Farms in sample		Yield		Yield of HYV's less OV's
	HYV's	OV's	HYV's	OV's	
	-- Number --		-- Kilograms --		
0	141	221	1,602	1,478	124
0-15	8	37	2,050	1,483	567
16-25	13	65	1,980	1,654	326
26-35	18	39	1,883	1,562	321
36-45	8	27	2,354	1,439	475
46-55	16	25	1,791	1,879	-88
56-65	19	20	2,160	2,055	105
66-75	9	8	2,046	1,830	216
76-85	5	9	2,226	2,068	158
86-95	6	6	2,332	1,654	678
96-105	6	12	2,561	2,578	-17
106-115	1	1	1,993	2,754	---
116+	9	15	2,279	2,121	158
Total	259	485	---	---	---
Fertilizer users	118	264	---	---	---
	-- Percent --				
Fertilizer users as a percentage of total	46	54	---	---	---

Source: Tabulations from sample of BAECON IAS.

similar differential over the OV group using the same amount of fertilizer. Of the other HYV fertilizer users, a little more than half the total used 45 or more pesos of fertilizer, but gained relatively small increments in yield, compared with the light fertilizer users of the HYV group, or compared with the OV group using the same amount of fertilizer.

COMPARISON OF IRRI TRIALS AND FARMERS' PRACTICES

The following section discusses fertilizer response and profitability in more detail. Since the aim is to generalize as much as is warranted, we will include additional data for comparative purposes. The first set of data is the widely used yield-fertilizer response curve for HYV's from the UNDP-FAO trials over a period of years in the Philippines. The single curve to be used here is the one for the Philippines, HYV, an average for the wet and dry season. 9/ It is not available by seasons. The second is the summary of IRRI fertilizer-response trials which is available by seasons. The third is a later year of the IAS--the 1971/72 wet season for the Philippines excluding Central Luzon (where tungro infestation damaged the crop).

IRRI trials are fundamentally different from farmers' practices with the trials carefully controlled, and typically only one factor is allowed to vary, with all others held optimum. Nevertheless, the trials are undertaken in an effort to help farmers and a comparison is required to obtain inferences for farm recommendations. In recommending farm practices, researchers adapt trial results with some adjustments and allowances on an ad hoc basis, using whatever other information is available.

Comparisons made in this report require some interpretation and some reservation. Thus, the slope of the yield response to fertilizer is about the same in the wet season for IRRI trials as the average for all farmers growing HYV's on irrigated land, although the level of yields for each fertilizer application is about twice as high for IRRI trials as for farmers. In the trials, phosphorus and potassium are held constant at optimum levels, weeds and grasses, pests, and diseases are carefully controlled, and only nitrogen application is varied. For the farms, little information is available on other factors and the weak "control" that is possible with multiple regression analysis is not like the controls employed for the trials.

Despite these reservations, the surprisingly similar average fertilizer response during the wet season for IRRI trials and for farmers on irrigated land provides a new perspective on the problem of low rice fertilization and low yields (fig. 5 and table 6). However, these are average relationships and year-to-year variations are large (fig. 6).

Wet Season

As mentioned earlier, the price per kilogram of nitrogen fertilizer in the Philippines has averaged about four times the price received by farmers for a kilogram of rough rice, and a ratio of 2.5 pesos of rice per peso of fertilizer is a rule of thumb often used to calculate the most profitable return from fertilization. If 4 to 1 is used for the fertilizer-rice price ratio, and a return of 2.5 to 1, excluding

9/ UNDP-FAO Soil Fertility and Research, Philippines, Final Report, Vol. I, p. 134-A.

Table 5--Philippines: Effect of rate of nitrogen application on rough rice yields of IR-8 and other HYV's in a farmer's field in Laguna, IRRI-conducted trials, 1967-71

Kilograms of nitrogen applied per hectare	Dry season 1967	Dry season 1968	Dry season 1969 1/	Dry season 1970 2/	Dry season 1971	Dry season 1967-71 average
	Kilograms per hectare					
Trials using IR-8:						
0	4,409	5,928	3,850	5,700	7,400	5,457
50	5,509	6,418	7,200	8,100	8,600	7,165
100	7,547	10,196	8,600	9,400	9,600	9,069
150	8,892	10,474	9,357	9,500	10,000	9,645
Trials using other HYV's:	Number					
Number of varieties:	5	5	3	5	7	--
	Kilograms per hectare					
Yields:						
0	3,799	5,152	4,430	5,420	6,120	4,984
50	5,051	6,629	6,570	6,760	7,920	6,586
100	6,468	8,786	7,750	8,100	8,680	7,957
150	7,218	8,863	8,270	7,600	8,700	8,130

Kilograms of nitrogen applied per hectare	Wet season 1967
	Kilograms per hectare
Trials using IR-8:	
0	2,756
20	3,720
40	4,187
60	5,070
80	5,539
Trials using other HYV's:	Number
Number of varieties:	5
	Kilograms per hectare
0	2,929
20	3,903
40	3,936
60	3,982
80	4,060

Kilograms of nitrogen applied per hectare	Wet season 1968	Wet season 1969 1/	Wet season 1970 2/	Wet season 1971	Wet season 1968-71 average
	Kilograms per hectare				
Trials using IR-8:					
0	3,416	6,200	4,200	4,200	4,504
25	5,332	6,300	4,500	4,500	5,158
50	5,843	7,100	5,450	4,800	5,798
75	6,082	7,382	6,200	2,200	5,466
Trials using other HYV's:	Number				
Number of varieties:	6	3	4	7	--
	Kilograms per hectare				
0	3,479	5,420	4,675	4,100	4,418
25	4,619	5,770	5,075	4,650	5,028
50	5,260	5,850	5,788	4,700	5,400
75	5,413	5,460	5,950	3,800	5,156

1/ 1969 figures from chart in 1969 Annual Report.
2/ 1970 figures from chart in 1970 Annual Report.

Source: IRRI Annual Reports.

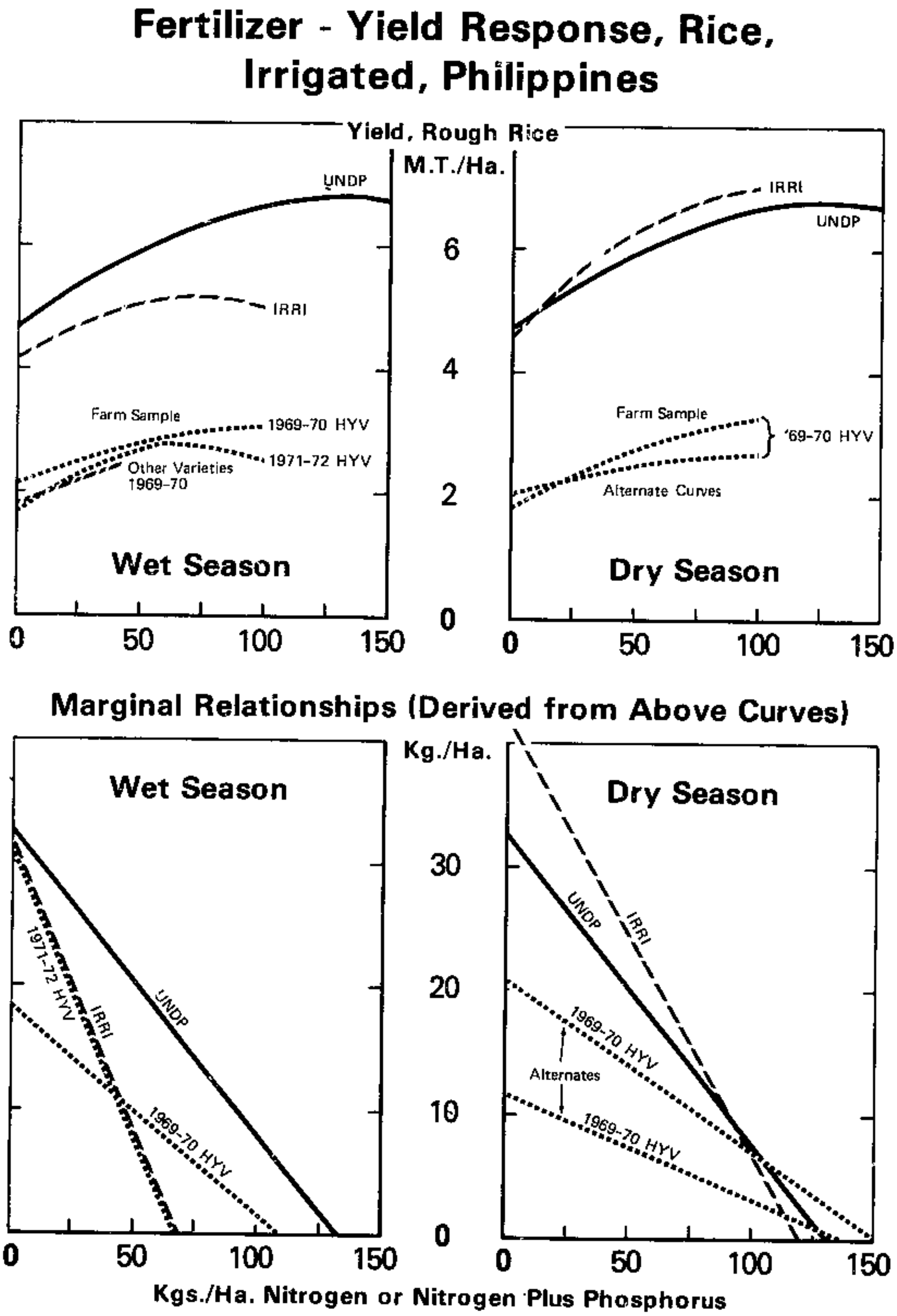
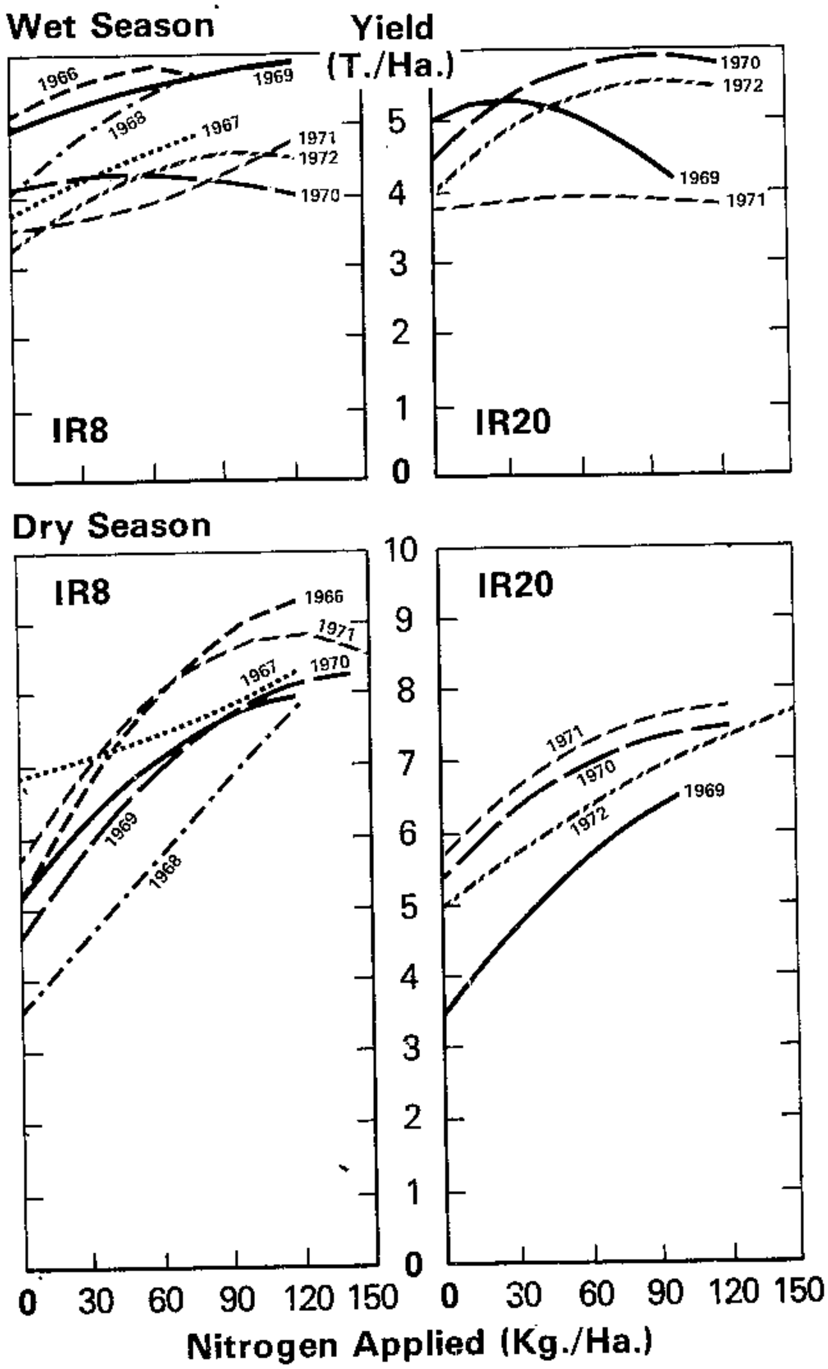

Fertilizer - Yield Response, Rice, Irrigated, Philippines
Yield, Rough Rice
M.T./Ha.
UNDP
IRRI
Farm Sample
1969-70 HYV
1971-72 HYV
Other Varieties 1969-70
Wet Season
'69-70 HYV
Alternate Curves
Dry Season
0
2
4
6
0
50
100
150
Marginal Relationships (Derived from Above Curves)
Kg./Ha.
Wet Season
Dry Season
1971-72 HYV
IRRI
UNDP
1969-70 HYV
Alternates
0
10
20
30
Kgs./Ha. Nitrogen or Nitrogen Plus Phosphorus

Figure 5

Variability in Yield Response of IR8 and IR20 Rice Varieties to Nitrogen, IRRI, 1966-72



Source: IRRI Annual Report, 1972

Figure 6

harvester's share, is calculated as the most profitable point, then this is reached where the yield response to fertilizer is 10 kilograms of rice per 1 kilogram of plant nutrient (N, or N+P). This marginal response is shown for the several curves in the lower panel of fig. 5. For the IAS 1969/70 wet season, the most profitable fertilizer usage level was not 35 kilograms, calculated above to account for the higher cost that farmers reported paying for fertilizer, but nearly 50 kilograms, because the marginal response curve is relatively flat, and the most profitable rate of fertilization is rather sensitive to price-cost changes.

The other wet season curves, the IRRI summary and the 1971/72 IAS, excluding Central Luzon, similarly show that the most profitable fertilizer usage is a little under 50 kilograms. These marginal response curves are much steeper, however, so that the most profitable rate of usage is less sensitive to price changes. This means that even with considerable shifts in the fertilizer-rice price ratio, or in the rule of thumb about rate of return, there would be little change in the most profitable rate of fertilization.

Although the individual farmer will have to adjust to his own fertilizer-response relationship, for the average shown here the most profitable application is a little less than 50 kilograms nitrogen per hectare, and there is a considerable penalty for applications much above or below this rate. For example, at 60 kilograms nitrogen per hectare, the marginal return is only 4 kilograms of rice for each kilogram of nitrogen, and at 68 the marginal return is zero.

For a fertilizer authority that wishes to obtain the maximum amount of rice from a given quantity of fertilizer available, rather different calculations are appropriate. If the allocation is made to maximize farmers' incomes, the amount to be supplied would be for fertilization at a little under 50 kilograms nitrogen per hectare, as previously explained. The authority would obtain about 20 kilograms of rough rice for each kilogram of nitrogen allocated. For smaller quantities of nitrogen per hectare, however, there is a divergence between the farmers' and the authorities' interests.

For example, at 25 kilograms nitrogen per hectare fertilization, the farmer is using less fertilizer than his optimum rate of nearly 50 kilograms, but the authority would be obtaining 26 kilograms of rice per kilogram of nitrogen allocated, compared with only 20 to 1 for the allocation of 50 kilograms of nitrogen per hectare.

Thus, for the IRRI wet season summary and for the IAS 1971/72 wet season curve excluding Central Luzon, there is a distinct divergence between the fertilization level that the individual grower would prefer (around 50 kilograms nitrogen per hectare) and the level that would maximize the rice output from a given and limited supply of fertilizer. The amount of extra rice that can be produced by a given fertilizer supply can be increased by reducing the allocation per hectare below the recommended or most profitable rate for the individual farmer. By a coincidence the marginal rate for the UNDP-FAO curve about coincides with the rate per hectare that is appropriate for the authority to use to estimate the rice production that can be obtained from a given limited quantity of fertilizer.

Qualifications

An important qualification of the generalizations above is that the IRRI curves are an average of wet season data from different years, and each of the two IAS curves is for a single season. As shown in the 1972 annual report of the Agricultural Economics Department of IRRI (reproduced here as fig. 6), the year-to-year variation in fertilizer response is surprisingly large in the wet season for the carefully controlled IRRI trials. Thus, even for IR-8 in the wet season, of the 7 trial years, 1966 and 1970 showed poor fertilizer response, whereas other years showed much more response.

For IR-20; there are 2 good years (1970 and 1972) and 2 years (1969 and 1971) with little yield response to fertilization. Although the IAS data for Philippine farmers for the 2 years shown have similar response to fertilization, large year-to-year variation seems likely.

The sets of curves of trials and for the IAS wet season irrigated HYV's point to similar average rates of optimal fertilization--a little under 50 kilograms of nitrogen per hectare--with nitrogen-rice price ratios about 4 to 1. This is somewhat below recommended rates based upon earlier and less complete data. Nevertheless, the shapes of the curves are different, and the coefficients determining the shape have uncomfortably large error terms and annual variations. The level of the yield curves varies greatly from the farm practices to IRRI-controlled trials.

Dry Season

With all these limitations, wet season data are more nearly convergent than dry season data. The IAS cross-section and regression results for the 1969/70 wet season were discussed above. No comparable data were collected for the 1971/72 dry season, and no other data have been tabulated. The general picture is shown in figures 5 and 6. Whereas the IAS curves were similar in both level and shape in the wet and dry season, the IRRI experiments are in sharp contrast between the seasons in slope, level, and variation from year to year.

The dry season fertilizer-response of trials in IRRI experiments are generally superior to the UNDP standard, both in level of yield and response to fertilizer (slope). The IRRI experiments obtained considerably higher response through low and intermediate ranges of fertilization and are equal to the UNDP-FAO results at the 10 to 1 marginal rate at around 90 kilograms of nitrogen per hectare, the most profitable rate of application where the nitrogen-rice price ratio is 4 to 1.

The smaller variation in fertilizer response during the dry season than in the wet season in IRRI experiments is shown in fig. 6. For IR-8, the almost uniform strong advance occurs in 5 of the 6 years, and the sixth-year response is above average in the wet season. All four IR-20 responses are strong.

For the IAS survey of farmers, the principal curve fitted for the dry season is not sufficiently different from the wet season curve to require any comment. However, the sample for the dry season is rather small, and the fertilizer-response curve is not firmly established by the regression calculation. An alternative regression curve is shown which has considerably greater slope than the one for the wet season, and a higher rate of fertilization would be profitable. The great difference from the IRRI experiments and trials has been bridged by the water-stress unsupervised farm trials.

In a series of trials, with severe, moderate, and light water-stress options, the moderate water stress was judged to be the most representative of average irrigated-paddy conditions in the dry season. The fertilizer response, and the differences in average yields between HYV's and OV's were similar to the results of the IAS dry season data. 10/

COMPARISON OF IRRI'S TRIALS IN A FARMER'S FIELD

Each year IRRI conducts experiments in a farmer's field to study varietal response to nitrogen fertilization under management conditions that are within reach of most Asian farmers (p. 162, 1971 Annual Report). The trials are performed in both the wet and dry seasons on irrigated land in Laguna. The varieties reported include IR-8, IR-5, and non-IRRI HYV's in the earlier years, and the newer IR-20 series in recent years.

Before the comprehensive analysis of IRRI fertilizer response trials became available, results from trials in farmers' fields were compared with the IAS data with results similar to those presented in this report. These data have not been published in quite the form in which they are summarized here (tables 5, 6 and figs. 7, 8).

LOW-YIELD AND HIGH-YIELD FARMS

A comparison was made of the characteristics of farms with high yields with those obtaining low yields, and with the average for all lowland irrigated farms, based on 1969/70 IAS data. Farms were arrayed by yield separately for HYV's and OV's, and the averages were computed for the highest fifth, the lowest fifth, and the average (tables 7 and 8).

For HYV farms, the upper quintile a,eraged 4,260 kilograms per hectare yield, compared with 1,020 kilograms for the lower quintile, or a ratio of 4,260 to 1,020 = 4.2 to 1. A much higher proportion of the upper quintile (83 to 42 percent) used fertilizer as well as chemicals (80 to 40 percent), with expenditures per hectare several times as high and more adequate irrigation reported. The average was intermediate in each of these respects.

For the OV group, the same general pattern prevailed with yields in the upper quintile 880 kilograms lower than the HYV's and the average 430 kilograms lower. Somewhat fewer OV growers used fertilizer than the corresponding HYV growers, and spent somewhat less per hectare and purchased a negligible quantity of chemicals.

10/ Wickham, Thomas H., in Annual Reports, IRRI, and mimeo seminar papers, including "Major Constraints to Rice Production with Emphasis on Yields in the Philippines" jointly with Robert W. Herdt, Apr. 22, 1974; and, "Effect of Moisture Stress Periods in Relation to Irrigation Systems", Apr. 23-27, 1973.

Table 6--Philippines: Constant and variables used to generate fertilizer-response yield curves shown in figures 5, 7, and 8

	Season	Constant	X_F(Fertilizer)	X_F^2
			-- Kilograms per hectare --	
IRRI trials in farmers' fields:				
All HYV, 1968-72	Dry	4,935.6	43.053	-.1429
All HYV, 1968-71	Wet	4,399.1	35.964	-.3416
IR-8, 1968-72	Dry	5,380.8	45.916	-.1132
IR-8, 1968-71	Wet	4,456.1	43.684	-.3944
UNDP-HYV (average)	Both	4,638	32.355	-.125
IRRI-average HYV, 1966-71	Dry	4,567	41.85	-.1771
	Wet	4,091	31.53	-.2321
IAS-irrigated:				
HYV, 1969/70 1/	Dry	2,041.4	11.188	-.0419
HYV, 1969/70 1/	Dry	1,806.3	20.78	-.0497
HYV, 1969/70	Wet	2,095	18.112	-.0858
Non-HYV, 1969/70	Wet	1,922.5	11.5	None
HYV, 1971/72	Wet	1,691	31.58	-.2329

1/ Alternate curves. Either fits the data as well as the other.

Formula: Yield of rough rice, kgs./ha. = Constant + X_F (kg. N/Ha.) + $(X_F)^2$.

Fertilizer - Rice Yield Response, a Farmer's Field in Laguna (IRRI), and UNDP - Philippines

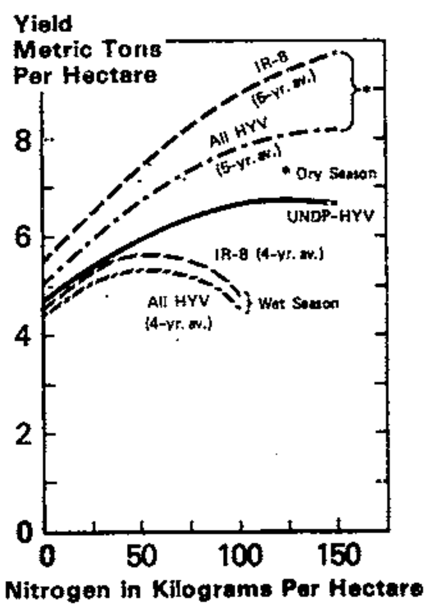
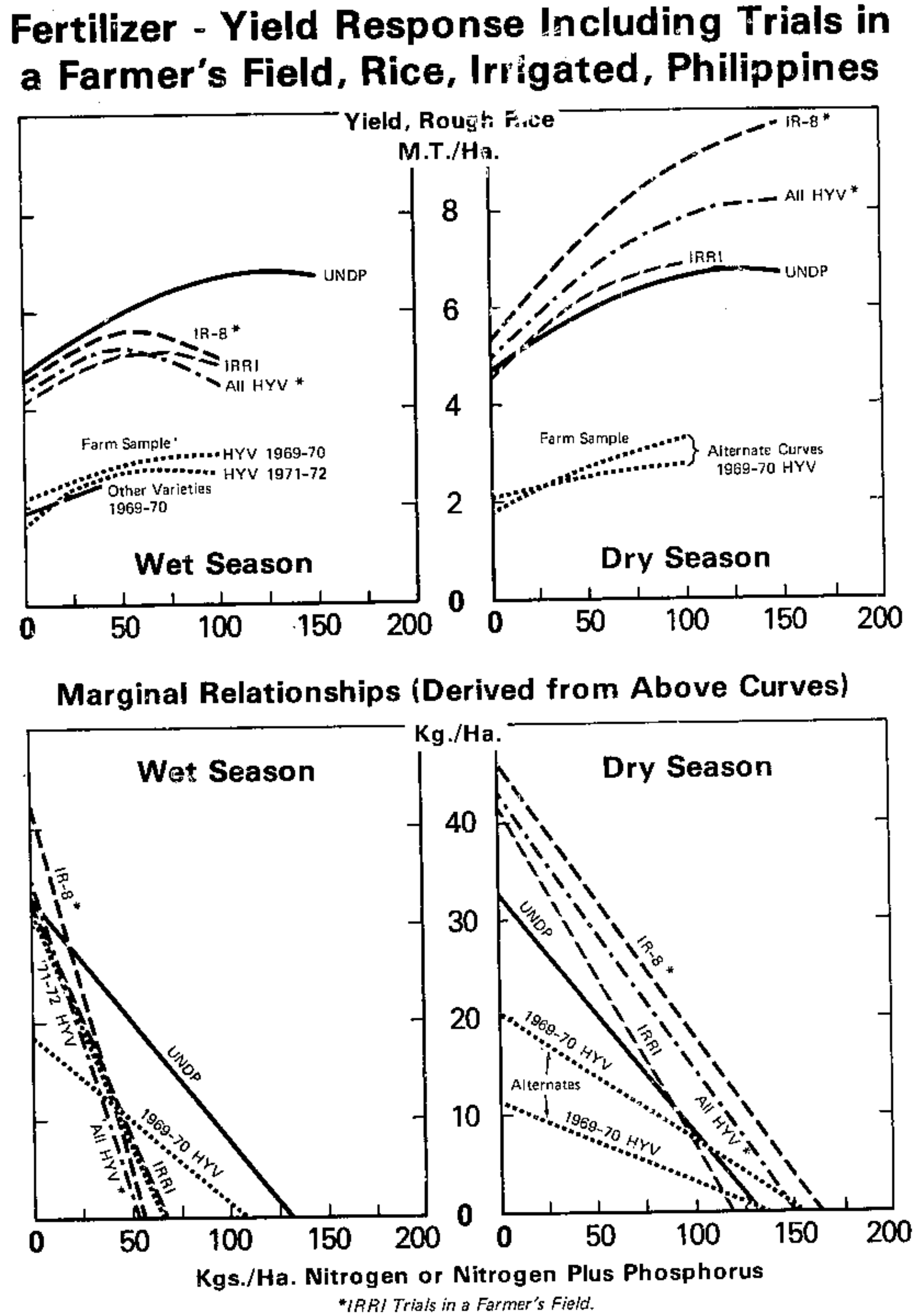


Figure 7



Fertilizer - Yield Response Including Trials in a Farmer's Field, Rice, Irrigated, Philippines
Yield, Rough Rice
M.T./Ha.
UNDP
IR-8 *
IRRI
All HYV *
Farm Sample
HYV 1969-70
HYV 1971-72
Other Varieties
1969-70
Wet Season
Alternate Curves
1969-70 HYV
Dry Season
0
2
4
6
8
0
50
100
150
200
Marginal Relationships (Derived from Above Curves)
Kg./Ha.
10
20
30
40
'71-72 HYV
1969-70 HYV
Alternates
Kgs./Ha. Nitrogen or Nitrogen Plus Phosphorus
*IRRI Trials in a Farmer's Field.

Figure 8

Table 7--Philippines: High-yielding varieties comparison of characteristics of high-yield, low-yield, and all farms, irrigated, wet season, 1969/70 1/

Item	Farms with yields in lowest quintile	Farms with yields in highest quintile	All farms
	-- Percent --		
Percentage of farms using:			
Fertilizer	42	83	68
Chemicals	40	80	66
Percentage of farms with adequate irrigation	57	90	72
Percentage of farms reporting irrigation systems owned by:			
Government	21	36	39
Communal organizations	25	27	28
Private owners	26	27	22
Farmer didn't know	28	10	11
	-- Mean value --		
Mean values of rice production factors:			
Fertilizer value (pesos/ha.)	11.5	63.9	40.0
Chemical value (pesos/ha.)	2.1	12.2	6.3
Production (kgs.)	2,136	8,360	4,721
Harvested area (ha.)	2.09	1.96	1.88
Size farm (ha.)	3.89	5.21	3.52
Yield (kgs./ha.)	1,021	4,264	2,438

1/ More of the farms in the highest and lowest quintiles were owned or partly owned by their operators than for all farms. For all three categories of farms, the wet season rice harvest takes place in November.

Source: Tabulations from sample of the BAECON IAS.

Table 8--Philippines: Other varieties comparison of characteristics of high-yield, low-yield, and all farms, irrigated, wet season, 1969/70 1/

Item	Farms with yields in lowest quintile	Farms with yields in highest quintile	All farms
	-- Percent --		
Percentage of farms using:			
Fertilizer	38	64	59
Chemicals	26	65	43
Percentage of farms with adequate irrigation	41	78	59
Percentage of farms reporting irrigation systems owned by:			
Government	14	43	35
Communal organizations	45	29	36
Private owners	17	16	18
Farmer didn't know	24	13	11
	-- Mean value --		
Mean values of rice production factors:			
Fertilizer value (pesos/ha.)	12.2	38.6	33
Chemical value (pesos/ha.)	1.5	3.7	3.3
Production (kgs.)	1,672	5,883	3,881
Harvested area (ha.)	2.05	1.80	1.98
Size farm (ha.)	3.21	2.45	2.61
Yield (kgs./ha.)	814	3,388	2,006

1/ Farms with lowest yields harvest in November. Those with high yields and all farms harvest most frequently in December.

Source: Tabulations from sample of the BAECON IAS.

IMPLICATIONS FOR RESEARCH AND POLICY

. If these comparisons indicate the present situation for IRRI and farm technology, what can be done to exploit HYV yield potentials on Philippine farms? International comparisons show that fertilizer use has expanded more slowly in the Philippines than in some other Asian countries. 11/ 12/ Research is needed to know exactly what must be done to raise the level of yield at any fertilizer level. As of now, recommendations are typically limited to those practices which are essential for good yields and the skills required to train extension workers (see, for example, Rice Manual, IRRI and University of Philippines, pp. 323-24, 1970).

As IRRI has stressed, and is now investigating, factors accounting for variations in rice yields under field conditions are not known. However, an analysis of the 1970 data and other studies indicate that farmers are using very limited quantities of chemicals for control of weeds, diseases, and pests. For weed and grass control, there are specific recommendations that would seem to be clearly profitable for the small proportion of farmers who have good water control and water supply.

Weeds and grass can be controlled without herbicides as reported from Taiwan, South Korea, and Japan. But the average size of paddy fields in the Philippines is about twice as large as in these countries, irrigation is less adequate, and weeds and grass may grow faster under the wet, tropical climate of the Philippines. Hand control of weeds and grasses may be too arduous in paddies in the Philippines to be practical, according to a Taiwan technician assigned to the Asian Pacific Council multiple-cropping project in Nueva Ecija. Little specific information is available on the weed control effort or damage due to inadequate control. In an IRRI study of Gapan, a more direct relationship was found between fertilizer application and weed growth than between fertilizer and rice yield. 13/

Wet Season, Irrigated High-Yielding Varieties

For irrigated HYV's, the wet season and the dry season trials show very different fertilizer responses, and data presented in this report are more nearly convergent for farms and experiments for the wet season than for the dry. In the wet season, the widely used UNDP-FAO yield-response curve is higher than the IRRI and far above IAS throughout the full range of fertilization rates.

11/ "The Impact of Devaluation on Fertilizer Use of Profitability in Philippine Rice Production," mimeo, IRRI, May 21, 1970, p. 1 and fig. 1. Similar results are reported by John T. Shields and Robert C. Gary of TVA in "The Fertilizer Industry in the Philippines," a paper prepared jointly with the Technical Working Committee, Presidential Fertilizer Commission, in cooperation with the Agency for International Development, 1971.

12/ "The Green Revolution: Second-Generation Problems," Falcon, W.P., p. 699; pp. 698-710; American Journal of Agricultural Economics, Dec. 1970, Vol. 52, No. 5.

13/ Barker, R., Dozina, G. Jr., and Fu-Shan, Liu, "The Changing Pattern of Rice Production in Gapan, Nueva Ecija, 1965-70." Dec. 11, 1971, IRRI Saturday Seminar.

Thus, the route to higher yields appears to be in improved practices other than fertilization that would make possible a better and more dependable fertilizer-yield response. IRRI is engaged in a research project to ascertain the constraints that are holding rice yields well below those obtained in trials, demonstrations, and on the high-yield farms.

Dry Season, Irrigated High-Yielding Varieties

In the dry season, the UNDP-FAO curve and the IRRI yield curve are very similar, with IRRI obtaining somewhat higher average yields and marginal response through lower and intermediate ranges of fertilization. The 10 to 1 response rate is reached at the same point on both curves--around 90 kilograms of nitrogen per hectare. The IAS yield levels and marginal response are considerably lower.

Since most of the rice in the Philippines, irrigated and rainfed, is grown in the wet season, and a minor proportion of farms have sufficient water for irrigation in the dry season, development of varieties having sustained high response to high rates of fertilizer application for the wet season would seem desirable. Farmers then could be informed of the technology to exploit the high-yield response of the new varieties. Since solar radiation is so important for the HYV's thus far developed, developing HYV's for the wet season may be difficult. But, it would be helpful in the Philippines--and elsewhere in the monsoon rice regions. Another possibility would be to develop better irrigation for the dry season and then teach the farmers to exploit the potential yield response of the HYV's.

Since both of these appear to be long-range rather than immediate options, one approach that appears feasible for the present is to find out why farmers are realizing so little of the high-production response and yield capabilities of HYV's in the dry season. Such a project would require neither scientific breakthroughs nor large financial or practical administrative allotments to begin the many steps required.

IRRI conducted a preliminary study of yield variation causes on a sample of farms, and has launched a multidisciplinary project to study "the factors preventing Asian rice farmers from getting the high yields that have been demonstrated to be possible using semidwarf rice varieties and complementary management practices." 14/ A number of other projects are underway to raise the level of technology employed by Philippine farmers including Asian Pacific Council's multiple-cropping and the Israeli Moshav Cooperative projects.

14/ Herdt, R.W., DeDatta, S.K., Gomez, K.A., and Wickham, T.H., "Identifying Constraints to Higher Yields on Asian Rice Farms." Working Paper I, International Rice Agro-Economic Network, June 1974.

Appendix table 1--Philippines: Yield advantage calculations (high-yielding varieties)

Year	Crop type	Area harvested: All	Area harvested: HYV's: Area	Area harvested: HYV's: Proportion of all	Area harvested: OV's	Yield per hectare: HYV's	Yield per hectare: OV's	Increment of HYV over OV yields: Absolute difference	Increment of HYV over OV yields: Relative difference
		1,000 hectares	1,000 hectares	Percent	1,000 hectares	Kilograms	Kilograms	Kilograms	Percent
1968	Irrigated	1,309	445.1	34.0	863.9	1,976	1,610	366	22.7
	Rainfed lowland	1,514	256.4	16.9	1,258	1,294	1,241	53	4.3
1969	Irrigated	1,483	912.8	61.6	570.0	1,778	1,619	159	9.8
	Rainfed lowland	1,407	438.9	31.2	967.9	1,126	1,091	35	3.2
1970	Irrigated	1,346	826.6	61.4	519.2	2,156	1,888	268	14.2
	Rainfed lowland	1,356	527.4	38.9	828.3	1,487	1,527	-40	-2.6
1971	Irrigated	1,471	985.0	67.0	485.5	2,024	1,932	92	4.8
	Rainfed lowland	1,277	580.4	45.4	697.0	1,615	1,580	35	2.2
1972	Irrigated	1,332	977.1	73.4	354.9	2,055	1,725	330	19.1
	Rainfed lowland	1,548	849.7	3.6	698.5	1,443	1,351	92	6.8
1973	Irrigated	1,241	872.8	70.3	368.1	1,951	1,742	209	12.0
	Rainfed lowland	1,436	807.1	56.2	629.4	1,277	1,111	166	14.9
	Irrigated average, 1968-73	1,364	837	61.4	527	990	1,753	237	13.5
	Rainfed lowland average, 1968-73	1,423	577	40.5	846	1,374	1,317	57	4.3

Source: Data from Bureau of Agricultural Economics, Philippines Department of Agriculture.

Appendix table 2--Philippines: Increase in rice production attributable to HYV's

Year	Crop type	HYV area	Increment of HYV yields over OV yields	Production gain from HYV's	Total rice production	Production gained through use of HYV's
		1,000 hectares	Kilograms per hectare	1,000 metric tons	1,000 metric tons	Percent
1968	Irrigated	445.1	366	162.9		
	Rainfed	256.4	53	13.6		
		701.5	252	176.5	4,563	3.9
1969	Irrigated	912.8	159	145.1		
	Rainfed	438.9	35	15.4		
		1,352	119	160.5	4,444	3.6
1970	Irrigated	826.6	268	221.5		
	Rainfed	527.4	-40	-21.1		
		1,354	148	200.4	5,232	3.8
1971	Irrigated	985.0	92	90.6		
	Rainfed	580.4	35	20.3		
		1,565	71	110.9	5,342	2.1
1972	Irrigated	977.1	330	322.4		
	Rainfed	849.7	92	78.2		
		1,827	219	400.6	5,100	7.9
1973	Irrigated	872.8	209	182.4		
	Rainfed	807.1	166	134.0		
		1,680	188	316.4	4,414	7.2
	Average, 1968-73					4.8

Source: Data from Bureau of Agricultural Economics, Philippines Department of Agriculture.

Appendix table 3--Philippines: Two methods of calculating yield gains attributable to HYV rice, 1968-73

Year	HVY's			Based on HYV crop type proportions			Alternative calculation based on actual averages		
	Production	Area	Yield	Calculated yield from other varieties (all lowland)	Calculated yield gain, HYV's over other varieties		Actual yield from other varieties (all lowland)	Actual yield differences of HYV's and other varieties (lowland)	
	1,000 metric tons	1,000 hectares	Kilograms	Kilograms	Kilograms	Percent	Kilograms	Kilograms	Percent
1968	1,212	701.5	1,729	1,477	252	17.1	1,390	339	24.4
1969	2,118	1,352	1,566	1,447	119	8.2	1,285	281	21.9
1970	2,566	1,354	1,896	1,748	148	8.5	1,668	228	13.7
1971	2,930	1,565	1,958	1,887	71	3.8	1,725	233	13.5
1972	3,232	1,827	1,769	1,550	219	14.1	1,465	304	20.7
1973	2,733	1,680	1,628	1,439	188	13.1	1,344	284	21.1
Average, (1968-73) ...						10.8			19.2

Source: Data from Bureau of Agricultural Economics, Philippines Department of Agriculture.

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