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BIOLOGICAL CONSTRAINTS TO FARMERS' RICE YIELDS IN THREE PHILIPPINE PROVINCES

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BIOLOGICAL CONSTRAINTS TO FARMERS' RICE YIELDS IN THREE PHILIPPINE PROVINCES[1]

ABSTRACT

Research on constraints to high rice yields in selected farmers' fields began in the 1974 wet season in Nueva Ecija, in the 1975 dry season in Camarines Sur, and in the 1976 dry season in Iloilo province, Philippines, and continued through 1977.

Results during the wet seasons in Nueva Ecija showed that a high level of inputs raised rice yields above the farmers' level by 1.6 t/ha in 1976 and by 1.3 t/ha in 1977. More than 50% of the difference in yield during the two wet seasons was due to improved insect control while the remainder was due to better fertilizer management. Farmers' weed control measures in the study area were adequate. In the 1977 dry season, the average yield increase from a high input level was 2.2 t/ha. Insect control contributed 48% to the difference while fertilizer and improved weed control contributed 43% and 9%, respectively.

In Camarines Sur, the yield gap between farmers' and high input levels was 0.7 t/ha during the 1976 wet season. Fertilizer contributed 66.6% to the gap while improved insect control accounted for 33.4%. Improved weed control made no contribution, indicating that the farmers in the study area controlled weeds adequately. No yield gap was recorded during the 1977 wet season because of typhoon damage to the crop that received a high level of fertilizer. During the 1977 dry season, the average yield difference was 2.4 t/ha. Fertilizer contributed 48% to the difference, weed control 12%, and insect control measures 40%.

In Iloilo, the high level of inputs raised yield above the farmers' level by 2.0 t/ha in the 1976 wet season and by 1.0 t/ha in the 1977 wet season. Fertilizer was the dominant test factor, contributing about one-half of the yield gap during the two wet seasons. In the 1977 dry season, the average yield gap was 1.3 t/ha. As in the wet seasons, fertilizer was the most important test factor, contributing two-thirds (68%) of the yield gap. Improved insect control and weed control accounted for the remainder of the gap.

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In the three study areas, results from three seasons showed that yields with intermediate levels of fertilizer nitrogen were similar to, or considerably higher than, the farmers' yields despite larger fertilizer applications by the farmers. That indicated that better fertilizer management was needed on the farm.

Summarizing data from 1974 to 1977 in Nueva Ecija, insufficient fertilizer or improper management of fertilizer was the most dominant constraint to high rice yields in the dry season; poor insect control was most serious in the wet season.

In Camarines Sur and Iloilo, insufficient amount and improper management of fertilizer appeared as the dominant constraints to high yields in both dry and wet seasons. In both provinces, however, insect and weed control measures need further improvement, particularly in the wet season, to increase grain yields beyond the current farmers' yields. Adequate weed control is particularly important in Iloilo, where direct seeding is gaining popularity.

Economic analysis of the yield-gap data shows that the high input levels were generally less profitable than farmers' present practices in the wet season. However, in the dry season, farmers in the three study areas could increase their profits by US$112/ha by spending US$164/ha more on inputs. The economically recoverable gap (ERG) in the wet season averaged 0.7 t/ha for the three provinces; in the dry season, the average ERG was 1.2 t/ha.

BIOLOGICAL CONSTRAINTS TO FARMERS' RICE YIELDS IN THREE PHILIPPINE PROVINCES

Despite impressive technological advances during the first decade of the International Rice Research Institute existence, national production data show increases barely high enough to meet population growth in the developing countries. The modern rice varieties and their associated cultural practices more than doubled the yield potential of tropical rice. Shortening the growth duration from more than 150 days to less than 125 days, with marked increase in grain yield potential, was perhaps the decade's most significant research result in agriculture as a whole and in rice research in particular. The improved rice varieties in part gave rise to the term *green revolution*. The introduction of such varieties and improved farming techniques failed, however, to substantially increase average yields in many tropical Asian countries.

Despite the technological breakthroughs, however, farmers in many of the rice-growing areas of South and Southeast Asia continue to grow traditional varieties. Even in countries where adoption of the modern varieties was widespread, such as in the Philippines, average farm yields remain below those obtained on experiment stations. Although yields of 6 to 8 t/ha are possible, good farmers get 3 to 4 t/ha; many farmers get only 1 t/ha.

Different researchers attribute to different causes the discrepancy between possible yield and actual yield of the modern rices but the factors limiting yield from farmers' fields can be mainly grouped into environmental constraints, technological and management constraints, and economic constraints.

ENVIRONMENTAL CONSTRAINTS

Rice yields vary greatly depending on such natural factors as climate, inherent soil and topographic conditions, and a multitude of factors controlled or influenced by man. Uncontrolled environment has a substantial yield-reducing impact, limiting the expected effects of management factors (IRRI 1974). The lack of sufficient and timely rains, and the occurrence of floods can easily destroy a rice crop. Available solar radiation and other factors associated with season also account for a decrease in grain yield. De Datta and Zarate (1970) showed that solar radiation during the 45 days before harvest affected rice yield. Low solar radiation and high relative humidity that generally prevail in tropical rice-growing areas during the wet season are unfavorable to high yield (IRRI 1977).

Environment and the quality of irrigation account for a significant portion of the gap between experiment station yield and actual farm yield. Variations in physical environment are major reasons for the difference in rice yields obtained among farmers (Castillo 1972, Barker and Mangahas 1971, Barker and Anden 1975).

TECHNOLOGICAL AND MANAGEMENT CONSTRAINTS

Chandler (1964) indicated that low rice yields in tropical countries appear to result from poor cultural practices, inadequate water and pest control, and, particularly, lack of non lodging varieties for use on soils with good fertility. Gomez (1974) observed that a critical yield constraint in farmers' fields seems to be the inefficient control of insects and diseases. Sicat (1974) reported that the constraints to agricultural production are overwhelming where expansion of irrigation and water control facilities is slow.

In a study in Cotabato, Philippines, nearly 100% adoption of modern rice varieties was accompanied by a sharp rise in the use of insecticides, herbicides, and tractors. However, the level of fertilizer input and rice yields remained very low. This was attributed principally to the inadequate irrigation facilities and extension services (IRRI 1975).

ECONOMIC CONSTRAINTS

Several economic and social factors prevent rice farmers from achieving high yields. The high cost of inputs, increased labor requirement, farmers' education level, and unavailability of inputs where and when needed are examples.

BIOLOGICAL CONSTRAINTS RESEARCH

Our interest is in identifying the reasons for the gap between potential farm yield and actual farm yield that is caused by biological constraints. The premise of this research is that the farmers' failure to exploit modern rice production technology causes wide discrepancies between actual and potential yields from the modern varieties.

Our study focused on the biological factors that cause the difference between actual and potential yields on several farms in Nueva Ecija, Camarines Sur, and Iloilo provinces, Philippines. Our experiments were in farmers' fields, with a researcher living in the study area to carefully monitor farmers' practices and other farm conditions.

DESIGN OF THE EXPERIMENTS

The approach to the identification and quantification of the major constraints to high yields at farm level has been reported elsewhere (Gomez 1977). We report only the methodology used in 1976 and 1977. For the 1976 dry and wet seasons, a modified factorial-management experiment was conducted in selected farmers' fields. The farmer selection procedure placed farmers in low, medium, and high yielding groups based on the data collected during the preliminary survey. An equal number of farmers was selected for each group.

Levels of inputs

Each test input consisted of two levels intermediate between the farmers' and high input levels of fertilizer and one intermediate level of insect control, and one test level for weed control. Input rates are given in tables in each section of this report. In the new split-plot design, insect control served as the main plot while fertilizer, weed control, and cultural practices were on the subplots.

For the fertilizer input in the 1976 wet season, nitrogen was applied in two equal split doses -- basal and 5 to 7 days before panicle initiation. Phosphorus and potash were in a basal application.

For insect control, the high level had two granular insecticide applications in the seedbed and the main crop received three granular treatments plus one foliar spray. The intermediate insect control level had one granular insecticide application in the seedbed and at least two granular applications to the main crop, with additional foliar spraying included if insect infestation was high.

The high level of weed control included an application of granular herbicide 4 days after transplanting and one hand weeding at 20-30 days after transplanting.

Levels and methods of applications of each test input, used by the farmer in his fields and known as the *comparable paddy*, were carefully simulated in the experiment.

In additional experiments, minifactorial and supplemental trials were included to identify the size of yield gap and contribution of various factors to the yield gap from a larger number of sample farms.

Minifactorial trials

The minifactorial experiment had a minimum of four farm sites in each study area. Each trial had two more treatments than the number of factors being tested: one treatment with all factors at high level; one with all factors at farmers' level, and others with each having all-but-one factor at the high level. One intermediate treatment, consisting of fertilizer at the I-2 level, weed control at high level, and insect control at intermediate level, was included in this experiment.

Supplemental trials

Supplemental trials had a minimum of 12 experimental sites at each location. Each trial had a minimum of one plot with all factors at the high level. Farmer's yield was measured by crop-cutting the farmer's field or sampling plot yield from comparable paddy chosen at the same farm.

In the 1977 dry season, the specific input levels for the complete factorial, minifactorial, and supplemental trials were the same. The high fertilizer level was 150 kg N/ha, 40 kg P_2O_5/ha, and 30 kg K_2O/ha. The I-1 level of fertilizer was 50 kg N/ha, 20 kg P_2O_5/ha, 10 kg K_2O/ha and I-2 was 100 kg N/ha, 30 kg P_2O_5/ha and 20 kg P_2O_5/ha. Nitrogen was applied in three split

applications -- basal (broadcast and incorporated), and topdressings at 20-30 days after transplanting and 5-7 days before panicle initiation. Phosphorus and potassium were applied basally. For insect control, high level included two foliar applications of insecticide in the seedbed and the main crop received one foliar and four granular applications. The intermediate insect control was somewhat flexible, i.e. insecticide was applied only when the incidence of a certain insect species has reached a certain critical level. High level of weed control was the same as in past seasons.

In the 1977 wet season, levels of fertilizer, insect control and weed control used in the complete factorial were the same as in 1976 wet season. The corresponding levels of each test factor used in the minifactorial and supplemental trials were the same as those used in the complete factorial. As in past seasons, farmers' practices were simulated in the experiments.

Management package. During the 1976 wet season and 1977 dry and wet seasons, a separate management package experiment in some experimental sites compared the performance of the farmers' variety with the latest improved variety with five management packages. This experiment provided a basis for judging the economic feasibility of input levels intermediate between the farmers' and the maximum yield level. In this experiment, all other cultural and management practices were at an optimum level.

DESCRIPTION OF THE STUDY AREAS

This report is based on experiments in three provinces in the Philippines (Fig. 1). Table 1 shows the rice crop area and production for seven important rice-growing provinces. About 40% of the total national rice land of 2.3 million ha is in these provinces.

Nueva Ecija. Nueva Ecija tops the total production list with 8.5% of the total national rice production. It also has the highest percentage (57%) of rice lands with irrigation. In 1974 it was selected as an area for the International Rice Agro-Economic Network (IRAEN) yield-constraints project in the Philippines.

Five municipalities (Muñoz, Talavera, Santo Domingo, Guimba, and Nampicuan) in Nueva Ecija province had yield constraints experiments in farmers' fields from the 1974 wet season to the 1977 wet season. These municipalities contain about 25% of the total rice area of the province (Table 2). Of the five municipalities, Guimba and Nampicuan are predominantly rainfed. A substantial portion of the rice areas in the other three municipalities is irrigated. About 25% of the total rice production of Nueva Ecija was from the five municipalities. The average rice yield in the province was 2.1 t/ha; yields in the five municipalities were from 2.0 t/ha to 2.5 t/ha.

Camarines Sur. Of the total 90,692 ha of rice lands in Camarines Sur province, in 1971, 60% were rainfed and 40% were irrigated. The 5 municipalities in Camarines Sur where the yield-constraints studies were conducted represent more than 24% of the total rice area in the province of which 33% was rainfed and 67% irrigated (Table 3). From July 1970 to June 1971, they produced 34% of the total rice in the province; their yields averaged

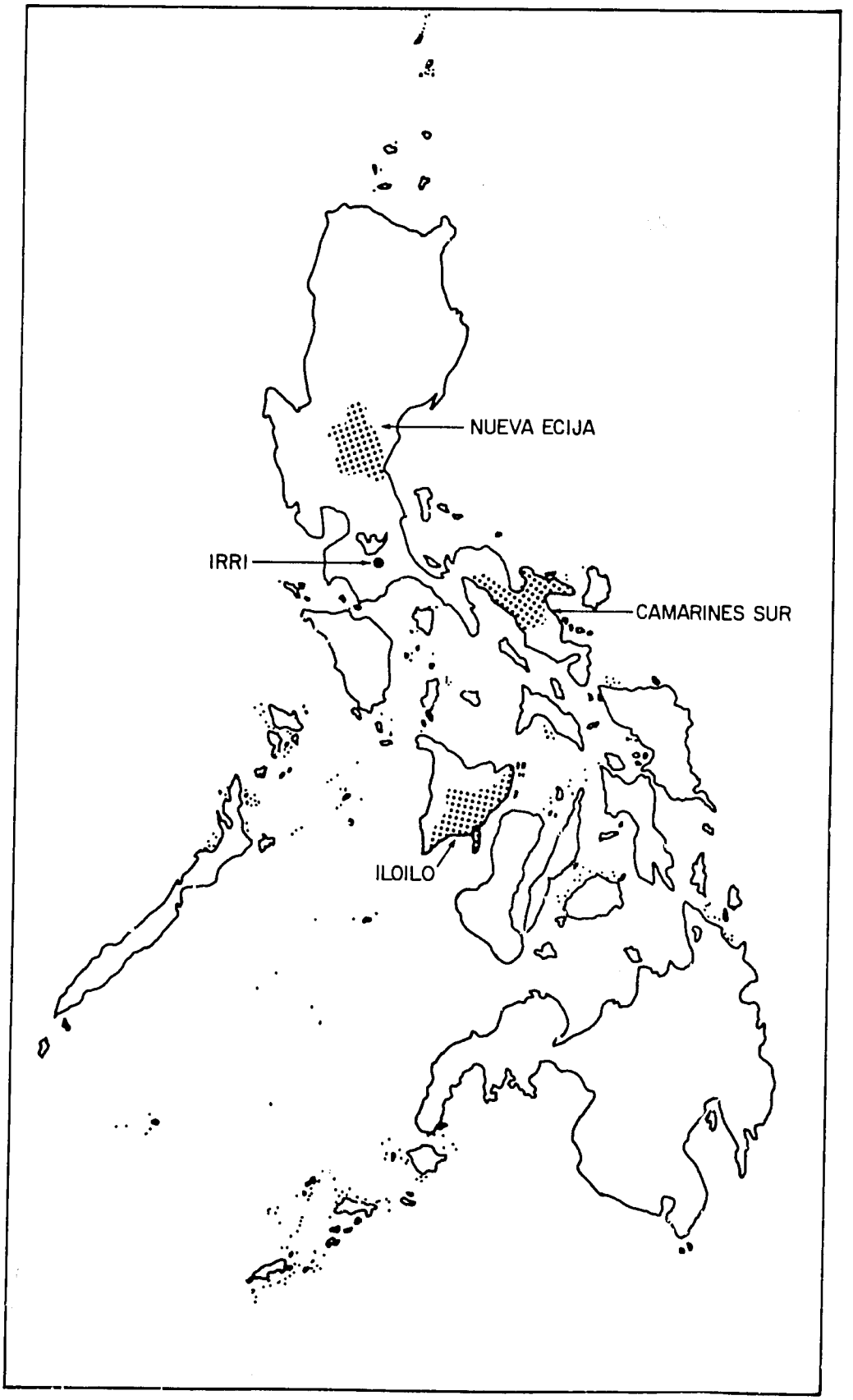

Fig. 1. Sites of yield constraint experiments in the Philippines.

Table 1. Total physical rice crop area and production of the 7 most important rice-growing provinces of the Philippines (NEDA 1971).

Province	Total physical rice crop area						Total production		Av yield (t/ha)
	Hectare	Percent of Philippines	Irrigated Hectare	Irrigated Percent	Rainfed Hectare	Rainfed Percent	Tons	Percent	
Cotabato	180,069	7.8	56,272	31	123,797	69	259,423	6.2	1.4
Nueva Ecija	164,992	7.2	93,299	57	71,693	43	354,266	8.5	2.1
Pangasinan	132,250	5.7	60,762	46	71,488	54	254,911	6.0	1.9
Iloilo	124,939	5.4	31,436	25	93,503	75	211,984	5.0	1.7
Isabela	103,092	4.5	53,965	52	49,127	48	253,297	6.0	2.4
Camarines Sur	90,692	3.9	36,364	40	54,328	60	137,762	3.3	1.5
Tarlac	85,100	3.7	45,042	53	40,057	47	191,274	4.6	2.2
Philippines	2,305,301		868,767	38	1,436,534	62	4,185,909		1.8

Table 2. Total physical rice crop area and production of 5 municipalities of Nueva Ecija province, Philippines[a/] where yield constraints experiments were conducted 1974-77 (NEDA 1971).

Municipality	Total physical rice crop area						Total production		Av yield (t/ha)
	Hectare	Percent of Nueva Ecija	Irrigated Hectare	Irrigated Percent	Rainfed Hectare	Rainfed Percent	Tons	Percent	
Guimba	14,031	8.5	3,440	25	10,591	75	29,717	8.4	2.1
Muñoz	9,794	5.9	7,743	79	2,051	21	24,136	6.8	2.5
Nampicuan	2,029	1.2	279	14	1,750	86	4,074	1.1	2.0
Santo Domingo	6,292	3.8	3,935	63	2,357	37	13,982	3.9	2.2
Talavera	7,285	4.4	6,675	92	610	8	15,496	4.4	2.1
Nueva Ecija	164,992		93,299	57	71,693	43	354,266		2.1

[a/] Data for the period July 1970-June 1971.

Table 3. Total physical rice crop area and production of 5 municipalities of Camarines Sur province, Philippines[a/] where yield constraints experiments were conducted 1975-77 (NEDA 1971).

Municipality	Total physical rice crop area						Total production		Av yield (t/ha)
	Hectare	Percent of Camarines Sur	Rainfed Hectare	Rainfed Percent	Irrigated Hectare	Irrigated Percent	Tons	Percent	
Pili	5,832	6.4	1,658	29	4,174	71	11,084	8.0	1.9
Ocampo	4,794	5.3	1,948	41	2,846	59	8,815	6.4	1.8
Naga	1,745	1.9	386	22	1,359	78	4,211	3.0	2.4
Minalabac	3,979	4.4	938	24	3,041	76	7,919	5.7	2.0
Bula	6,133	6.8	2,394	39	3,738	61	15,002	10.9	2.4
Total	22,483	24.8	7,324	33	15,158	67	47,031	34.0	2.1
Camarines Sur	90,692		54,328	60	36,364	40	137,762		1.5

[a/] Data for the period July 1970-June 1971.

2.1 t/ha. Irrigation water is from streams by gravity flow or from canals or pumps.

Iloilo. Iloilo province had 124,939 ha of total physical rice crop in 1971, of which 75% was rainfed and 25% under some form of irrigation.

The 8 municipalities of Iloilo province where the yield constraints studies were conducted had only 15.3% of the total rice area in the province, 43% of which was rainfed and 57% irrigated. They produced 20.6% of the total rice in the province; the average yield was 2.3 t/ha (Table 4).

We present the data from experiments conducted during the period from the 1974 wet season through the 1977 wet season in the three study areas. Methodology for the study is detailed by De Datta et al (1978). Detailed discussion of results, however, will be limited to the last three crop seasons. Results from earlier tests (from 1974 wet season to 1976 dry season) are discussed elsewhere (Barker et al 1977).

NUEVA ECIJA PROVINCE, 1976 *Wet season*

During the 1976 wet season, experiments were conducted on three rainfed farms (3, 5, 9 in Fig. 2) and six irrigated farms (1, 2, 4, 6, 7, 8 in Fig. 2) in Nueva Ecija province. The average levels of fertilizers used by the cooperating farmers were 57 kg N/ha and 13 kg P_2O_5/ha (Table 5). None of the farmers applied any potassium fertilizer. Farmers' level of insect control consisted of about two foliar applications with insecticides; about half the farmers made an additional application of granular insecticides. Three of the nine farmers used chemicals to control weeds, two farmers did either hand or rotary weeding, and four farmers did not weed. The high levels of each test input are shown also in Table 5 and the intermediate levels of fertilizers and insect control are in Table 6.

Yield gap and its components

Irrigated farms. Grain yields at the farmers' level of inputs in irrigated fields were generally low (Fig. 2). Out of 6 irrigated farms, 2 had yields below 2 t/ha, 3 had yields between 2.0 and 3.0 t/ha, and only 1 had yields above 4 t/ha. The average yield with farmers' inputs was 2.6 t/ha (Table 7). A severe outbreak of tungro virus prevented most farmers from getting high yields. One farm had yields of 1 t/ha because the farmer used IR20, a variety susceptible to tungro virus. Even varieties such as IR26 and IR30, which were originally believed resistant to tungro virus were seriously infected.

The high level of inputs produced yields that ranged from 3.3 to 4.4 t/ha, and averaged 4.2 t/ha. Again, the lowest yield was obtained with IR20, which was severely infected with tungro virus despite a high level of insect control. For one farm there was no yield gap between the farmer's and high inputs because of yield losses caused by lodging of one plot with high inputs. Yield gaps ranged from 0 to 2.4 t/ha (Fig. 2) and averaged 1.6 t/ha (Table 7).

Table 4. Total physical rice crop area and production in 8 municipalities of Iloilo province, Philippines[a] where yield constraints experiments were conducted in 1976-77 (NEDA 1971).

Municipality	Total physical rice crop area						Total production		Av yield
	Hectare	Percent of Iloilo	Rainfed		Irrigated				
			Hectare	Percent	Hectare	Percent	Tons	Percent	(t/ha)
Ajuy	2,958	2.4	1,215	41	1,743	59	5,687	2.7	1.9
Cabatuan	4,246	3.4	4,148	98	98	2	7,516	3.5	1.8
Dingle	931	0.7	570	61	361	39	2,275	1.1	2.4
Leganes	1,736	1.4	89	5	1,646	95	3,481	1.6	2.0
Pavia	1,687	1.3	403	24	1,284	76	4,263	2.0	2.5
Pototan	4,045	3.2	1,229	30	2,815	70	14,031	6.6	3.5
San Miguel	1,844	1.5	1,254	68	590	32	3,061	1.4	1.6
Zarraga	1,754	1.4	259	15	1,495	85	3,551	1.7	2.0
Total	19,201	15.3	9,167	43	10,032	57	43,865	20.6	2.3
Iloilo	124,939		93,503		31,436		211,984		1.7

[a] Data for the period July 1970-June 1971.

Table 5. High and farmers' levels of inputs in yield-constraints experiments in farmers' fields, Nueva Ecija, Philippines, 1974-1977.

Input level	Sites (no.)		Fertilizer (kg/ha)			Weed control treatments[a] (no.)		Insecticide applications[b] (no.)	
	Irrigated	Rainfed	N	P_2O_5	K_2O	M	C	F	G
					1974 wet season				
Farmers'	7	3	37	21	0	0.4	0.3	1.1	0.4
High	7	3	120	60	60	1.0	1.0	5.0	3.0
					1975 wet season				
Farmers'	6	5	79	22	2	0.3	0.4	0.9	0.4
High	6	5	75	30	20	0.0	1.0	3.0	2.0
					1976 wet season				
Farmers'	6	3	57	13	0	0.2	0.3	1.9	0.4
High	6	3	100	40	30	1.0	1.0	1.0	3.0
					1977 wet season				
Farmers'	28	9	64	30	8	0.4	0.4	2.3	0.7
High	28	9	100	40	30	1.0	1.0	2.3	3.0
					1975 dry season				
Farmers'	3	0	118	52	0	0.7	0.3	1.0	1.0
High	3	0	120	30	30	0.0	1.0	3.0	2.0
					1976 dry season				
Farmers'	9	0	76	34	1	0.9	0.4	1.6	0.4
High	9	0	150	40	30	1.0	1.0	1.0	4.0
					1977 dry season				
Farmers'	28	0	93	41	4	0.8	0.5	1.9	0.6
High	28	0	150	40	30	1.0	1.0	1.0	4.0

[a] M = mechanical weeding either by hand or by rotary weeder, C = chemical herbicide.

[b] F = foliar spray (Hytox, Azodrin, Brodan, Parapest, etc.), G = granular (Lindane, Furadan, Diazinon, etc.) to paddy water. The main field crops were treated. In some cases, seedbeds were also treated.

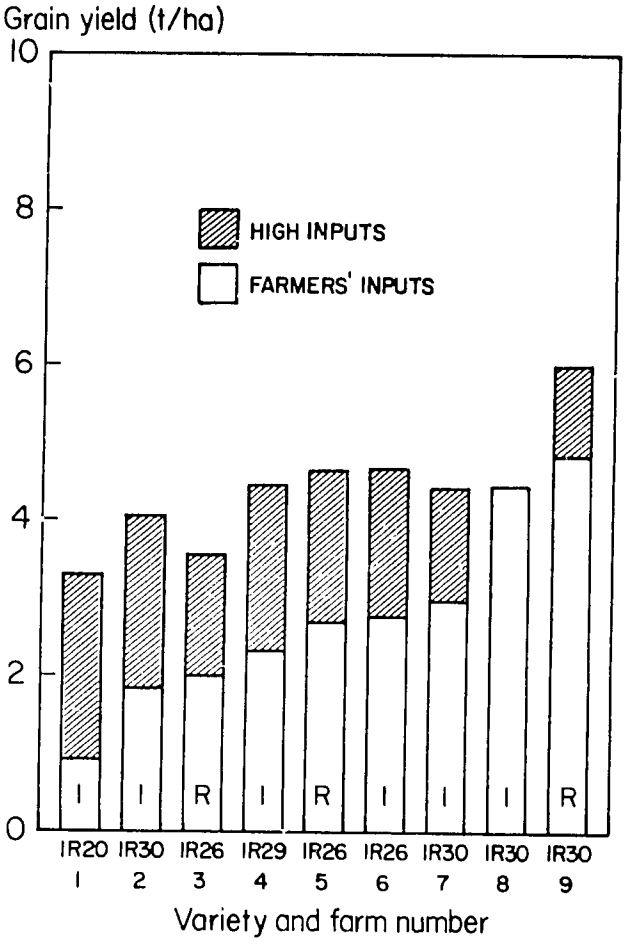

Fig. 2. Variations in yield gap between farmers' fields in farm yield constraints studies in Nueva Ecija province, Philippines, 1976 wet season (Each bar represents one farm; I = irrigated, R = rainfed).

Table 6. Farmers' and intermediate levels of fertilizer and insect control in yield-constraints experiments, Nueva Ecija, Philippines, 1976-1977.

Sites (no.)		Fertilizer level (kg/ha)									Insecticide applications[a] (av no.)			
		Farmers'			Intermediate 1			Intermediate 2			Farmers'		Intermediate 1	
Irrigated	Rainfed	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	F	G	F	G
						1976 dry season								
9	0	76	34	1	50	20	10	100	30	20	1.6	0.4	0	2.0
						1976 wet season								
6	3	57	13	0	40	20	10	70	30	20	1.9	0.4	0	2.0
						1977 dry season								
7	0	125	36	0	50	20	10	100	30	20	1.6	0.6	0	1.4
						1977 wet season								
8	2	82	35	10	40	20	10	70	30	20	2.1	0.5	1.6	1.1

[a] F = foliar, G = granular.

Table 7. Average yields at farmers' and high levels of inputs in irrigated and rainfed farmers' fields, Nueva Ecija, Philippines, 1974-1977.

Water condition	Sites (no.)	Grain yield (t/ha)		
		Farmers' inputs	High inputs	Difference
		1974 wet season		
Irrigated	7	1.8	2.1	0.3
Rainfed	3	1.8	2.7	0.9
		1975 wet season		
Irrigated	6	3.3	3.9	0.6
Rainfed	5	3.1	3.8	0.7
		1976 wet season		
Irrigated	6	2.6	4.2	1.6
Rainfed	3	3.2	4.8	1.6
		1977 wet season		
Irrigated	28	4.1	5.2	1.1
Rainfed	9	3.8	5.5	1.7
		1975 dry season		
Irrigated	3	4.3	5.2	0.9
		1976 dry season		
Irrigated	9	4.0	6.5	2.5
		1977 dry season		
Irrigated	28	4.8	7.0	2.2

Rainfed farms. Farmers' yields from rainfed fields ranged from 2.0 to 4.8 t/ha (Fig. 2), and averaged 3.2 t/ha (Table 7). With high inputs, yields ranged from 3.6 to 6.0 t/ha and averaged 4.8 t/ha. Tungro virus seriously reduced yields from farmers' inputs on two farms because of inadequate crop protection. Drought at the heading stage, in addition to tungro virus struck one farm and caused low yields at both levels of inputs. The highest grain yields at both input levels were obtained, where tungro was not a major problem despite tungro infection in surrounding farms. The average yield gap was 1.6 t/ha, similar to that on the irrigated farms.

The average grain yields at the farmers' and high-input levels on rainfed farms were substantially higher than those on irrigated farms (Table 7). The reason could be that farmers on rainfed areas used an average of 85 kg N/ha, while farmers with irrigation used only 44 kg N/ha, and the tungro problem was more serious on irrigated than on rainfed farms.

Average of irrigated and rainfed farms. Combined data on irrigated and rainfed farms show the average 1976 wet-season yield gap as 1.6 t/ha, about 1 t/ha higher than the 1975 wet-season gap (Table 8). One reason for the small yield gap during the 1975 wet season was that farmers used a high rate of nitrogen similar to the high-level rate used (Table 5). Further, the potential yield in farmers' fields was apparently not attained by using only 75 kg N/ha. Improved insect control contributed 0.9 t/ha (61%) of the 1.6-t/ha average yield gap in 1976 wet season, while the high level of fertilizer accounted for 0.6 t/ha (39%). The high level of weed control made no contribution to the gap (Table 9, Fig. 3).

The magnitude of contributions of the three test factors to the 1976 yield gap was not consistent with the findings during the 1975 wet season. As mentioned earlier, tungro virus infection was widespread in the 1976 wet season. That explains why improved insect control made the highest contribution to the yield gap, reversing the results obtained during the 1975 wet season, when there was no major pest outbreak.

Effect of the test factors on grain yield

Fertilizer. The high level of fertilizer produced significantly higher yields than the farmers' level in the 1976 wet season (Table 10). On 6 farms, the intermediate fertilizer levels increased yields over the farmers' level -- with an average of 0.5 t/ha yield increase from the higher intermediate level (I-2). Although the farmers' average level of fertilizer nitrogen was higher than the first intermediate level (I-1), the increase in grain yield of 0.2 t/ha, although perhaps not statistically significant, indicate that the I-1 fertilizer application was more efficient. To confirm that, yields with the farmers' level of nitrogen were compared with those with intermediate and high levels, weed and insect control constant at the farmers' or the high level. The average yields obtained are in Table 11. Among 6 farms that applied more than 40 kg N/ha 4 had substantially lower yields than with the I-1 level of fertilizer nitrogen even though the farmers' rates were higher than 40 kg/ha (Table 11). On two farms, yields for the farmers' and I-1 levels were about equal despite the greater amount of nitrogen used at the farmers' level. On the average, I-1 yielded 0.4 t/ha higher than the farmers' level. When the farmers' level of nitrogen was similar with the high level (A. Aquino), a 0.4-t/ha difference was recorded in favor of the high level. A similar trend in yield was noted even when the levels of weed and insect control were high.

Insect control. The high level of 1976 wet-season insect control produced significantly higher yields than did the farmers' level on 7 of 9 farms; the average yield difference was 0.9 t/ha (Table 10). Similarly, yields with intermediate insect control were significantly higher than yields with the farmers' level on five farms. Low farmers' yields were largely due to inadequate insect protection particularly against the green leafhopper.

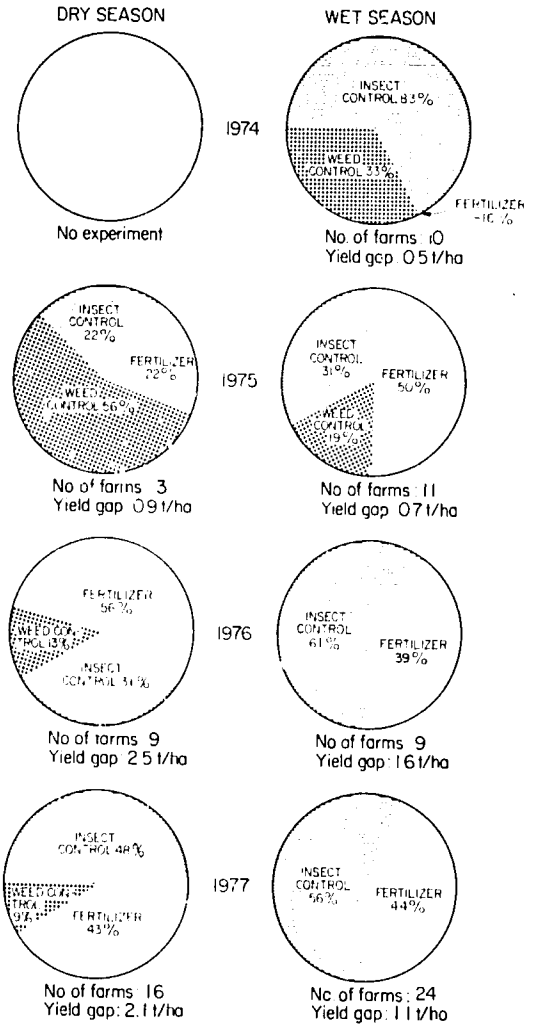

Fig. 3. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Nueva Ecija province, Philippines, 1974-1977.

Table 8. Average yields for irrigated and rainfed sites at farmers' and high levels of inputs in yield constraints experiments in farmers' fields, Nueva Ecija province, Philippines, 1974-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)		
		Irrigated	Rainfed	Farmers' inputs	High inputs	Difference
1974	Wet	7	3	1.8	2.3	0.5
1975	Wet	6	5	3.2	3.9	0.7
1976	Wet	6	3	2.8	4.4	1.6
1977	Wet	28	9	4.0	5.3	1.3
1975	Dry	3	0	4.3	5.2	0.9
1976	Dry	9	0	4.0	6.5	2.5
1977	Dry	28	0	4.8	7.0	2.2

Table 9. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Nueva Ecija, Philippines, 1974-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)			Contribution[a] (t/ha)			
		Irrigated	Rainfed	Farmers' inputs	High inputs	Difference	Fertilizer	Weed control	Insect control	Residual
1974	Wet[b]	7	3	1.8	2.3	0.5	-0.1	0.2	0.5	-0.1
1975	Wet	6	5	3.2	3.9	0.7	0.3	0.1	0.2	0.1
1976	Wet	6	3	2.8	4.4	1.6	0.6	0.0	0.9	0.1
1977	Wet	18	6	4.2	5.3	1.1	0.4	0.0	0.5	0.2
1975	Dry[b]	3	0	4.3	5.2	0.9	0.2	0.5	0.2	0.0
1976	Dry	9	0	4.0	6.5	2.5	1.4	0.3	0.8	1.0
1977	Dry	16	0	5.2	7.3	2.1	0.9	0.2	1.0	0.0

[a] Measured as yield decrease from high input due to a reduction from high to farmers' level of each input.

[b] Land preparation was included in these experiments but had no significant effect on yield.

Table 10. Grain yield with different levels of inputs, Nueva Ecija, Philippines, 1976-1977.

Year	Season	Sites (no.)		Grain yield[a] (t/ha)								
				Fertilizer level				Insect control			Weed control	
		Irrigated	Rainfed	F	I-1	I-2	H	F	I	H	F	H
1976	Dry	9	0	4.5	4.6	5.5	5.8	4.8	4.9	5.6	5.0	5.3
1976	Wet	6	3	3.3	3.5	3.8	3.9	3.1	3.7	4.0	3.6	3.6
1977	Dry	7	0	5.8	5.5	6.4	6.7	5.8	5.6	6.9	6.1	6.2
1977	Wet	8	2	4.8	4.9	5.2	5.2	4.8	4.8	5.4	5.0	5.0

[a] F = farmers' level, I = intermediate, H = high. Data are averages over all levels of other test inputs.

Weed control. The high level of 1976 wet-season weed control gave no added yield over and above the farmers' level (Table 10), indicating that the farmers controlled weeds adequately.

Cultural practices. Table 12 shows the 1976 wet-season yield differences between high cultural practices (HCP) and farmers' cultural practices (FCP) in 9 complete factorial trials. On the average, farmers' and high cultural practices gave similar yield at all management levels.

Varieties. Varietal differences were also tested by comparing the yield performance, under different management levels, of the farmers' varieties with that of a test variety (Table 13). Four farmers grew IR30, three grew IR26, one grew IR20 and one grew IR29. The test variety for all farms was IR36, which outyielded the farmers' varieties across all management levels primarily because of its high-yield characteristics and its resistance to tungro.

Table 11. Grain yields from farmers' and test levels of fertilizer with farmers' and high levels of weed and insect control measures in experiments in farmers' fields, Nueva Ecija, Philippines, 1976 wet season.

Farmers (no.)	Variety	Farmers level of nitrogen application		Weed and insect control measures	Grain yield[b] (t/ha)			
		Rate (kg/ha)	Timing (DT)[a]		Farmers'	I-1	I-2	H
1	IR20	0	-	Farmers'	0.9	0.8	1.2	1.2
				High	2.8	3.2	3.4	3.4
2	IR30	0	-	Farmers'	1.8	2.7	3.0	3.0
				High	3.1	2.9	3.5	4.1
3[c]	IR26	98	14, 37	Farmers'	2.0	2.3	2.4	2.4
				High	2.5	3.2	3.3	3.6
4	IR29	31	10	Farmers'	2.3	2.9	3.6	3.9
				High	3.4	4.2	4.2	4.5
5[c]	IR26	78	31	Farmers'	2.7	4.1	3.0	3.8
				High	4.1	3.9	3.9	4.7
6	IR26	51	28, 45	Farmers'	2.8	3.8	3.6	3.5
				High	4.3	4.3	4.9	4.7
7	IR30	49	3, 31	Farmers'	3.0	3.4	3.4	4.0
				High	3.8	3.9	4.1	4.4
8	IR30	130	10	Farmers'	4.4	4.2	4.2	4.2
				High	3.9	4.3	4.3	4.4
9[c]	IR30	78	18	Farmers'	4.8	4.7	5.0	5.2
				High	5.8	5.2	6.1	6.0
Av		57		Farmers'	2.8	3.2	3.3	3.5
				High	3.7	3.9	4.2	4.4

[a] DT = days after transplanting.

[b] Test rates of nitrogen: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha; H (high) = 100 kg N/ha. Time of application = basal and 5-7 days before panicle initiation.

[c] Rainfed farm.

Table 12. Yields with high level (HCP) of cultural practices and those with farmers' level (FCP) in experiments in farmers' fields, Nueva Ecija, Philippines, 1976-1977.

Sites (no.)		Level of practices	Grain yield[a] (t/ha) at management level			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
			1976 wet season			
6	3	Farmers'	3.4	4.3	5.1	4.3
6	3	High	3.6	4.2	4.8	4.2
			1977 dry season			
7	0	Farmers'	5.4	5.2	8.1	6.2
7	0	High	5.3	4.8	7.2	5.8
			1977 wet season			
8	1	Farmers'	4.5	4.5	5.6	4.8
8	1	High	4.2	4.3	5.3	4.6

[a] Data are averages of test and farmers' varieties from the complete factorial trials only.

Table 13. Yields of farmers' varieties compared with those of test varieties for input packages grown with high and farmers' levels of cultural practices in yield-constraints experiments in farmers' fields, Nueva Ecija, Philippines, 1976-1977.

Sites (no.)		Variety	Grain yield[a] (t/ha)			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
			1976 wet season			
6	3	Farmers'[b]	3.0	3.6	4.4	3.7
6	3	Test (IR36)	4.1	4.8	5.5	4.8
			1977 dry season			
7	0	Farmers' (IR36)	5.3	5.0	7.6	6.0
7	0	Test (IR26)	5.4	5.0	7.7	6.0
			1977 wet season			
8	1	Farmers' (IR36 and IR32)	4.6	4.6	5.6	4.9
8	1	Test (IR42)	4.1	4.1	5.3	4.5

[a] Data are average yields from complete factorial trials only.

[b] Farmers' varieties = IR20, IR26, IR29 and IR30.

NUEVA ECIJA PROVINCE, 1977 *Dry season*

During the 1977 dry season, three types of experiments were grown in Nueva Ecija province to determine the magnitude of the yield gap -- complete factorial on 7 farms, minifactorial on 9 farms, and supplemental trials on 12 farms. No rainfed crop is grown in the dry season. All sites were pump irrigated. The average levels of fertilizers applied by the farmers were 93 kg N/ha, 41 kg P_2O_5/ha, and 4 kg K_2O/ha (Table 5). The farmers used an average of two foliar insecticide applications; about half supplemented foliar insecticides with granular insecticides. One farmer did not apply any insecticide at all. All farmers controlled weeds either by hand pulling or rotary weeding or by a combination of chemicals and hand weeding.

Yield gap and its components

Yields at the farmers' level of inputs were highly variable; they ranged from 3.2 t/ha to 8.6 t/ha (Fig. 4) and averaged 4.8 t/ha (Table 7). Farm 2 with the lowest yield, used only 34 kg N/ha and no phosphorus and potassium fertilizers. The high yield (farm 28) was from 164 kg N/ha, a rate higher

than the high experimental level. Yields varied widely among farms even with fixed inputs as the high level. Yields at high inputs ranged from 4.7 t/ha to 8.9 t/ha, averaging 7.0 t/ha. Only 4 of 28 farms had yields lower than 6.0 t/ha. Stem rot at the ripening stage reduced yields on farms 5 and 1. On farms 6 and 10, improper management of fertilizer nitrogen and wide plant spacing contributed to low yields.

On other farms, where yields varied from 6.0 t/ha to 8.9 t/ha, yield variations could have been the result of differences in environment because the farmers' fields were scattered in 4 municipalities in the study area. No obvious factor to explain the yield variations from farm to farm. The average yield gap of 2.2 t/ha was similar to the 2.5-t/ha average yield gap obtained from 9 farms during the 1976 dry season.

Effect of test factors on grain yield

The calculation of relative contribution of each test factor to the yield gap includes only the data from the complete factorial and minifactorial experiments. Yields from farmers' levels of inputs from these experiments ranged from 3.2 t/ha to 8.6 t/ha (average 5.2 t/ha) while those from the high level produced yields ranging from 5.4 t/ha to 8.9 t/ha (average 7.3 t/ha), generating an average yield gain of 2.1 t/ha (Table 9).

Improved insect control contributed 48% (1.0 t/ha) to the yield gap while fertilizer accounted for 43% (0.9 t/ha) (Fig. 3). The lower yield gain from fertilizer, compared with that in the previous dry season (Table 9), was caused by the application of more nitrogen (106 kg N/ha) by the farmers.

Fertilizer. Considering only the complete factorial experiment, the average yield obtained by the cooperating farmers was only 0.3 t/ha higher than the average yield with the I-1 fertilizer level (Table 10) even though the farmers used a rate of nitrogen substantially higher than the I-1 level (Table 6). However, a yield increase of 0.6 t/ha over the farmers' level was obtained with the I-2 fertilizer level despite a higher rate of fertilizer used by the farmers. That again indicated poorer application method and timing of fertilizer nitrogen by farmers. A further yield increase of 0.3 t/ha was obtained with the high level of fertilizer application.

The results are in good agreement when the comparisons are made either with insect and weed control measures at farmers' level or at high level (Table 14). Averaged data from 9 minifactorial trials show that the high level of fertilizer gave an added yield of 0.9 t/ha, a result similar to those obtained from the 7 complete factorial trials.

Insect control. Because of heavy stem borer infestation during the tillering and flowering stages on most farms, the high level of insect control produced significantly higher grain yields than the farmers' and intermediate levels (Table 10). Grain yields from the farmers' and intermediate levels of insect control were similar.

In the minifactorial trials, the high level of insect control provided an additional yield of 0.9 t/ha over the farmers' level, similar to that in the complete factorial trials.

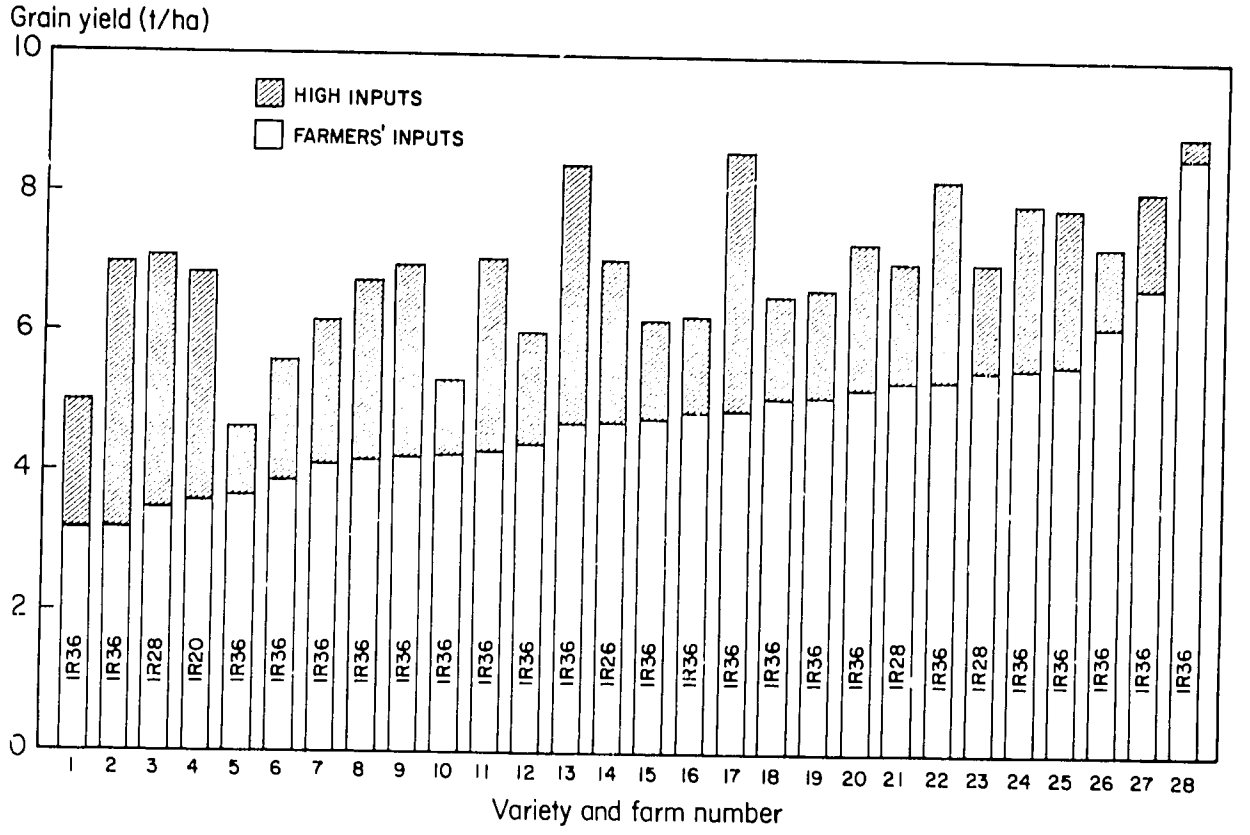

Fig. 4. Variations in yield gap between farmers' fields in farm yield-constraints studies in Nueva Ecija province, Philippines, 1977 dry season (Each bar represents one farm; all pump irrigated).

Weed control. In complete factorial and minifactorial trials, improved weed control gave only a modest yield increase over the farmers' level, as in 1976 dry season (Table 10).

Cultural practices. As in the previous season, farmers' and high levels of cultural practices involving test and farmers' varieties were compared at three levels of management in seven complete factorial trials. All farmers used IR36 and the test variety IR26. Grain yields are given in Table 12. At farmers' management level average yields with both cultural practices were similar. However, at intermediate and high levels of management, average yields with farmers' cultural practices were higher by 0.4 t/ha and 0.9 t/ha, respectively. Rat damage, and possibly bird damage, accounted for lower yields in plots with high cultural practices because the high-level plots were harvested much later than the farmers' plots. Plant density may also have contributed to some degree because farmers generally used closer spacing.

Table 14. Grain yields from farmers' level and test levels of fertilizer with farmers' and high levels of weed and insect control measures in yield-constraints experiments in farmers' fields, Nueva Ecija, Philippines, 1977 dry season.

Farmers (no.)	Variety	Weed and insect control measures	Nitrogen applied (farmers' level)		Grain yield[b] (t/ha)			
			Rate (kg/ha)	Timing (DT)[a]	Farmers'	I-1	I-2	H
13	IR36	Farmers'	143	18, 24, 39, 43	4.8	5.5	6.2	6.4
		High			6.6	6.9	7.6	8.4
17	IR36	Farmers'	81	22, 36	4.9	4.8	5.2	6.3
		High			6.6	6.0	6.9	8.6
20	IR36	Farmers'	132	14, 44	5.3	4.6	4.5	5.3
		High			5.9	5.4	6.9	7.4
28	IR36	Farmers'	164	14, 32, 37, 40	8.6	5.7	7.6	8.2
		High			8.2	6.8	8.0	8.9
27	IR36	Farmers'	125	8, 35, 40	6.8	5.7	7.3	6.2
		High			8.1	7.6	8.1	8.1
9	IR36	Farmers'	194	12, 34	4.3	5.5	6.0	6.2
		High			6.8	5.8	6.4	7.0
2	IR36	Farmers'	34	27	3.2	4.3	5.2	6.6
		High			4.0	5.1	6.2	7.0
Av		Farmers'	125		5.4	5.2	6.0	6.4
		High			6.6	6.2	7.2	7.9

[a] DT = days after transplanting.

[b] Test rates of nitrogen: Intermediate levels: I-1 = 50 kg N/ha, I-2 = 100 kg N/ha; High level (H): 150 kg N/ha. Time of application = basal, 20-30 days after transplanting and 5-7 days before panicle initiation.

Varieties. Yields from farmers' and test varieties were compared in the complete factorial experiments. All farmers grew IR36 and used IR26 as test variety. IR36 and IR26 gave similar average yields of 6.0 t/ha on all farms (Table 13).

NUEVA ECIJA PROVINCE, 1977 *Wet season*

During the 1977 wet season, the 1977 dry-season experiments were repeated on 37 farms -- 28 irrigated and 9 rainfed. The farmers applied fertilizer at an average level of 64 kg N/ha, 30 kg P_2O_5/ha and 8 kg K_2O/ha (Table 5). One farmer did not apply any insecticide and the rest used foliar insecticides at the frequency of 1 to 7 applications, averaging 2.3 applications. Nineteen farmers used granular insecticides as additional insect control measures. Twelve farmers did not control weeds, but the rest used hand weeding or chemical weed control, or both.

Yield gap and its components

Irrigated farms. Farmers' yields with irrigation varied from 2.4 to 6.0 t/ha (Fig. 5), averaging 4.1 t/ha (Table 7). Yield was low (2.4 t/ha) in the minifactorial trial because of typhoon damage. In the complete factorial experiment, a low yield of 2.8 t/ha was also largely due to typhoon damage. Farmers' yields in supplemental trials were low because of typhoon damage and inefficient fertilizer use and insect control.

With high inputs, yields ranged from 3.2 to 6.9 t/ha and averaged 5.2 t/ha. The highly variable yields with high inputs were due to typhoons on 14 farms and brown planthopper infestation on 2 farms. Such adverse factors often discourage farmers from using high-input modern technology. The average yield gap was 1.1 t/ha, 0.5 t/ha lower than the average yield gap identified on irrigated farms during the 1976 wet season (Table 7).

Rainfed farms. Yields with farmers' inputs in rainfed fields ranged from 2.6 to 5.0 t/ha, and averaged 3.8 t/ha (Table 7). With high inputs, grain yields ranged from 3.4 to 6.5 t/ha and averaged 5.5 t/ha. The average yield gap was similar to that for the three rainfed farms during the preceding wet season. Drought at the reproductive stage was a major problem at both input levels on farms 2, 5, and 8.

As in the 1976 wet season, the average yield with high inputs was higher in rainfed than in irrigated sites. It appears that typhoon damage caused higher yield losses in irrigated sites than did drought in some rainfed farms. Furthermore, insect pressure, particularly leaf rollers, was greater in irrigated than in rainfed areas. On the other hand, yields in irrigated farms were 0.3 t/ha higher than those in rainfed farms. That may have been partly from a lower rate of fertilizer nitrogen applied by the rainfed farmers (51 kg N/ha) than by irrigated farmers (68 kg N/ha).

Average of irrigated and rainfed farms. Combined yield data from the irrigated and rainfed sites (complete factorial, minifactorial, and supplemental experiments) show an average yield gap of 1.3 t/ha (Table 8). But the average yield gap identified from complete factorial and minifactorial trials was reduced to 1.1 t/ha (Table 9). As in the 1976 wet season, only improved insect control (0.5 t/ha) and the high level of fertilizer (0.4 t/ha) were responsible for the yield gap. Improved weed control made no contribution to the yield gap (Fig. 3).

Effect of the test factors on grain yield

Fertilizer. In the complete factorial experiment, the high level of fertilizer outyielded the farmers' level by 0.4 t/ha (Table 10) mainly because the farmers used less fertilizer. The average farmers' yield was similar to the average yield obtained with the I-1 level even though farmers used twice as much nitrogen. Yield increased by 0.4 t/ha with the I-2 level even though the farmers used slightly more fertilizer (Table 6). These results hold even in comparisons made at either farmers' or high levels of weed and insect control (Table 15), confirming earlier findings that the farmers were applying their fertilizers improperly. As indicated in Table 15, the cooperating farmers did not apply fertilizer basally but topdressed their nitrogen fertilizer as early as 6 days or as late as 42 days after transplanting.

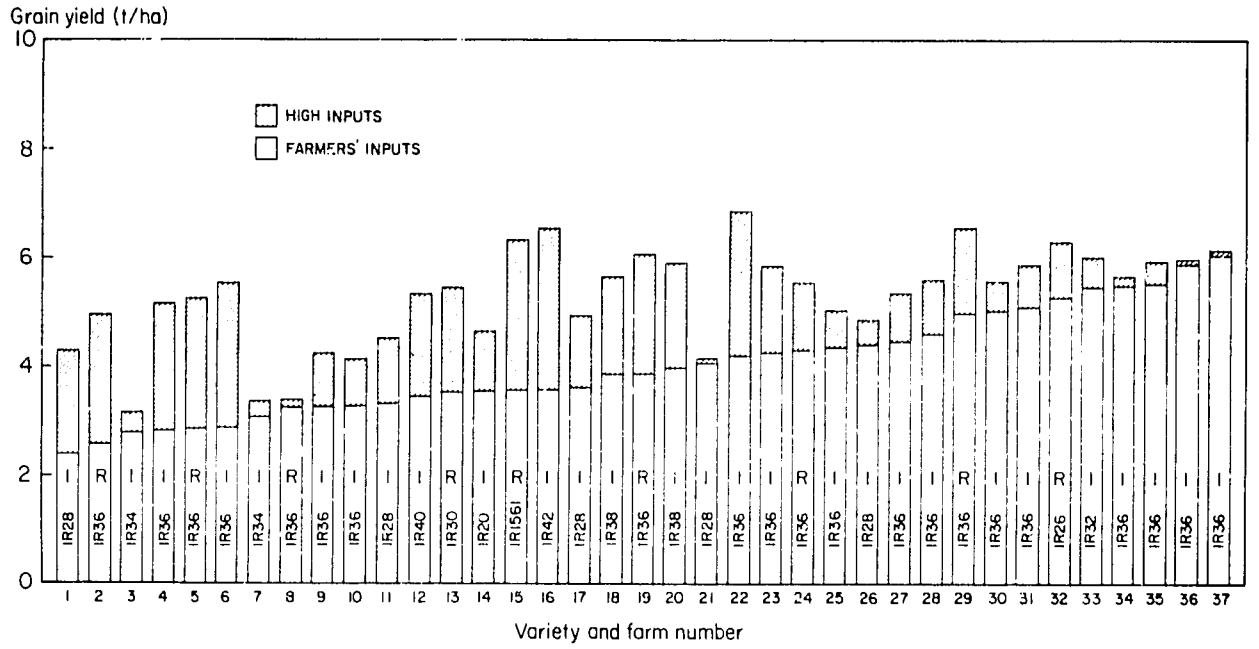

Fig. 5. Variations in yield gap between farmers' fields in farm yield-constraints studies in Nueva Ecija province, Philippines, 1977 wet season (Each bar represents one farm; I = irrigated, R = rainfed).

Insect control. The high level of insect control gave an added yield of 0.6 t/ha over the farmers' and intermediate levels (Table 10). Stem borer and whorl maggot infestations during the early growth stages and high incidence of leaf roller, leaf folder, and stem borer from maximum tillering to heading stages accounted for the substantial yield losses at farmers' and intermediate levels of insect control.

Weed control. As in the 1976 wet season, the farmers' and high levels of weed control gave similar yields (Table 10). Weed control practices of the cooperating farmers were considered adequate.

Cultural practices. Yield differences between farmers' and high cultural practices are given in Table 12. On the average, yields obtained with farmers' cultural practices had a slight advantage over those obtained with high cultural practices at all management levels. The high level of cultural practices produced higher yields than the farmers' level across all management levels on only one out of nine farms; the farmers' level of cultural practices produced significantly higher yields on three farms, and the high level and farmers' practices gave similar yields in the rest of the farms.

Table 15. Grain yields from farmers' and test levels of fertilizer and farmers' and high levels of weed and insect control in yield constraints experiments in farmers' fields, Nueva Ecija province, Philippines, 1977 wet season.

Farmers (no.)	Variety	Farmers' level of Nitrogen application		Weed and insect control level	Grain yield[b] (t/ha)			
		Rate (kg/ha)	Timing (DT)[a]		Farmers'	I-1	I-2	H
4	IR36	110	14, 37	Farmers'	2.8	2.0	2.2	2.9
				High	4.8	3.5	4.1	5.2
5[c]	IR36	85	6	Farmers'	2.8	3.6	4.4	4.1
				High	4.2	4.8	5.0	5.2
23	IR36	57	12, 35	Farmers'	4.3	4.6	5.1	5.4
				High	4.9	5.4	5.8	5.8
25	IR36	177	10, 41	Farmers'	4.3	5.3	5.3	4.0
				High	5.0	5.9	5.4	5.0
29[c]	IR36	73	16	Farmers'	5.0	5.1	5.0	6.0
				High	5.8	5.4	6.3	6.5
30	IR36	65	9, 42	Farmers'	5.0	5.3	4.9	5.2
				High	5.8	5.9	6.2	5.6
31	IR36	36	19, 34	Farmers'	5.1	5.1	5.6	5.7
				High	5.6	5.5	5.7	5.9
33	IR32	101	17, 31	Farmers'	5.4	5.6	6.1	6.2
				High	4.9	5.5	5.6	6.0
34	IR36	51	19, 34	Farmers'	5.5	5.3	5.8	5.2
				High	5.5	5.8	5.9	5.7
35	IR36	66	28	Farmers'	5.5	5.0	5.0	5.2
				High	5.3	5.8	6.0	5.9
Av		82		Farmers'	4.6	4.7	5.0	5.0
				High	5.2	5.4	5.6	5.7

[a] DT = days after transplanting.

[b] Nitrogen test rates: Intermediate levels: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha; H (high) = 100 kg N/ha. Time of application = basal and 5-7 days before panicle initiation.

[c] Rainfed farm.

Varieties. As in previous seasons, farmers' and test varieties were tested for yield performance in the management package component of the complete factorial trials. The test variety on all farms was IR42. Eight farmers grew IR36 and one grew IR32. Another farmer grew IR36 but because of drought produced no yield with the test variety. On the average, the farmers' variety outyielded the IR42 by 0.4 t/ha (Table 13). Typhoon damage contributed largely to grain losses of IR42 which has longer maturity than the farmers' varieties and, in some cases, rat damage was a problem when the IR42 was the only crop left in the field. However, on two farms where both varieties were not damaged, IR42 yielded 0.8 t/ha and 1.2 t/ha higher than the farmers' variety.

Management package project

An additional series of experiments was conducted to evaluate intermediate levels between the farmers' practices and the improved or recommended set of practices. The incremental steps between treatments usually involve a simultaneous change in more than one input. The management package project tests the different input combinations selected to represent different yield levels and production costs. The detailed methodology is described by De Datta et al (1976).

1976 wet season. The management package experiment was on one farm. The input levels are described in Table 16. Subsoil placement of insecticide was tried at the M_3 and M_4 levels. The average grain yield for 5 management packages for the test variety IR36 was 0.5 t/ha higher than that for the farmer's variety, IR30 (Table 17), but only at M_1 and M_2 were its yields significantly higher.

IR30 suffered from tungro virus, and both varieties lodged; that resulted in a maximum grain yield of about 5.0 t/ha.

These results clearly suggest that levels of tungro and lodging resistance must be increased further in the modern varieties to minimize farmers' risk of getting low yields.

1977 dry season. The same management experiment was on one irrigated farm. The farmers used a higher nitrogen level than and about the same rate of phosphorus as those in the M_4 level. They used insect and weed control measures at the M_2 level (Table 16).

Yields of the farmer's (IR36) and test (IR26) varieties steadily rose from M_2 to M_5 levels (Table 17). The average yield at the farmers' level (M_1) was not significantly different from that at M_3 despite the higher amounts of fertilizer used at the farmers' level. That indicates that the farmer did not apply fertilizer properly. The farmer's insect control measures were inadequate and there was stem borer damage at heading. Varietal differences were noted only at M_5 where IR36 gave significantly higher yield than IR26.

1977 wet season. The management package experiment was on two irrigated farms. The farmers' average levels of fertilizer were at M_2 level for N, M_4 level for P_2O_5, and half that of M_3 level for K_2O (Table 16). Average levels of farmer's insect and weed control were at M_2 level. The farmer's variety was IR36 and the test variety IR42.

Average yields for farmers' and test varieties rose steadily from M_2 to M_5 package levels (Table 17). On one farm IR42 significantly outyielded IR36 at all management levels. Yield of the farmer's variety at M_5 was 0.4 t/ha lower than that at both M_3 and M_4, and 0.3 t/ha lower than that at the farmers' management level. The low yield level of M_5 was attributed to lodging and a high incidence of leaf rollers during the reproductive growth stage. The yields of IR42 were the same at M_1 and M_2 but as the input level was raised to M_5, a corresponding yield increase of 0.4 or 0.3 t/ha per increase was obtained. On the other farm, however, a substantial yield difference was recorded at all management levels, except M_5, for the two varieties. IR36 gave higher yields than IR42 but IR42 suffered yield losses

Table 16. Average levels of farmers' inputs and levels of four input management packages, Nueva Ecija province, Philippines, 1976-1977.

Sites (no.)		Package level[a]	Fertilizer level (kg/ha)			Insecticide applications[b] (av no.)					Weed control treatments[c] (av no.)	
						Seedbed		Field				
Irrigated	Rainfed		N	P_2O_5	K_2O	F	G	R	F	G	M	C
						1976 wet season						
1	0	M_1	49	29	0	1	0	0	2	1	0	0
		M_2	40	10	0	0	0	0	2	0	1	0
		M_3	60	20	20	0	1	1	0	0	0	1
		M_4	80	30	30	2	0	1	0	1	1	1
		M_5	100	40	40	0	2	0	1	4	1	1
						1977 dry season						
1	0	M_1	132	27	0	0	0	0	3	0	1	0
		M_2	40	10	0	0	0	0	2	0	1	0
		M_3	80	20	20	0	1	1	0	0	0	1
		M_4	120	30	30	1	1	1	1	0	0	1
		M_5	160	40	40	0	2	0	1	4	1	1
						1977 wet season						
2	0	M_1	43	27	11	0	0	0	3	0	1	0
		M_2	40	10	0	0	0	0	3	0	1	0
		M_3	60	20	20	0	1	1	0.5	0	0	1
		M_4	80	30	30	0	2	1	1	1	0	1
		M_5	100	40	40	0	2	0	2.5	4	1	1

[a] M_1 = farmers' level of application of the three inputs. M_2-M_5 have levels of fertilizer, insect control, and weed control, as listed in this table.

[b] G = granular, R = rootzone placement of liquid carbofuran, F = foliar.

[c] M = mechanical weeding, by either hand or rotary weeder, C = chemical weedicide.

Table 17. Average grain yields of farmers' and test varieties compared at farmers' and four input management packages and grown with high levels of cultural practices, Nueva Ecija province, Philippines, 1976-1977.

Sites (no.)		Variety[a]	Grain yield[b] (t/ha)					
Irrigated	Rainfed		M_1[c]	M_2	M_3	M_4	M_5	Av
					1976 wet season			
1	0	IR30	3.8	3.1	4.8	4.8	4.8	4.3
1	0	IR36 (t)	5.0	5.2	4.5	4.4	4.9	4.8
					1977 dry season			
1	0	IR36	5.4	4.4	5.7	6.1	7.8	5.9
1	0	IR26 (t)	5.6	4.2	5.7	6.4	7.3	5.9
					1977 wet season			
2	0	IR36	4.6	4.3	5.1	5.3	5.4	4.9
2	0	IR42 (t)	4.8	4.8	5.2	5.6	6.3	5.3

[a] t = test variety.

[b] Management packages (M_2, M_3, M_4, and M_5) have varying levels of fertilizer, insect control, and weed control. These are shown in Table 16.

[c] Farmers' level.

from typhoon damage and IR36 was harvested before the typhoon. The average grain yields of both farms show that IR42 yielded higher at M_2, M_4, and M_5 levels than the farmers' variety but not at M_1 and M_3 levels (Table 17).

SUMMARY OF YIELD GAP AND CONSTRAINTS IN NUEVA ECIJA PROVINCE

The average yields with farmers' inputs and high levels of inputs, and the number of sites covered by the study from 1974 to 1977, are summarized in Table 18.

Results from 40 farms in three dry seasons show that the average increase in yield from high inputs over the farmers' inputs was 2.1 t/ha (Table 18).

The average contribution of each of the three test factors to the yield gap during the same period is presented in Figure 6. In the dry seasons, fertilizer was the most important test factor, accounting for about 50% of the yield gap. Insect control contributed 38%, and weed control contributed 14%. In four wet seasons, the average potential yields (high-level inputs) in irrigated and rainfed farms were similar (Fig. 7). However, the average yield gap was 1.4 t/ha in rainfed, compared with 1.0 t/ha in irrigated farms.

Results on 54 farms during 4 wet seasons indicate that improved insect control contributed 56% to the 1 t/ha yield gap while fertilizer accounted for 33%. Improved weed control contributed a modest 11% to the gap (Fig. 6).

CAMARINES SUR PROVINCE, 1976 *Wet season*

During the 1976 wet season, experiments were on one rainfed (farm 1 in Fig. 8) and five irrigated farms (farms 2, 3, 4, 5, and 6 in Fig. 8). The farmer-cooperators used, on the average, 34 kg N/ha, 8 kg P_2O_5, and 6 kg K_2O/ha (Table 19). No fertilizer was applied on farms 1 and 4 and neither P_2O_5 nor K_2O was used on farm 3. The average farmers' level of insect control was three foliar sprays, but one application of granular insecticide was made on farm 6.

For weed control, either hand weeding or rotary weeding, or both, were used on all farms except farm 1, and granular herbicides were used on farms 1, 3, and 6. The rainfed farm was neither hand weeded nor rotary weeded.

Table 19 shows the high level of each test input and Table 20, the intermediate levels of fertilizer and insect control.

Yield gap and its components

Irrigated farms. On irrigated farms grain yields from the farmers' level of inputs were low. Among 5 irrigated farms only 3 had yields higher than 3 t/ha from the farmers' level of inputs; the other 2 had yields below 3 t/ha. Yields from the farmers' inputs averaged 3.2 t/ha (Table 21).

On farm 4, no fertilizer was applied. On farm 2, where the obsolete variety IR5 was planted but 71 kg N/ha was used, severe rat damage and some drought

Table 18. Average grain yields with farmers' and high level of inputs in yield constraints experiments in farmers' fields, Nueva Ecija province, Philippines, 1974-1977.

Season	Sites (no.)					Grain yield (t/ha)		
	1974	1975	1976	1977	Total	Farmers' inputs	High inputs	Difference
Dry	0	3	9	28	40	4.6	6.7	2.1
Wet	10	11	9	37	67	3.4	4.5	1.1

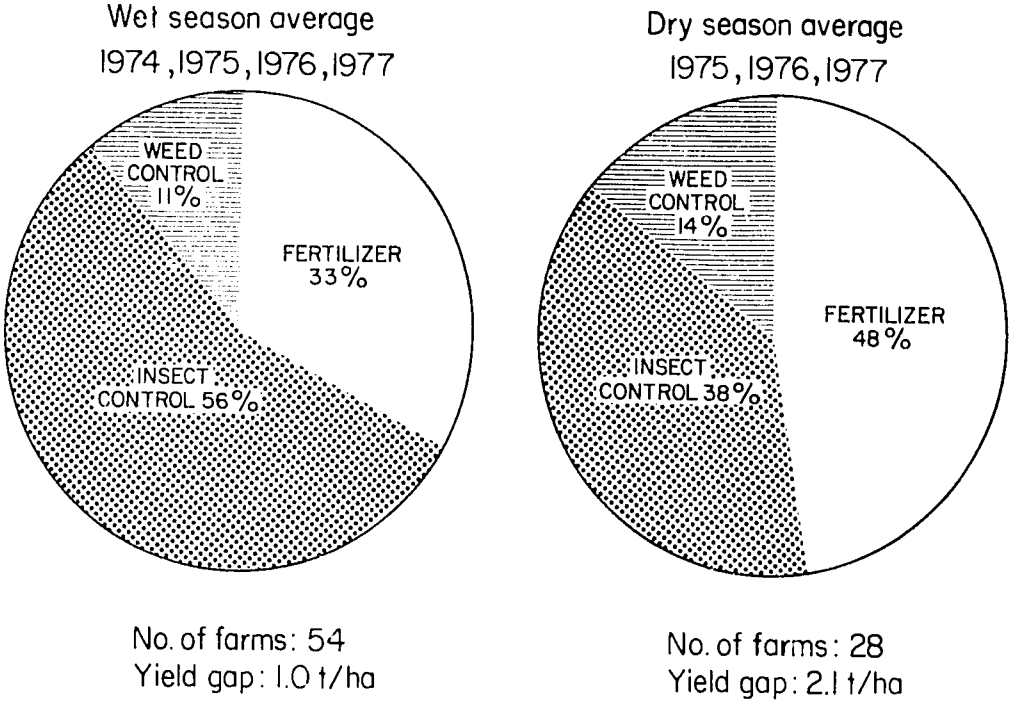

Fig. 6. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Nueva Ecija province, Philippines, 1974-1977

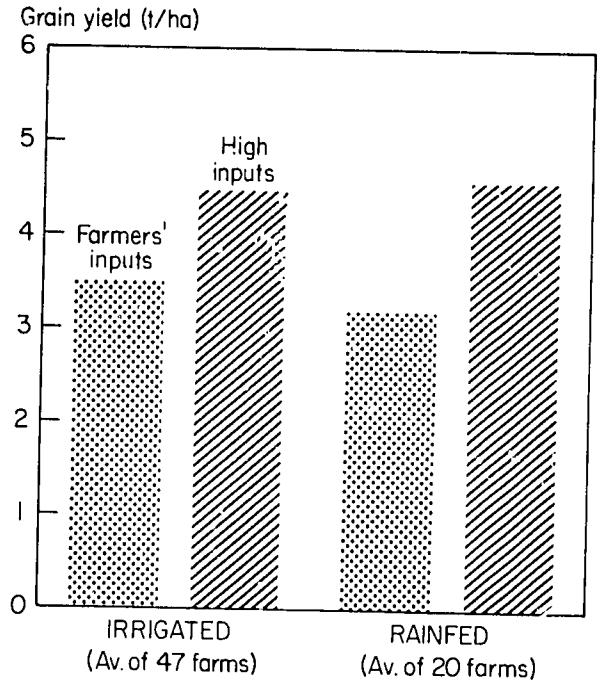

Fig. 7. Average wet-season yields with farmers and high level of inputs on irrigated and rainfed farms, Nueva Ecija province, Philippines, 1974-1977 wet season.

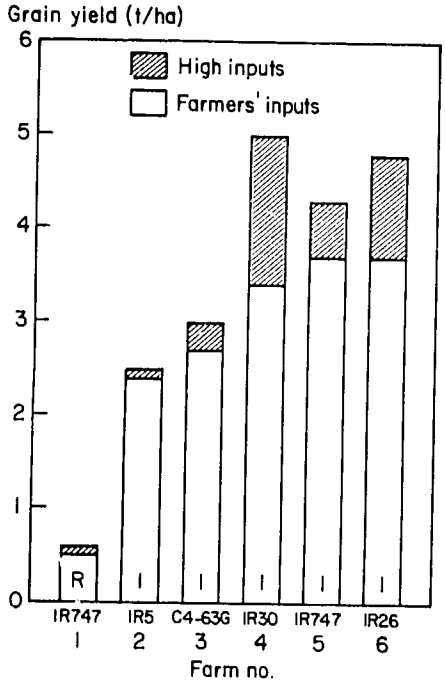

Fig. 8. Variations in yield gap between farmers' fields in farm yield-constraints studies in Camarines Sur province, Philippines, 1976 wet season (Each bar represents one farm; R = rainfed I = irrigated).

Table 19. High and farmers' levels of inputs in yield-constraints experiments in farmers' fields. Camarines Sur province, Philippines, 1975-1977.

Input level	Sites (no.)		Fertilizer (kg/ha)			Weed control[a]		Insecticide applications[b] (no.)	
	Irrigated	Rainfed	N	P_2O_5	K_2O	M	C	F	G
						1975 dry season			
Farmers'	3	0	36	14	14	1.0	0.3	1.3	0
High			120	30	30	0	1.0	3.0	2.0
						1975 wet season			
Farmers'	4	2	28	15	8	0.5	1.0	3.3	0
High			75	30	20	0	1.0	3.0	2.0
						1976 dry season			
Farmers'	5	0	43	25	10	0.8	0.8	4.0	0.2
High			150	40	30	1.0	1.0	1.0	4.0
						1976 wet season			
Farmers'	5	1	34	8	6	1.3	0.5	3.0	0.2
High			100	40	30	1.0	1.0	1.0	3.0
						1977 dry season			
Farmers'	20	0	54	6	5	0.8	0.6	2.5	0.0
High			150	40	30	1.0	1.0	1.0	4.0
						1977 wet season			
Farmers'	18	9	54	13	12	0.9	0.5	2.8	0.2
High			100	40	30	1.0	1.0	1.0	3.0

[a] Data show average number of mechanical weeding operations (M) either by hand or by rotary weeder, or of chemical herbicide (C) application.

[b] Data show average number of foliar (F) sprays or of granular (G) applications of insecticide to paddy water.

during the crop's critical growth period caused the low yield. Farms 3, 5, and 6 used a moderate level of fertilizer but did not manage it efficiently.

The high level of inputs produced yields that averaged 3.9 t/ha (Table 21).

Rainfed farm. Only on farm 1 were yields from both levels of inputs low because of drought at a critical growth period of the crop. The gap between the yield at the farmers' level of inputs (0.5 t/ha) and that at the high level (0.7 t/ha) was 0.2 t/ha (Table 21).

Average of irrigated and rainfed farms. Combined data for irrigated and rainfed farms show that the average yield gap in 1976 wet season was 0.7 t/ha, slightly lower than the 1.0-t/ha yield gap in the 1975 wet season (Table 22).

One reason for the greater yield gap in the 1975 wet season was the farmers' use of a lower rate of fertilizer nitrogen. The high level of fertilizer and

Table 20. Farmers' and intermediate levels of fertilizer and insect control used in yield-constraints experiments[a] in farmers' fields. Camarines Sur province, Philippines, 1976-1977.

Sites (no.)		Fertilizer level (kg/ha)									Insecticide applications[b] (no.)			
		Farmers'			Intermediate 1			Intermediate 2			Farmers'		Intermediate	
Irrigated	Rainfed	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	F	G	F	G
							1976 wet season							
5	1	34	8	6	40	20	10	70	30	20	3.0	0.2	0	2.0
							1977 dry season							
6	0	63	6	3	50	20	10	100	30	20	3.5	0.0	0	2.0
							1977 wet season							
5	3	37	6	2	40	20	10	70	30	20	2.1	0.2	0	2.0

[a] Complete factorial experiment.

[b] F = foliar application, G = granular application.

Table 21. Average yields from farmers' and high levels of inputs on irrigated and rainfed farmers' fields. Camarines Sur, Philippines, 1975-1977.

Farm type	Sites (no.)	Grain yield (t/ha)		
		Farmers' inputs	High inputs	Difference
			1975 wet season	
Irrigated	4	3.4	4.4	1.0
Rainfed	2	3.9	5.0	1.1
			1976 wet season	
Irrigated	5	3.2	3.9	0.7
Rainfed	1	0.5	0.7	0.2
			1977 wet season	
Irrigated	18	4.7	5.1	0.4
Rainfed	9	3.8	4.7	0.9

Table 22. Yields at farmers' and high level of inputs in yield-constraints experiments in farmers' fields. Camarines Sur province, Philippines, 1975-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)		
		Irrigated	Rainfed	Farmers' inputs	High inputs	Difference
1975	Wet	4	2	3.6	4.6	1.0
1976	Wet	5	1	2.7	3.4	0.7
1977	Wet	18	9	4.2	4.7	0.5
1975	Dry	3	0	3.9	5.6	1.7
1976	Dry	5	0	3.3	4.9	1.6
1977	Dry	20	0	4.2	6.1	1.9

good water management in 1975, even in rainfed farms, gave significantly higher yields than the farmers' input levels.

The high level of fertilizer contributed 66.6% to the 0.7-t/ha yield gap during the 1976 wet season (Fig. 9). The high level of insect control accounted for 33.4% of the yield gap and the high level of weed control made no contribution -- indication that the farmers in the study area controlled weeds adequately.

The magnitude of the contribution to yield gap made by the 1976 test factors was not consistent with that found in the 1975 wet season when the high level of insect control made the highest contribution. There was a high insect pest incidence in 1975 and the farmers in the study area used a relatively low level of insect control.

Effect of test factors on grain yield

Fertilizer. On 5 of 6 farms, the yield obtained with 40 kg N/ha /Intermediate-1 (I-1)/ was higher than that obtained with the farmers' level of fertilizer (Table 20), but the yield increase was significant only on farm 4, where no fertilizer was used. Considering all farms, the Intermediate 2 (I-2) level of fertilizer gave an average yield increase of 0.4 t/ha on 4 of 6 farms (Table 23). The high level of fertilizer gave significantly higher yield than did the farmers' level only on farm 4, where no fertilizer was applied, and on farm 6, where only 49 kg N/ha was used.

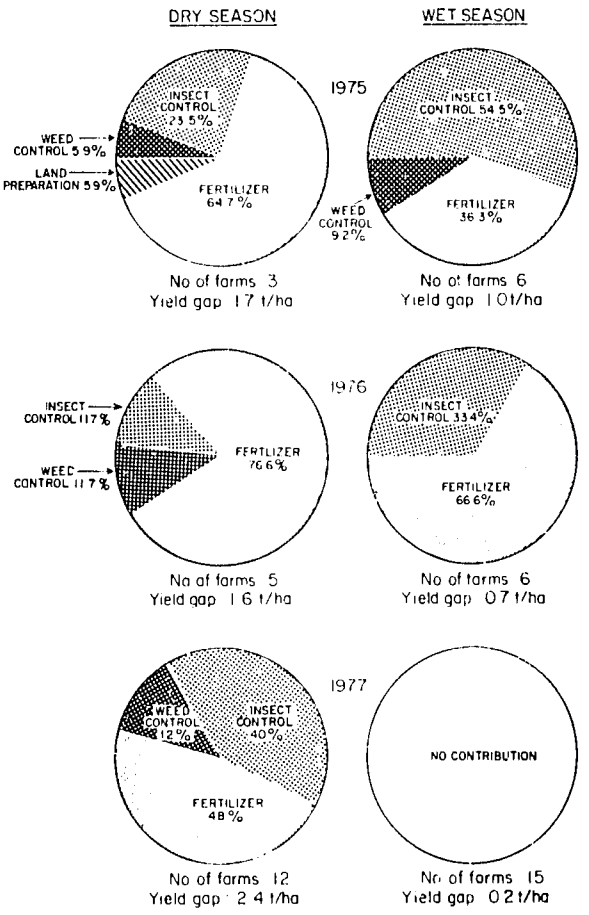

Fig. 9. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Camarines Sur province, Philippines, 1975-1977.

Table 23. Grain yield under different levels of inputs used in yield-constraints experiments[a/] in farmers' fields. Camarines Sur province, Philippines, 1976-1977.

Year	Season	Sites (no.)		Grain yield[b/] (t/ha)								
		Irrigated	Rainfed	Fertilizer				Insect control			Weed control	
				F	I-1	I-2	H	F	I	H	F	H
1976	Dry	5	0	3.4	3.6	4.2	4.7	3.9	4.0	4.1	3.9	4.1
1976	Wet	5	1	2.8	3.0	3.2	3.2	3.0	3.0	3.2	3.0	3.1
1977	Dry	6	0	4.1	4.5	5.4	5.3	4.4	4.8	5.3	4.7	4.9
1977	Wet	5	3	3.2	3.6	3.5	3.4	3.4	3.5	3.4	3.4	3.4

[a/] Complete factorial experiments.

[b/] F = farmers' level, I = intermediate level, H = high level.

Grain yields obtained by using farmer's, first intermediate (1-1), second intermediate (I-2), and high level of fertilizer management with farmers' and high levels of weed and insect control were also compared (Table 24).

On 4 of 6 farms (farms 2, 3, 5, and 6), higher grain yields were obtained with 40 kg N/ha (I-1) than with 39-71 kg N/ha. That showed that the farmers managed their fertilizer inefficiently.

Insect control. The high level of insect control produced a significantly higher yield than the farmer's level on only farm 3, where 3 foliar insecticide sprays were applied but at an inappropriate time. On the average, however, neither the intermediate level nor the high level of insect control gave significantly higher yield than the farmers' level (Table 23).

Weed control. The yield from the high level of weed control with 2,4-D granules 4 days after transplanting was not significantly higher than that from the farmers' method of weed control, indicating that most farmers controlled the weeds on their farms (Table 23).

Cultural practices. Table 25 shows the yield difference between high cultural practices and farmer's cultural practices in six complete factorial trials. With the farmers' and intermediate levels of management, high cultural practices gave higher grain yields than farmer's cultural practices only in 2 of 6 farms. On the average, the high cultural practices showed no significant advantage over the farmers' practices on any farm.

Varieties. Varietal differences were tested in the management package component of the complete factorial trials. A recently introduced test variety (IR36) was compared with the farmers' varieties at three levels of management (Table 26). Farmer's and high cultural practices were used in all trials. IR36 outyielded the farmer's variety on three of six farms with the farmer's level of management and on all farms with intermediate management. With higher input levels the fertilizer responsiveness of IR36 became evident.

With a high level of management IR36 outyielded the farmer's variety on only 3 of 6 farms. The yield gain was not significant because many farmers planted high yielding fertilizer-responsive varieties such as IR26.

CAMARINES SUR PROVINCE, 1977 *Dry season*

The 1977 dry season tests included a complete factorial experiment on six farms, a minifactorial experiment on six farms and supplemental trials on eight farms (Fig. 10). All sites were irrigated by pump or canal water. Farms 1, 9, and 11 received no fertilizer and 10 farms received no phosphorus and potassium (farms 3, 4, 6, 9, 11, 12, 13, 15, 16, and 19).

On the average, farmers applied only 54 kg N/ha, 6 kg P_2O_5/ha, and 5 kg K_2O/ha (Table 19). The farmers' insect control consisted of one to five foliar sprays but most farmers sprayed about three times. Granular insecticides were not commonly used.

Table 24. Grain yields under farmers' and test levels[a] of fertilizer under farmers' and high levels of weed and insect control measures in yield-constraints experiments in farmers' fields. Camarines Sur province, Philippines, 1976 wet season.

Farm No.	Variety	Weed and insect control measures	Nitrogen applied (Farmers' level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing (DT)	Farmers'	I-1	I-2	H
5	IR747	Farmers'	45	22, 36, & 41	3.7	3.9	4.0	3.7
		High			4.0	4.0	4.6	4.3
6	IR26	Farmers'	49	5 & 17	3.7	4.2	4.6	4.7
		High			3.7	4.2	4.7	4.8
1	IR747[b]	Farmers'	0	-	0.5	0.6	0.8	0.5
		High			0.4	0.4	0.6	0.7
3	C4-63G	Farmers'	39	59	2.7	2.8	1.9	2.7
		High			2.7	3.1	3.1	3.0
4	IR30	Farmers'	0	-	3.4	3.9	4.2	4.1
		High			3.8	4.5	5.0	5.0
2	IR5	Farmers'	71	7 & 46	2.4	2.7	2.4	2.3
		High			2.7	2.5	2.6	2.5
		Farmers'	34		2.7	3.0	3.0	3.0
		High			2.9	3.1	3.4	3.4

[a] Test rates of nitrogen: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha, high level (H) = 100 kg N/ha. Time of application: basal and 5-7 days before panicle initiation.

[b] Rainfed farm.

Table 25. Yields with cultural practices at a high level compared with those at the farmers' level for input packages in yield-constraints experiments[a] in farmers' fields. Camarines Sur province, Philippines, 1976-1977.

Sites (no.)		Level of cultural practices	Grain yield (t/ha)			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
			1976 wet season			
5	1	Farmers'	2.8	3.1	3.4	3.1
		High	2.7	3.1	3.2	3.0
			1977 dry season			
5	0	Farmers'	3.8	4.3	5.9	4.7
		High	4.0	4.6	6.1	4.9
			1977 wet season			
5	3	Farmers'	3.0	3.5	3.3	3.3
		High	2.8	3.4	3.2	3.1

[a] Complete factorial experiments. Av of data for farmers' and the test varieties.

Table 26. Yields of farmers' varieties compared with those of test varieties for input packages grown with high and farmers' levels of cultural practices in yield-constraints experiments in farmers' fields.[a] Camarines Sur province, Philippines, 1976-1977.

Sites (no.)		Variety	Grain yield (t/ha)			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
			1976 wet season			
5	1	Farmers'[b]	2.6	2.9	3.3	2.9
		Test (IR36)	2.8	3.3	3.3	3.1
			1977 dry season			
5	0	Farmers'[c]	3.5	4.5	6.0	4.7
		Test (IR26 and IR36)	4.0	4.2	6.1	4.9
			1977 wet season			
5	3	Farmers'[d]	3.0	3.6	3.2	3.3
		Test (IR42)	2.7	3.4	3.2	3.1

[a] Av of data for farmers' and high cultural practices.

[b] Farmers used IR747, IR5, C4-63G, IR30, and IR26.

[c] Farmers used IR1006, IR36, and IR747.

[d] Farmers used Masjava and IR36.

On 15 of 20 farms weeds were controlled by hand or rotary weeding, but on farms 2 and 9 no weeding was done. On 11 farms herbicides were used for good weed control.

The high levels of each test input are shown in Table 19 and the intermediate levels of fertilizer and insect control in Table 20.

Yield gap and its components

Yields at the farmer's level of inputs ranged from a low 1.0 t/ha to 5.8 t/ha, and averaged 4.2 t/ha (Table 22). In supplemental trials on farms 14 to 20, yields higher than 5.0 t/ha were due to the farmer's intensive management levels in the comparable paddy. This resulted in the comparable paddy's yields being higher than the average of all other paddies belonging to the same farm.

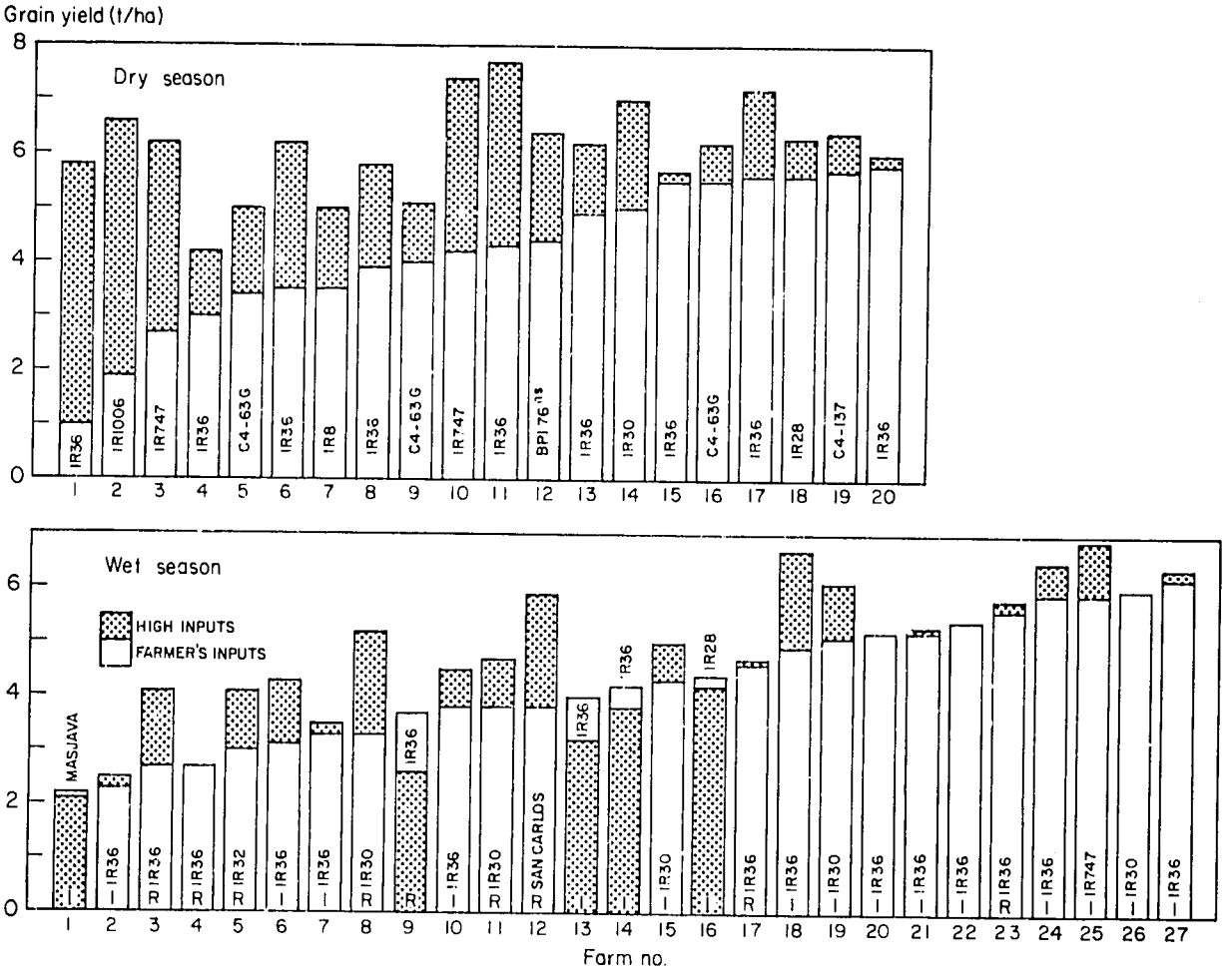

Fig. 10. Variations in yield gap between farmers' fields in farm yield-constraints studies in Camarines Sur province, Philippines, 1977 dry and wet seasons (Each bar represents one farm; R = rainfed, I = irrigated).

Yields at the high level of inputs ranged from 4.2 t/ha to 7.7 t/ha, and averaged 6.1 t/ha (Table 22). Nineteen of 20 farms produced yields higher than 5.0 t/ha. The highest yield (7.7 t/ha) was on a farm with excellent water and weed management practices. The yield gap of 1.9 t/ha was slightly higher than the 1976 dry season yield gap of 1.6 t/ha because in 1977 most farmers planted IR36 which showed high response to high level of inputs, especially fertilizer.

In general insect problems were low, and on most farms insect control was good. Bacterial leaf blight was observed on farm 15 at a late stage of the crop but only in plots with the high level of fertilizer. Farm-to-farm yield variations that occurred at high input levels were not great and were attributed to various degrees of drought. The average yield gap of 1.9 t/ha was more than twice that in the 1976 wet season.

The relative contribution of the test factors to the yield gap was computed for the complete and minifactorial experiments. Yields at the farmer's level of inputs for these experiments ranged from 1.0 t/ha to 5.4 t/ha, and averaged 3.5 t/ha (Table 27). The high input levels produced yields ranging from 4.2 t/ha to 7.7 t/ha, with an average 5.9 t/ha. Fertilizer accounted for 48% of the 2.4 t/ha yield gap and a high level of weed control accounted for 12% of the gap (Fig. 9). High insect control practices accounted for 40% of the yield gap.

The higher yield gap in the 1977 dry season than in the 1976 dry season was mainly due to a wider adoption of fertilizer-responsive varieties by farmers. The magnitude of the contribution made by fertilizer and weed and insect control differed from that in the 1976 dry season. The contribution of fertilizer declined because farmers applied more fertilizer in the 1977 dry season. The increase in the insect control's contribution to the yield gap in the 1977 dry season was due to increased insect problems.

Effect of test factors on grain yield

Fertilizer. On 5 of 6 farms (farms 2, 5, 6, 8, and 15), the I-1 level of fertilizer (Table 20, 50 kg N/ha) gave a higher yield than the farmer's level but the yield increase was significant only on farm 15 where the farmer applied 77 kg N/ha, but at the wrong time. Using the I-2 and high levels of fertilizer (100 kg N/ha and 150 kg N/ha), yield increases were obtained on all 6 farms, but the increase was significant only on farms 6 and 15. The I-1, I-2, and high levels gave higher average grain yield than the farmer's fertilizer level (Table 23) because some farms applied a low level of nitrogen.

Grain yields were compared at various fertilizer test levels with the farmer's level of fertilizer under farmer's and high level of weed and insect control (Table 28). On 4 of 6 farms, the yields from the I-1 level of fertilizer (50 kg N/ha) were similar to or higher than those from the farmers' level (48 to 90 kg N/ha), indicating that high yields were possible with a low rate of fertilizer if it is properly applied.

With high levels of weed and insect management, the I-1 level of fertilizer gave higher yield than the farmers' level in three farms. With the I-2 level of fertilizer, yields were higher on all six farms at the farmers' levels of weed and insect control and on five of six farms at the high level of weed and insect control. The high level of fertilizer increased yield on only 4 of 6 farms at both the farmers' and the high levels of weed and insect control. One farmer applied 90 kg N/ha in 3 split doses and had a yield comparable to that from the high level of fertilizer. High-level fertilizer plots had more spikelet sterility and more insect damage than the farmers' plots. The average of all farms shows that yields from the two intermediate levels of fertilizer were higher than those from the farmers' level at both farmers' and high weed and insect control levels (Table 28). Yields from the high level of fertilizer, coupled with high weed control, demonstrated the importance of insect control when a high rate of fertilizer is applied to modern rice varieties.

Insect control. Table 23 shows the average yield increase over the farmers' due to intermediate and high levels of insect control. The

intermediate level of insect control gave higher yields than the farmers' level on all farms but the increase was most pronounced on 4 farms where 2 to 4 foliar insecticide applications by farmers did not adequately control insects. The high level of insect control gave higher yields than the farmers' level on all 6 farms.

Weed control. The high level of weed control increased yield slightly on 5 of 6 farms but, as in the 1976 wet season, the increase was not significant. That indicated that yields could not be substantially increased by a high level of weed control because most farmers practiced good weed control.

Cultural practices. Farmers' and high levels of cultural practices with test and farmer's varieties were compared at three management levels in six complete factorial experiments. Data were obtained from only five farms (Table 25). During the dry season there was a definite yield advantage from the use of a high level of cultural practices at all levels of management. Increased yields from intermediate and high management levels, irrespective of cultural practices, were due to higher levels of inputs.

Varieties. Yields of farmers' and test varieties with the farmers', intermediate, and high management levels in the management package component of the complete factorial experiments were compared (Table 26). Farmers used different varieties (Fig. 10). The test variety was IR36 on farms that used other varieties and IR26 where farmers used IR36.

For both the farmer's and the test variety, there was an increase in yield due to the increase in the management level. The test varieties yielded more than the farmer's variety at all levels of management, although the difference in yield was not significant.

Table 27. Relative contribution of three inputs (insect control, fertilizer, and weed control) toward the improvement of rice yields in farmers' fields. Camarines Sur province, Philippines, 1975-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)			Contribution[a] (t/ha)			
		Irrigated	Rainfed	Farmer's inputs	High inputs	Difference	Fertilizer	Weed control	Insect control	Residual
1975	Wet	4	2	3.6	4.6	1.0	0.4	0.1	0.6	-0.1
1976	Wet	5	1	2.7	3.4	0.7	0.4	0	0.2	0.1
1977	Wet	10	5	3.6	3.8	0.2	-0.1	-0.1	-0.2	0.6
1975	Dry[b]	3	0	3.9	5.6	1.7	1.1	0.1	0.4	0
1976	Dry	5	0	3.3	4.9	1.6	1.3	0.2	0.2	-0.1
1977	Dry	12	0	3.5	5.9	2.4	1.2	0.3	1.0	-0.1

[a] Measured as yield decrease from high inputs due to a reduction from high to farmers' level of each input.

[b] Land preparation, included in these experiments, contributed 0.1 t/ha to the yield gap.

Table 28. Grain yields under farmers' and test levels[a] of fertilizer under farmers' and high levels of weed and insect control measures in yield-constraints experiments.[b] Camarines Sur province, Philippines, 1977 dry season.

Farm Number	Variety	Weed and insect control measures	Nitrogen applied (Farmer's level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing[c] (DT)	Farmers'	I-1	I-2	H
15	IR36	Farmers'	77	35, 55	5.5	6.5	6.9	4.9
		High			6.1	7.5	7.2	5.7
8	IR36	Farmers'	42	26, 32	3.9	4.8	4.7	4.6
		High			4.4	4.4	6.3	5.8
3	IR747	Farmers'	48	22, 41	2.7	2.7	4.1	4.9
		High			5.8	4.5	5.7	6.2
5	C4-63	Farmers'	90	0, 29 and 51	3.4	4.3	4.9	3.3
		High			5.1	5.3	5.7	5.0
2	IR1006	Farmers'	18	21, 31	1.9	2.8	4.0	3.4
		High			3.3	3.9	5.7	6.6
6	IR36	Farmers'	64	0	3.5	4.5	5.2	5.8
		High			4.8	4.6	5.8	6.2
Av		Farmers'	46		3.5	4.3	5.0	4.5
		High			4.9	5.0	6.0	5.9

[a] Test rates of nitrogen: Intermediate level: I-1 = 50 kg N/ha, I-2 = 100 kg N/ha, high level (H) = 150 kg N/ha. Time of application: Basal, 30 DT and 5-7 days before panicle initiation.

[b] Complete factorial experiment.

[c] DT = days after transplanting.

CAMARINES SUR PROVINCE, 1977 *Wet season*

The experiments in the 1977 dry season were repeated on a total of 27 farms -- 18 canal- or pump-irrigated and 9 rainfed -- during the 1977 wet season (Fig. 10).

The farmers applied fertilizer at an average rate of 54 kg N/ha, 13 kg P_2O_5/ha, and 12 kg K_2O/ha (Table 19). Farms 1, 3, and 12 received no fertilizer; farms 9, 10, 11, 14, 17, and 27 received neither phosphorus nor potassium. Farm 21 received no potassium.

On 23 of 27 farms, weeds were controlled by hand or rotary weeding. Weeds were not controlled on farms 1 and 2. Thirteen farmers controlled weeds with either 2,4-D spray or granules supplemented by rotary weeding and spot hand weeding.

To control insects, all farms used foliar sprays up to five times, but averaged only three times. Only four farms (farms 1, 7, 10, and 14) used granular insecticides in addition to foliar sprays.

Yield gap and its components

Irrigated farms. The yield gap was computed from all three types of experiments mentioned earlier. Grain yields at the farmers' level of inputs ranged from 2.2 t/ha to 6.2 t/ha and averaged 4.7 t/ha (Table 21). Eight of 18 farms produced grain yields higher than 5 t/ha and 5 farms produced more than 4 t/ha.

Under the high level of inputs, yields ranged from 2.1 t/ha to 6.9 t/ha (Fig. 10). There was no yield gap on farms 20, 22, and 26 which used a high rate of fertilizer and good weed and insect control. On farms 1, 13, 14, and 16 the crop grown with a high level of fertilizer lodged during a typhoon and gave low yields. Farm 1 was planted to a low-yielding traditional variety. The average yield gap on the irrigated farms was only 0.4 t/ha (Table 21).

Rainfed farms. Rainfed experiments were on 9 farms (Fig. 10). The grain yield from the farmers' level of inputs ranged from 2.7 t/ha to 5.6 t/ha and averaged 3.8 t/ha (Table 21). For the high level of inputs the yields ranged from 2.6 t/ha to 5.9 t/ha and averaged 4.7 t/ha. The average yield gap was 0.9 t/ha, which was higher than on the irrigated farms because most of the rainfed farms had harvested their crops before a November typhoon. Only farm 9 suffered lodging damage during the typhoon.

Average of irrigated and rainfed farms. For all farms the grain yields from the farmers' level of inputs varied from 2.2 t/ha to 6.2 t/ha and averaged 4.2 t/ha (Table 22). Yields from the high level of inputs averaged only 4.7 t/ha, giving a yield gap of 0.5 t/ha. The reason for the low yield gap, compared with that in the 1976 wet season, was lodging caused by the typhoon. The crop with the farmers' level of fertilizer did not, however, lodge as much as the ones with high levels of fertilizer.

The calculation of relative contribution of each test factor to the yield gap includes only the data from the complete and minifactorial experiments.

Farmer's yields varied from 2.2 t/ha to 5.4 t/ha and averaged 3.6 t/ha (Table 27). For the high level of inputs, yields varied from 2.1 t/ha to 5.4 t/ha and averaged 3.8 t/ha, which gave a small yield gap of 0.2 t/ha.

Data averaged for all farms showed that the test factors did not contribute to the yield gap.

Effect of test factors on grain yield

Fertilizer. The average grain yields from different levels of fertilizer are shown in Table 23. The I-1 level of fertilizer (40 kg N/ha), gave a significantly higher yield than the farmers' level of fertilizer application on farms 4 and 9. Farm 4 (rainfed) applied only 14 kg N/ha and farm 9 applied 41 kg but at a late growth stage and all at one time.

The I-2 level (70 kg N/ha) of fertilizer, gave higher yields on 5 of 8 farms but the yield gain was significant on only 4 farms. The high level of

fertilizer (100 kg N/ha) gave more yield than the farmers' level of fertilizer on 5 of 8 farms but the increase was significant on only one farm. The high level of fertilizer did not increase yield on other farms because of lodging caused by a typhoon. On the average, neither the intermediate levels nor the high level of fertilizer gave significantly higher yields than the farmers' level.

However, when the 1-1 level of nitrogen was compared with the farmers' level at the farmers' and high levels of weed and insect control (Table 29), similar or higher yields were obtained on 4 of 8 farms where farmers' fertilizer was applied at 41-84 kg N/ha. That indicated that those farmers could increase their fertilizer efficiency by a proper time and method of application.

Similarly, the 1-2 level of fertilizer gave higher yields on five of eight farms with farmer's and high levels of weed and insect control because it used less nitrogen than the I-2 level.

Insect control. During the wet season, yields from the intermediate and high levels of insect control were not significantly higher than those from the farmers' level of insect control on any farm although the intermediate level increased the yield on 3 farms and the high level increased it on 3 farms. The reason was that on many farms the crop lodged under high fertilizer even though it was better protected from insects.

The farmers generally controlled insects well on most farms. Inadequate drainage in the farmer's fields and in the experimental plots increased the infestation of whorl maggots. Proper drainage and a few foliar insecticide sprays controlled the insect well.

Weed control. As in the 1976 wet season a high level of weed control caused no significant yield increase in any farm because of the farmers' excellent weed control (Table 23).

Cultural practices. Farmers' and high-level cultural practices involving a test variety (IR42) and farmers' varieties were compared at three levels of management. The average results are in Table 25. On the average, neither the intermediate nor the high management level showed a yield advantage from a high level of cultural practices, even at the farmers' management level.

Varieties. The yield performance of farmers' varieties and that of a test variety (IR42) were compared in the management package component of the complete factorial experiment (Table 26). The test variety IR42 matured much later than the farmers' variety, which was IR36 on most farms.

Under all management levels the test variety produced lower yields than the farmers' variety because it was severely damaged by typhoon. That suggests that an early maturing, high-yielding variety has an advantage during the wet season when late-season adverse weather is encountered. The later maturing IR42 also attracted rats from earlier harvested areas.

Management package project

1976 wet season. During the 1976 wet season, the management package experiment was on only one irrigated farm. The input levels used are shown in Table 30.

The farmer used IR1529 and the test variety was IR36. The farmer used a higher nitrogen level than M3. To control insects, the farmer used four foliar insecticide sprays and no granular insecticide. Weeds were controlled by hand weeding and rotary weeding.

The farmer's variety performed better than the test variety at all management levels except M1 and M4. However, on the average, neither the test variety nor the management levels gave higher yield increases than the farmers' practice (Table 31). The farmers' and the test varieties were heavily damaged by rats.

1977 dry season. The farmers' and various management levels used on one canal irrigated farm during the 1977 dry season are shown in Table 30. The nitrogen level used by the farmer was higher than M2 but lower than M3. The farmer used four foliar applications and no granular insecticides to control insects and liquid herbicide and hand weeding for weed control. The farmers' variety was IR36 and the test variety IR26.

Table 29. Grain yields at farmers' and test levels[a] of fertilizer under farmers' and high levels of weed and insect control measures in yield-constraints experiments[b] in farmers' fields. Camarines Sur province, Philippines, 1977 wet season.

Farm No.	Variety	Weed and insect control measures	Nitrogen applied (Farmers' level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing[c] (DT)	Farmers'	I-1	I-2	H
4[d]	IR36	Farmers'	14	B	2.7	3.5	2.9	2.8
		High			2.8	3.1	3.1	2.7
9[d]	IR36	Farmers'	41	33	3.7	3.4	3.9	2.9
		High			2.4	3.3	2.9	2.6
3[d]	IR36	Farmers'	0	0	2.7	3.7	3.9	4.9
		High			3.1	4.6	4.6	4.1
14	IR36	Farmers'	46	42	4.2	3.5	3.6	4.0
		High			4.2	3.7	4.0	3.8
7	IR36	Farmers'	82	6, 22, 45	3.3	3.3	3.0	3.3
		High			2.9	3.4	2.9	3.5
10	IR36	Farmers'	55	43	3.8	3.7	4.3	3.9
		High			3.4	4.0	3.8	4.5
1	Masjava	Farmers'	0	0	2.2	2.7	2.7	2.1
		High			2.7	2.9	2.8	2.1
13	IR36	Farmers'	84	B, 39	4.0	4.0	3.2	3.9
		High			3.6	4.3	3.6	3.2
Av		Farmers'	40		3.3	3.5	3.4	3.5
		High			3.1	3.7	3.5	3.3

[a] Test rates of nitrogen: Intermediate level: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha, high level (H) = 100 kg N/ha. Time of application: Basal (B) and 5-7 days before panicle initiation.

[b] Complete factorial experiment.

[c] DT = days after transplanting.

[d] Rainfed farms.

Table 30. Average levels of farmers' inputs and levels of four management packages in management package experiments. Camarines Sur province, Philippines, 1976-1977.

Sites (no.)		Package level[a]	Fertilizer (kg/ha)			Insecticide application[b] (no.)					Weed control treatments[c] (no.)	
						Seedbed		Field				
Irrigated	Rainfed		N	P_2O_5	K_2O	F	G	R	F	G	M	C
								1976 wet season				
1	0	M1	71	17	17	1	0	0	4	0	3	0
		M2	40	10	0	0	0	0	2	0	1	0
		M3	60	20	20	0	1	1	0	0	0	1
		M4	80	30	30	2	0	1	0	1	1	1
		M5	100	40	40	0	2	0	1	4	1	1
								1977 dry season				
1	0	M1	64	0	0	0	0	0	4	0	1	1
		M2	40	10	0	0	0	0	2	0	1	0
		M3	80	20	20	0	1	1	0	0	0	1
		M4	120	30	30	1	1	1	1	0	0	1
		M5	160	40	40	0	2	0	1	4	1	1
								1977 wet season				
2	1	M1	47	12	12	0	0	0	2.6	0.7	1	0
		M2	40	10	0	0	0	0	3	0	1	0
		M3	60	20	20	0	1	1	0.5	0	0	1
		M4	80	30	30	0	2	1	1	1	0	1
		M5	100	40	40	0	2	0	2.5	4	1	1

[a] M1 = farmers' level of application of the three inputs; M2-M5 = have levels of fertilizer, insect control and weed control, as listed in this table.

[b] F = foliar, G = granular, R = rootzone placement of liquid carbofuran.

[c] M = mechanical weeding either by hand or rotary weeder, C = chemical herbicide.

The test variety outyielded the farmer's variety at all management levels except M4 where the crop lodged and was damaged by rats. The grain yield from the farmers' management was the lowest with his variety. The test variety's average yield was higher than the farmers' (Table 31).

1977 wet season. During the 1977 wet season, the same experiment was conducted on one rainfed and two irrigated farms. The input levels are shown in Table 30. On the average, the farmers' inputs were higher than M2. Farmers made only one hand or rotary weeding and 2 or more foliar sprays of insecticides. The 2 irrigated farms used granular insecticides to supplement foliar application.

The variety used by all farmers was IR36 and the test variety was IR42. The farmers' variety yielded more at M1 than at M2 and the test variety produced higher yields than the farmers' at all management levels (Table 31).

On the rainfed farm, which suffered intermittent water shortages, the test variety performed better than the farmers' variety at all management levels. On an irrigated farm that had a severe whorl maggot problem M1 had a yield comparable to that of M4 because the test variety (IR42) lodged during a

Table 31. Average grain yields of farmers' varieties and test varieties compared at farmers' and four input management packages and grown under high levels of cultural practices. Camarines Sur province, Philippines, 1976-1977.

Sites (no.)		Variety	Grain yield[a] (t/ha)					
Irrigated	Rainfed		M1[b]	M2	M3	M4	M5	Av
			1976 wet season					
1	0	Farmers' (IR1529)	2.7	2.9	3.2	2.2	2.9	2.8
		Test (IR36)	2.7	2.7	1.9	2.8	2.4	2.5
			1977 dry season					
1	0	Farmers' (IR36)	2.3	3.1	4.6	4.2	5.1	3.8
		Test (IR26)	4.4	5.0	5.1	3.7	5.1	4.7
			1977 wet season					
2	1	Farmers' (IR36)	2.6	2.4	2.9	3.0	3.1	2.8
		Test (IR42)	2.8	2.7	3.6	3.4	3.8	3.3

[a] Management packages (M2, M3, M4 and M5) contain varying levels of fertilizer, insect control, and weed control, as shown in Table 30.

[b] Farmers' level.

typhoon. On one irrigated farm, higher yields were obtained with less than the farmers' level of nitrogen (82 kg N/ha), which suggested that the farmer did not use fertilizer efficiently.

SUMMARY OF YIELD GAP AND CONSTRAINTS IN CAMARINES SUR PROVINCE

The average yields from farmers' and high level-inputs for all sites in Camarines Sur province, 1975-77 are summarized in Table 32.

Results from 28 farms in 3 dry seasons show that, on the average, yields from high inputs were 1.8 t/ha higher than yields from farmers' inputs (Table 32). Fertilizer was the most important of three test factors contributing to the yield gap during the same period (Fig. 11).

Results from 39 farms and 3 wet seasons show that, on the average, yields from high inputs were 0.6 t/ha higher than yields from farmers' inputs (Table 32).

Results from 12 farms in 2 wet seasons indicate that fertilizer contributed 45.4% to the yield gap and insect control accounted for 48.8%. Improved weed control gave only a modest increase (Fig. 11).

Table 32. Average grain yields from farmers' and high level of inputs in yield-constraints experiments in farmers' fields. Camarines Sur province, Philippines, 1975-1977.

Sites (no.)				Grain yield (t/ha)		
1975	1976	1977	Total	Farmers' inputs	High inputs	Difference
				Dry season		
3	5	20	28	4.0	5.8	1.8
				Wet season		
6	6	27	39	4.0	4.6	0.6

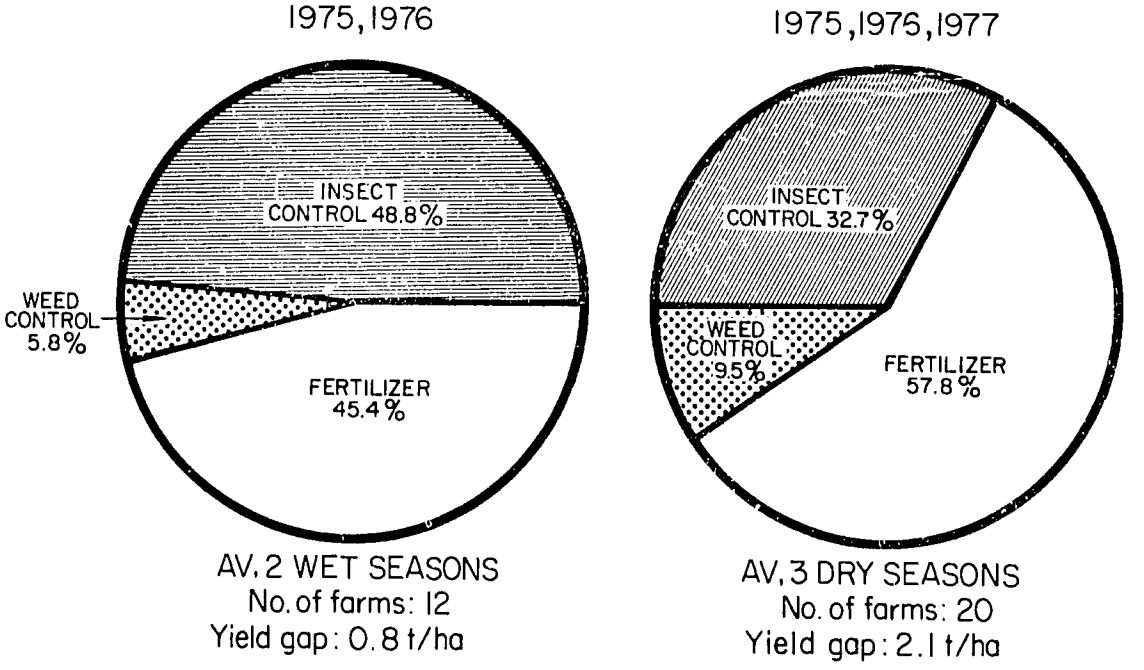

Fig. 11. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Camarines Sur province, Philippines, 1975-1977.

The average yield using farmers' input of 27 irrigated farms during 3 wet seasons was 4.2 t/ha and that from a high input level was 4.8 t/ha, giving an average yield gap of 0.6 t/ha. During the same period the yields from farmers' inputs on 12 rainfed farms averaged 3.4 t/ha and those from high input levels averaged 4.2 t/ha, giving a yield gap of 0.8 t/ha -- slightly higher than the yield gap on irrigated farms.

The grain yields from both farmers' and high input levels on rainfed farms were lower than those on irrigated farms because of uneven distribution of rainfall during the critical growth periods of the crop.

ILOILO PROVINCE, 1976 *Wet season*

The wet season Iloilo province experiments were on 5 irrigated and two rainfed farms. The average levels of each test input used by the farmers were generally lower than those used at high level (Table 33). The intermediate levels of fertilizers and insect control are given in Table 34.

Yield gap and its components

Irrigated farms. Yields from farmers' inputs on irrigated farms averaged 3.3 t/ha; those from high inputs averaged 5.2 t/ha. The resulting yield gap was 1.9 t/ha (Table 35). The large yield gap was due primarily to the farmers' low fertilizer level and improper timing of its application.

Rainfed farms. The average grain yield obtained with the farmers' input was 0.2 t/ha higher on the rainfed farms than on the irrigated farms (Table 35). The average rate of fertilizer applied on the two rainfed farms was, however, twice as high as that on the irrigated farms. Low yields on rainfed farms were attributed to poor weed control. One farmer did no weed control and the other farmer hand weeded late (40 days after transplanting).

For the high inputs on rainfed farms the average yield was 5.5 t/ha, which was 0.3 t/ha higher than the average yield recorded on the irrigated farms. Insect population and rat infestation were higher on the irrigated farms than on the rainfed. The average yield gap was 2.0 t/ha (Table 35).

Average of irrigated and rainfed farms. Combined data for irrigated and rainfed farms showed that the farmers' yields varied from 2.9 to 3.8 t/ha (Fig. 12), and averaged 3.3 t/ha (Table 36). Average yields with high inputs ranged from 4.5 to 6.0 t/ha and averaged 5.3 t/ha. The yield gap was 2.0 t/ha. Differences in farmers' input levels and management practices partly explained yield variations. The relative contribution of fertilizer was 44% of the yield gap, largely because the farmers applied low rates of fertilizer. Insect control contributed 31%; weed control 25% (Fig. 13).

Effect of test factors on grain yield

Fertilizer. The grain yield increase from the high level of fertilizer was significant on 6 of 7 farms. On those farms, farmers applied all their fertilizer late (28 to 40 days after transplanting). The farmers' average

Table 33. High levels and farmers' levels of inputs in yield-constraints experiments in farmers' fields. Iloilo province, Philippines, 1976-1977.

Input level	Sites (no.)		Fertilizer (kg/ha)			Weed control treatments[a] (no.)		Insecticide applications[b] (no.)	
	Irrigated	Rainfed	N	P_2O_5	K_2O	M	C	F	G
					1976 dry season				
Farmers'	2	0	37	9	0	0.5	1.0	2.0	0.0
High			150	40	30	1.0	1.0	1.0	4.0
					1976 wet season				
Farmers'	5	2	43	11	5	0.8	0.1	1.3	0.1
High			100	40	30	1.0	1.0	1.0	3.0
					1977 dry season				
Farmers'	17	0	66	11	3	1.3	0.7	1.8	0.2
High			150	40	30	0.8	1.0	2.3	3.6
					1977 wet season				
Farmers'	19	4	55	12	5	0.9	0.3	2.3	0.0
High			100	40	30	0.9	1.2	2.0	3.5

[a] M = either by hand or by rotary weeder, C = chemical herbicide.

[b] Av no. of foliar (F) sprays -- parapest, mipcin, azodrin, brodan, etc. -- or of granular (G) applications of basudin 10, lindane, furadan, etc., to paddy water.

Table 34. Farmers' and intermediate levels of fertilizer and insect control in yield-constraints experiments[a] in the farmers' fields. Iloilo province, Philippines, 1976-1977.

Sites (no.)		Fertilizer (kg/ha)									Insecticide applications[b] (no.)			
		Farmers'			Intermediate 1			Intermediate 2			Farmers'		Intermediate	
Irrigated	Rainfed	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	F	G	F	G
							1976 wet season							
5	2	43	11	5	40	20	10	70	30	20	1.3	0.1	0.0	2.0
							1977 dry season							
4	0	92	6	0	50	20	10	100	30	20	3.0	0.2	1.8	2.0
							1977 wet season							
6	3	71	22	8	40	20	10	70	30	20	2.8	0.0	2.4	2.7

[a] Complete factorial experiment.

[b] F = foliar application, G = granular application.

Table 35. Average yields with farmers' level and high level of inputs in irrigated and rainfed farmers' fields. Iloilo province, Philippines, 1976 and 1977 wet seasons.

Farm type	Sites (no.)	Grain yield (t/ha)		
		Farmers' inputs	High inputs	Difference
		1976 wet season		
Irrigated	5	3.3	5.2	1.9
Rainfed	2	3.5	5.5	2.0
		1977 wet season		
Irrigated	19	4.0	5.0	1.0
Rainfed	4	3.4	4.3	0.9

Table 36. Yields from farmers' level and high level of inputs in yield-constraints experiments in farmers' fields. Iloilo province, Philippines, 1976-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)		
		Irrigated	Rainfed	Farmers' inputs	High inputs	Difference
1976	Wet	5	2	3.3	5.3	2.0
1976	Dry	2	0	3.1	5.6	2.5
1977	Wet	19	4	3.9	4.9	1.0
1977	Dry	17	0	4.0	5.3	1.3

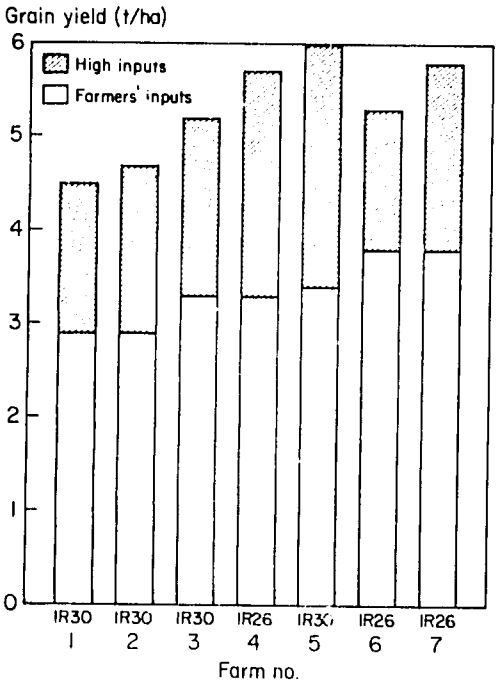

Fig. 12. Variations in yield gap between farmers' fields in farm yield-constraints studies in Iloilo province, Philippines, 1976 wet season (Each bar represents one farm).

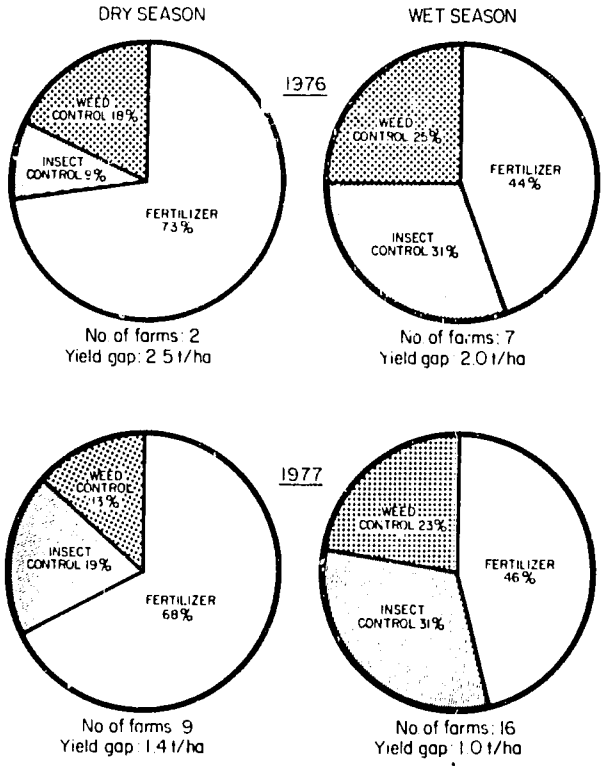

Fig. 13. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Iloilo province, Philippines, 1976-1977.

level of fertilizer, particularly nitrogen was slightly higher than I-1 but the farmers' average yield was 0.4 t/ha lower than that from the I-1 level (Table 37). That indicates that fertilizer efficiency can be increased by improved timing of application. A further yield increase of 0.3 t/ha was obtained with the I-2 fertilizer level. These results are similar for comparisons made with insect and weed control measures at the farmers' level and at a high level (Table 38).

Insect control. Although the farmers applied adequate insecticides, crops on two farms were seriously damaged by leaf folders. The intermediate insect control level yield was 0.3 t/ha higher than the farmers' level and the high level of insect control gave an additional yield of 0.3 t/ha (Table 37). The yield increases were not, however, statistically significant.

Weed control. Improved weed control significantly increased yield on most farms, and gave an average of 0.5 t/ha more than the farmers' practices (Table 37). Low average yields with farmers' weed control was attributed to late hand weeding on three farms and no weeding on one farm. The other three farms were hand weeded between 22 and 25 days after transplanting.

Cultural practices. Farmers' and high levels of cultural practices, involving test and farmers' varieties, were compared at three levels of management at all test sites. The average grain yields are in Table 39. The effect of the high level of cultural practices, which included 21-day-old seedlings planted at 20- x 20-cm spacing, on grain yield was modest for farmers' management when compared with the farmers' method of planting and seedling age. At the intermediate and high management levels, grain yields from farmers' and high cultural practices were similar.

Varieties. Farmers' and test varieties grown at three levels of management at all test sites were also compared for yield performance. Four farmers grew IR30 and three farmers grew IR26. The test variety was IR36 at all sites. It and farmers' varieties gave similar yields at the intermediate and high management levels (Table 40). IR36 was moderately affected by bacterial leaf blight on four farms. There was no significant difference in grain yields between the test and farmers' varieties on six of seven farms.

ILOILO PROVINCE, 1977 *Dry season*

During the 1977 dry season, three types of experiments were conducted on irrigated farms -- four complete factorial, five minifactorial and eight supplemental trials. Only two cooperating farmers (farms 2 and 16) transplanted their crop; the rest direct-seeded on puddled soil. The average level of fertilizer applied by the cooperating farmers was 66 kg N/ha, 11 kg P_2O_5/ha, and 3 kg K_2O/ha (Table 33). One farmer (farm 2, minifactorial experiment) did not apply any fertilizer. All but one (farm 2) of the cooperating farmers used two or more insecticide sprays. One farmer (farm 1) used granular insecticide in addition to sprays. Thirteen of 17 farmers used herbicides to control weeds -- 10 used sprays and 3 farmers (farms 1, 4, and 7) used a granular form. Herbicides were applied about 2 weeks after seeding. Hand weeding was done between 25 and 45 days after seeding on 12 farms.

Table 37. Grain yield from different levels of inputs in yield-constraints experiments[a/] in farmers' fields. Iloilo province, Philippines, 1976-1977.

Year	Season	Sites (no.)		Grain yield[b/] (t/ha)								
				Fertilizer				Insect control			Weed control	
		Irrigated	Rainfed	F	I-1	I-2	H	F	I	H	F	H
1976	Dry	2	0	3.7	4.6	5.3	5.4	4.7	4.8	4.8	4.5	5.0
1976	Wet	5	2	3.8	4.2	4.5	4.5	4.0	4.3	4.6	4.0	4.5
1977	Dry	4	0	3.8	3.6	4.4	4.6	4.0	4.1	4.2	4.1	4.1
1977	Wet	6	3	3.9	4.1	4.2	4.4	4.0	4.1	4.3	4.0	4.2

[a/] Complete factorial experiment only.

[b/] F = farmers' level, I = intermediate level, H = high level. Data were averaged over all levels of other test inputs.

Table 38. Grain yields from farmers' level and test levels[a/] of fertilizer under farmers' and high level of weed and insect control measures in yield-constraints experiments in farmers' fields. Iloilo province, Philippines, 1976 wet season.

Farm no.	Variety	Weed and insect control measures	Nitrogen applied (Farmers' level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing (DT)[b/]	Farmers'	I-1	I-2	H
5	IR30	Farmers'	44	38, 55	3.4	4.2	4.8	4.5
		High			4.8	4.7	5.2	6.0
7	IR26	Farmers'	46	50	3.8	3.8	4.4	4.6
		High			5.0	4.5	5.8	5.8
3	IR30	Farmers'	38	30	3.3	4.1	4.4	4.6
		High			3.9	4.6	4.9	5.2
4[c/]	IR26	Farmers'	[d/]		3.3	3.8	4.2	4.1
		High			5.2	5.1	5.5	5.7
1	IR30	Farmers'	24	28	2.9	3.9	3.2	3.4
		High			3.3	3.5	4.2	4.5
2	IR30	Farmers'	16	40	2.9	3.8	3.8	4.0
		High			4.1	4.4	4.1	4.7
6[c/]	IR26	Farmers'	70	4, 60	3.8	4.6	4.6	4.3
		High			4.7	5.1	5.8	5.3
Av		Farmers'	43		3.3	4.0	4.2	4.2
		High			4.4	4.6	5.1	5.3

[a/] Test rates of nitrogen: Intermediate level: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha; High level (H) = 100 kg N/ha. Time of application: basal and 5-7 days before panicle initiation.

[b/] DT = days after transplanting.

[c/] Rainfed farms.

[d/] No data available.

Table 39. Yields with cultural practices at a high level compared to the farmers' level for input packages in yield-constraints experiments in farmers' fields.[a] Iloilo province, Philippines, 1976-1977.

Sites (no.)		Level of cultural practices	Grain yield (t/ha)			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
			1976 wet season			
5	2	Farmers'	3.7	4.5	5.1	4.4
		High	3.9	4.6	5.1	4.5
			1977 dry season			
4	0	Farmers'	4.3	4.3	4.7	4.4
		High	4.1	4.4	5.9	4.8
			1977 wet season			
6	3	Farmers'	4.1	4.6	5.0	4.6
		High	3.9	4.3	5.0	4.4

[a] Complete factorial experiment only. Data are averages of farmers' and test varieties.

Yield gap and its components

Grain yields at the farmers' level of inputs ranged from 2.3 to 5.5 t/ha (Fig. 13), and averaged 4.0 t/ha (Table 36). Water shortage, and low levels and poor management of inputs on some farms contributed to the low yields. With high inputs, grain yields ranged from 2.7 to 8.0 t/ha, and averaged 5.3 t/ha. The average yield gap was 1.3 t/ha (Table 36). Water shortage was the main reason for low yields from high inputs on some farms. The lowest yield was on a farm with an acute water shortage. It was noted that crops that had received the high fertilizer rate were more affected by drought than those given the lower fertilizer rate. The highest yield was obtained where there was adequate water and good land preparation. Ten farmers produced more than 5.0 t/ha with high inputs.

The average yield from high inputs during the 1977 dry season and that during the 1976 dry season were similar (Table 36). However, the yield gap in the 1977 dry season was smaller than that in 1976. The reason was the considerably higher input levels used by the farmers in 1977.

Table 40. Yields of farmers' varieties compared with those of test varieties for input packages grown with high and farmers' levels of cultural practices in yield-constraints experiments in farmers' fields. Iloilo, Philippines, 1976-1977.[a/]

Sites (no.)		Variety	Grain yield (t/ha)			
Irrigated	Rainfed		Farmers'	Intermediate	High	Av
				1976 wet season		
5	2	Farmers' (IR30 & IR26)	3.6	4.5	5.2	4.4
		Test (IR36)	4.0	4.6	5.0	4.5
				1977 dry season		
4	0	Farmers' (IR30 & IR26)	3.7	3.8	5.0	4.2
		Test (IR36)	4.7	4.9	6.5	5.3
				1977 wet season		
6	3	Farmers' (IR747, IR26, IR30 & IR36)	3.5	4.1	4.6	4.1
		Test (IR42)	4.5[b/]	4.8[b/]	5.3[c/]	4.9

[a/] Data are averages of farmers' and high cultural practices.

[b/] Av, 7 farms.

[c/] Av, 6 farms.

Calculation of the relative contribution of the test factors to the yield gap was made from data from four complete factorial and five minifactorial experiments. The high-input level gave 1.4 t/ha higher yield than the farmers' level. Fertilizer contributed 1.2 t/ha; insect control, 0.3 t/ha; and weed control, 0.2 t/ha to the yield gap (Table 41).

Among the three test factors studied, fertilizer consistently made the highest contribution to the yield gap.

Effect of test factors on grain yield

Fertilizer. The complete factorial experiment included two levels of fertilizer intermediate between the farmers' and high levels (Table 34). Grain yields under each level are shown in Table 37. The high level of fertilizer gave substantially more yield than the farmers' level because the farmers' fertilizer rates were low. Although the average rate of nitrogen applied by the farmers was almost double that of the I-1 level, the yield difference was only slight, but the I-2 fertilizer level gave 0.6 t/ha higher yield than the farmers' level with almost the same nitrogen level. These fertilizer results held at high or farmers' levels of weed and insect control (Table 42). This indicates that the farmers did not use fertilizer properly.

Insect control. The intermediate and high levels of insect control gave yields similar to that from the farmers' level (Table 37). Leaf rollers and leaf folders were identified on 4 farms. Whorl maggots were only noted on two farms and dead hearts and white heads were critical on only 1 farm. Brown planthoppers and green leafhoppers were present on all farms but caused little damage to the crops.

Table 41. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields. Iloilo province, Philippines, 1976-1977.

Year	Season	Sites (no.)		Grain yield (t/ha)			Contribution[a] (t/ha) of			
		Irrigated	Rainfed	Farmers' inputs	High inputs	Difference	Fertilizer	Weed control	Insect control	Residual
1976	Wet	5	2	3.3	5.3	2.0	0.7	0.4	0.5	0.4
1976	Dry	2	0	3.1	5.6	2.5	1.6	0.4	0.2	0.3
1977	Wet	12	4	3.6	4.6	1.0	0.6	0.3	0.4	-0.3
1977	Dry	9	0	4.0	5.4	1.4	1.2	0.2	0.3	-0.3

[a] Measured as yield decrease from high input due to a reduction from high to farmers' level of each input.

Table 42. Grain yields under farmers' level and test levels[a] of fertilizer under farmers' and high level of weed and insect control measures in yield-constraints experiments,[b] in farmers' fields. Iloilo province, Philippines, 1977 dry season.

Farm no.	Variety	Weed and insect control measures	Nitrogen applied (Farmers' level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing (DS)[c]	Farmers'	I-1	I-2	H
1	IR30	Farmers'	130	14, 44, 74	2.3	2.3	2.9	2.7
		High			2.7	2.5	2.9	2.7
3	IR30	Farmers'	27	33	3.7	4.5	4.4	5.2
		High			3.9	4.3	5.4	6.5
12	IR30	Farmers'	174	15, 42	4.3	3.8	5.1	4.7
		High			5.2	3.2	4.9	5.4
13	IR26	Farmers'	39	17, 48	4.3	4.8	4.1	5.2
		High			4.0	4.4	4.8	5.3
Av		Farmers'	92		3.6	3.8	4.1	4.4
		High			3.9	3.6	4.5	5.0

[a] Test rates of nitrogen: I-1 = 50 kg N/ha, I-2 = 100 kg N/ha, H = 150 kg N/ha. All levels applied basal, 30 DS and 5-7 days before panicle initiation.

[b] Complete factorial experiment.

[c] DS = days after seeding.

Weed control. The high level of weed control and the farmers' weed control gave similar yields on all but one farm, indicating that the farmers' weed control was adequate.

Cultural practices. At the farmers' and intermediate management levels, high cultural practices were no better than the farmers' cultural practices for all farms. However, at the high management level the high cultural practices increased grain yield by 1.2 t/ha (Table 39).

Varieties. In general, farmers in Iloilo used early maturing varieties or lines (Fig. 14). Averaging all management levels, the test variety IR36 gave a yield 1.1 t/ha higher than the farmers' variety (Table 40). At the high management level, IR36 yielded 8.7 t/ha on one farm while the farmers' variety (IR26) yielded only 5.5 t/ha.

ILOILO PROVINCE, 1977 *Wet season*

During the 1977 wet season, there were 23 experiments in farmers' fields -- 9 complete factorial, 7 minifactorial, and 7 supplemental trials. Farms 1, 8, 10, and 11 were in rainfed areas. Eight farms (farms 1, 6, 7, 10, 15, 18, 20, and 21) transplanted seedlings. The other farms did direct seeding on puddled soil.

The average level of fertilizer applied by the cooperating farmers was 55 kg N/ha, 12 kg P_2O_5/ha, and 5 kg K_2O/ha (Table 33). The farmer (farm 2) who did not use fertilizer during the dry season did not apply any fertilizer during the wet season.

All cooperating farmers used 2 or more sprays of insecticide but only one farmer (farm 5) used granular insecticide in addition. Weeds were controlled with herbicide spray or one hand weeding. Seven cooperators used a combination. Hand weeding or herbicide spraying was done between 15 and 50 days after seeding.

Yield gap and its components

Irrigated farms. Nineteen trials were on irrigated farms, where farmers' yields were from 2.6 to 4.9 t/ha (Fig. 14), and averaged 4.0 t/ha. The high level of inputs produced yields from 3.4 to 6.7 t/ha, and averaged 5.0 t/ha. The average yield gap was 1.0 t/ha (Table 35). The low yields from farmers' inputs (Fig. 14) were due to several factors, including poor management and lack of inputs; inadequate water supply, rendering the application of fertilizer and granular insecticides ineffective; high incidence of bacterial leaf blight; and prolonged inundation during the early growth stage.

A complete factorial experiment (farm 3) that yielded 6.5 t/ha during the dry season produced only 4.0 t/ha in the wet season because of bird and rat damage at seeding time.

Rainfed farms. Because of an acute water shortage on some rainfed farms during the growing period, the grain yields obtained from both farmers' and

high input levels averaged lower than those on irrigated farms. Farmers' inputs produced an average yield of 3.4 t/ha. Yields from high inputs averaged 4.3 t/ha (Table 35). The average yield gap was 0.9 t/ha, similar to that for irrigated farms.

A long drought period in late September greatly reduced rice yields on rainfed farms. Three farms planted in early August gave a better response than a farm (farm 1) that was planted in late September and received rain only at planting time and again in November (47 days after transplanting).

Average of irrigated and rainfed farms. Combining the data from irrigated and rainfed farms with complete factorial, minifactorial, and supplemental trials, the yields with farmers' inputs averaged 3.9 t/ha.

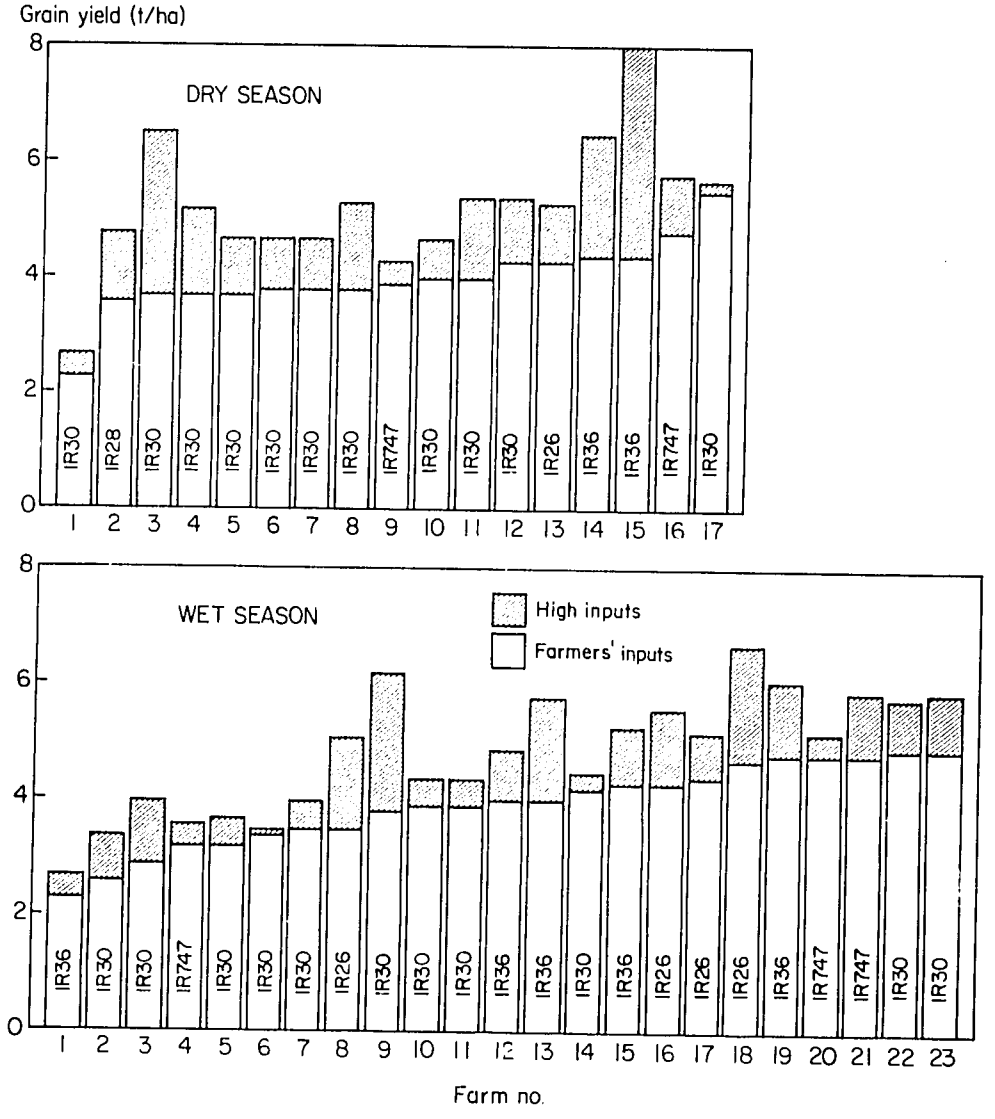

Fig. 14. Variations in yield gap between farmers' fields in farm yield-constraints studies in Iloilo province, Philippines, 1977 dry and wet seasons (Each bar represents one farm).

The average yield gap due to high inputs was 1.0 t/ha (Table 36). The decreased yield gap in the 1977 wet season (compared with that in 1976) was attributed to increased farmers' inputs, drought, insect and disease incidence on highly fertilized plots, lodging, and rat damage. The calculation of relative contribution of each major test factor to the yield gap includes only the data from the complete factorial and minifactorial experiments. Averaging 16 farms with these two experiments, the yield gap between farmers' and high inputs was also 1.0 t/ha (Table 41).

Effect of test factors on grain yield

Fertilizer. The high level of fertilizer provided an average yield of 0.5 t/ha higher than the farmer's fertilizer level (Table 37). As in the dry season, the average rate of nitrogen applied by farmers was almost twice the rate in the I-1 level. However, the average yield with I-1 was slightly higher than that with the farmers' level. The I-2 level outyielded the farmers' level by 0.3 t/ha with the same rate of nitrogen. I-2 had a more pronounced effect on grain yield than the farmers' level at the optimum levels of insect and weed control (Table 43). The results suggest that the farmers' yields could be increased significantly by proper fertilizer management and improved insect and weed control practices. The farmers' fertilizer rates and timing of application varied from farm to farm. On some fertilizer was applied as late as 46 days after transplanting or 65 to 67 days after seeding. Only on 2 of 9 farms was fertilizer applied basally.

Insect control. The intermediate level of insect control gave no yield advantage over the farmers' level (Table 37). Even with a high level of insect control, the yield gain of 0.3 t/ha was not appreciable because of the factors already noted.

Weed control. The high level of weed control provided only a modest yield increase (0.2 t/ha) over the farmers' weed control practices (Table 37).

Cultural practices. The high level of cultural practices gave no yield advantage over the current farmers' cultural practices at any level of management (Table 39).

Varieties. Farmers' and test varieties were compared for yield performance in the complete factorial trials. Two farmers grew IR26, three grew IR30, another three grew IR36, and one grew IR747. The test variety was IR42 in all trials. The grain yields are given in Table 40. Averaging all management levels from 9 trials, IR42 outyielded the farmers' variety by 0.8 t/ha. All varieties increased yield with increased management level. Under a high management level, the highest yield obtained from IR42 was 6.9 t/ha; the average of 6 farms was 5.3 t/ha.

Management package project

1976 wet season. Management-package experiments were on one irrigated and one rainfed farm during the 1976 wet season. The inputs used by the farmers are in Table 44. The average fertilizer level used by the farmers (M1) was higher than M2. The insect and weed control practiced by the farmers were comparable to M2 and M3 but much lower than M5. Farmers used IR26 and IR30, and the test variety was IR36 (Table 45).

On the rainfed farm the farmers' variety outyielded the test variety by 0.3 t/ha. This yield difference was attributed to damage to IR36 by bacterial leaf blight. On the irrigated farm, the average grain yields of the farmer's variety and the test variety were the same. The yields of both the farmers' and the test variety steadily increased from M2 to M5. The grain yield from the farmers' management was higher than that from M2 but lower than that from M3 on the rainfed farm. The results suggest that, aside from using a minimal amount of fertilizer, the farmers did not use it properly. Because there was no basal application plus incorporation of fertilizer before transplanting, for that season fertilizer-use efficiency was low.

Table 43. Grain yields under farmers' level and test levels[a/] of fertilizer under farmers' and high level of weed and insect control measures in yield-constraints experiments[b/] in farmers' fields. Iloilo province, Philippines, 1977 wet season.

Farm no.	Variety	Weed and insect control measures	Nitrogen applied (Farmers' level)		Grain yield (t/ha)			
			Rate (kg/ha)	Timing (DS)[c/]	Farmers'	I-1	I-2	H
19	IR36	Farmers'	23	11, 46[d/]	4.8	5.3	4.9	5.5
		High			5.0	5.8	6.8	6.1
3	IR30	Farmers'	39	36	2.9	3.0	3.1	3.4
		High			3.4	3.9	3.4	4.0
10	IR30	Farmers'	121	31, 65	3.9	3.8	4.2	4.5
		High			4.3	4.2	4.6	4.4
15	IR36	Farmers'	55	40	4.3	4.0	3.6	4.3
		High			5.5	4.7	5.5	5.3
18	IR26	Farmers'	170	0, 27, 67	4.6	4.7	5.1	4.6
		High			4.8	5.3	7.3	6.7
9	IR747	Farmers'	53	48	3.2	2.6	3.6	3.1
		High			3.4	3.5	3.5	3.6
8	IR26	Farmers'	90	20, 51	3.5	4.6	4.2	5.0
		High			4.6	4.1	4.9	5.1
2	IR30	Farmers'	38	21, 45	3.9	4.6	4.3	4.3
		High			4.1	4.1	4.1	4.4
1	IR36	Farmers'	50	0[d/]	2.3	1.8	2.4	2.4
		High			2.6	2.1	2.9	2.7
Av.		Farmers'	71		3.7	3.8	3.9	4.1
		High			4.2	4.2	4.8	4.7

[a/] Test rates of nitrogen: Intermediate levels: I-1 = 40 kg N/ha, I-2 = 70 kg N/ha; High level (H) = 100 kg N/ha. Time of application: basal and 5-7 days before panicle initiation.

[b/] Complete factorial experiment.

[c/] DS = days after seeding.

[d/] Days after transplanting (DT).

Table 44. Average levels of farmers' inputs and levels of 4 inputs in management package experiments. Iloilo province, Philippines, 1976-1977.

Sites (no.)		Package[a] level	Fertilizer (kg/ha)			Insect control[b]					Weed control[c]	
						Seedbed		Field				
Irrigated	Rainfed		N	P_2O_5	K_2O	F	G	R	F	G	M	C
						1976 wet season						
2	0	M1	54	14	7	0	0	0	1.5	0	1	0
		M2	40	10	0	0	0	0	2	0	1	0
		M3	60	20	20	0	1	1	0	0	0	1
		M4	80	30	30	2	0	1	0	1	1	1
		M5	100	40	40	0	2	0	1	4	1	1
						1977 dry season						
1	0	M1	174	0	0	0	0	0	4	0	1	1
		M2	40	10	0	0	0	0	2	0	1	0
		M3	80	20	20	0	1	1	0	0	0	1
		M4	120	30	30	1	1	1	1	0	0	1
		M5	160	40	40	0	2	0	1	4	1	1
						1977 wet season						
2	1	M1	78	25	7	0.3	0	0	2.7	0	1	0
		M2	40	10	0	0	0	0	3	0	1	0
		M3	60	20	20	0	1	1	0.5	0	0	1
		M4	80	30	30	0	2	1	1	1	0	1
		M5	100	40	40	0	2	0	2.5	4	1	1

[a] M1 = farmers' level of application of three inputs. M2-M5 = have levels of fertilizer, insect control and weed control as listed in this table.

[b] F = foliar, G = granular, R = rootzone placement of liquid carbofuran.

[c] M = mechanical weeding either by hand or rotary weeder, C = chemical herbicide.

1977 dry season. During the 1977 dry season there was one experiment on an irrigated farm. The input levels used are shown in Table 44; the values of each package are shown in Table 45. Application of carbofuran to the subsoil was evaluated at M3 and M4. The average yield of the test variety, IR36, was the same as that of the farmers' variety IR30. With IR30, the grain yields from M4 and M5 were significantly higher than M1. The low yield response to the high farmer's level of fertilizer (174-0-0) was attributed to improper timing of its application.

1977 wet season. During the 1977 wet season, experiments were on one rainfed and two irrigated farms. The input levels used by the farmers and various management levels are shown in Table 44. IR26 was grown on the rainfed farm; IR30 on one irrigated farm and IR36 on the other. The test variety was IR42.

The farmers' fertilizer-use level was between M3 and M4. Farmers made one hand weeding and two or more insecticide sprays. The test variety outyielded the farmers' variety by 0.4 t/ha (Table 45).

Table 45. Average yield of farmers' varieties and test varieties compared at farmers' and 4 input management packages and grown with high levels of cultural practices. Iloilo province, Philippines, 1976-1977.

Sites (no.)		Variety	Grain yield (t/ha)					
Irrigated	Rainfed		M1[a]	M2	M3	M4	M5	Av
			1976 wet season					
1	1	Farmers'[b]	4.4	4.4	5.1	5.5	5.8	5.0
		Test (IR36)	4.2	4.2	5.0	5.1	5.4	4.8
			1977 dry season					
1	0	Farmers' (IR30)	4.1	3.4	4.7	5.6	5.1	4.6
		Test (IR36)	4.5	3.6	4.2	5.7	5.0	4.6
			1977 wet season					
2	1	Farmers'[c]	3.9	3.6	4.2	4.3	4.6	4.1
		Test (IR42)	4.1	4.2	4.6	5.0	4.7	4.5

[a] M1 = farmers' level of management.

[b] Farmers used IR26 and IR30.

[c] Farmers used IR26, IR30, and IR36.

At M5, yields of the farmers' variety ranged from 3.9 t/ha to 5.7 t/ha, and averaged 4.6 t/ha. The test variety's yield ranged from 3.9 t/ha to 5.2 t/ha, and averaged 4.7 t/ha. The lowest yield was on the rainfed farm. Compared with the farmers' management, the M5 level gave 0.7 t/ha higher yield with the farmers' variety and 0.6 t/ha with the test variety. Yields from M3 and M4 were also higher than yields from the farmers' (M1) level.

SUMMARY OF YIELD GAP AND CONSTRAINTS IN ILOILO PROVINCE

The 1976-77 average yields from the farmers' and high level of inputs for all Iloilo sites are summarized in Table 46. In the dry seasons, 19 experiments were conducted in farmers' fields. From those the average grain yield at the farmers' level of inputs was 3.9 t/ha and yield from a high level of inputs was 5.3 t/ha. The average yield gap was 1.4 t/ha.

Table 46. Average grain yield with farmers' level of inputs and high level of inputs in yield-constraints experiments in farmers' fields. Iloilo province, Philippines, 1976-1977.

Sites (no.)				Grain yield (t/ha)		
1975	1976	1977	Total	Farmers' inputs	High inputs	Difference
				Dry season		
0	2	17	19	3.9	5.3	1.4
				Wet season		
0	7	23	30	3.8	5.0	1.2

The average contributions of each test factor to the yield gap were calculated from complete and minifactorial trials (Fig. 15). The average wet-season yield for 30 farms was 3.8 t/ha from the farmers' level of inputs and 5.0 t/ha from the high level. The average yield gap was 1.2 t/ha (Fig. 16). The average yield recorded at the farmers' level of inputs was slightly lower on rainfed than on irrigated fields (Fig. 17).

Results from the complete factorial and minifactorial trials also indicated that fertilizer contributed the highest percentage (45.6%) to the yield gap while improved insect control contributed 29.4% and weed control 25% (Fig. 15).

ECONOMIC ANALYSIS

Maximum yield inputs

Table 47 summarizes the economic returns obtainable from maximum input levels for rice production in several wet- and dry-season trials in three provinces in the Philippines. The data are from Herdt et al (1978). There was a clear tendency of maximum yield technology to perform relatively better in the dry season than in the wet season.

The average maximum input levels cost three times as much as the average farmers' input levels. In the wet season, by spending an extra US$122/ha, Nueva Ecija farmers could have obtained an increased profit of US$4/ha. Iloilo farmers could have increased their profits by US$46/ha by spending an extra US$141/ha. However, in Camarines Sur province, farmers would decrease their profits US$68/ha by spending an extra US$134/ha. In the dry season,

farmers in the three provinces could have increased their profits by an average of US$112/ha by spending $164/ha above their current input per hectare. There was some site-to-site variability in these results, but the general trend was similar.

Input combinations

The combination of inputs which *ex post* were found to give the highest profit with the greatest frequency in the wet season were identified as farmers' weed control, intermediate insect control, and a high intermediate fertilizer level. In the dry season, the input combination most frequently found economically best was the farmers' weed control, intermediate insect control and a high fertilizer level. In 1975, "management packages" were tested and the best package was M3 in the wet season and M4 in the dry season. The yields obtained with those combinations of inputs were defined as maximum profit yields, and the difference between the farmers' and the maximum profit yield was defined as the economically recoverable gap (ERG) (Herdt et al 1978).

Data summarizing the ERG are shown in Table 48 for the three provinces. In the wet season, the total gap averaged 1.1 t/ha and the ERG 0.7 t/ha. The ERG was 100% of the total yield gap in Camarines Sur because the maximum input treatment gave a lower yield than the intermediate treatment in 1977 and the two gave the same yield in 1975. Thus in the wet season, it appears that yields could be profitably raised by about 0.7 t/ha -- from the average farmers' level of 3.4 to 4.1 t/ha.

In the dry season, the 2.2 t/ha total yield gap was exactly twice the wet season gap. The ERG averaged 1.2 t/ha, again twice the wet-season level. There was variability among provinces, but on the average, the ERG was 55% of the total gap. This shows that in the dry season, yields could be profitably increased from the farmers' level of 4.1 t/ha to 5.3 t/ha.

METHODOLOGICAL PROBLEMS ENCOUNTERED IN THE STUDY AREAS

To obtain a study area with uniform agroclimatic conditions as well as manageable number of test sites, a small area and few sites were chosen. However, the test farms included were too few to adequately represent the widely different farming conditions that exist in a province, making the interpretation of the results appropriate only for a limited area.

Selection of sample farms

One criterion in selecting the experimental sites was the farm's accessibility. Farmers along good roads, whose farms are also located along or near good roads, are probably *better* farmers because they can easily get to supply centers, purchase needed inputs and easily transport the inputs to their farms. Further, agricultural extension workers generally visit easily accessible farms more often than those in remote areas. These factors have, therefore, resulted in the unrepresentativeness of the experimental farms to the rest of the farms in the study areas.

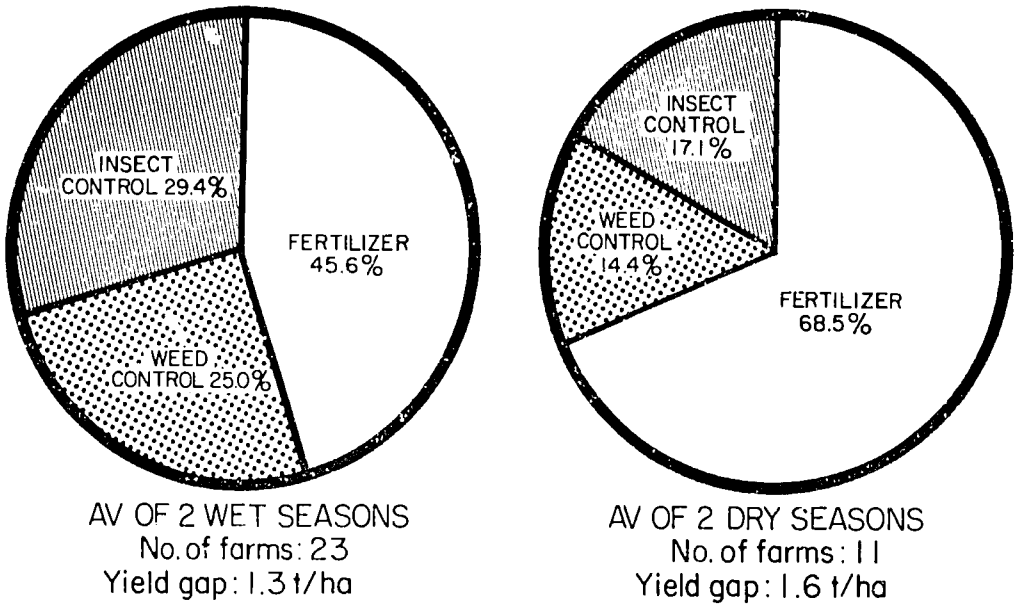

Fig. 15. Relative contribution of three inputs (insect control, fertilizer, and weed control) to the improvement of rice yields in farmers' fields, Iloilo province, Philippines, 1976-1977.

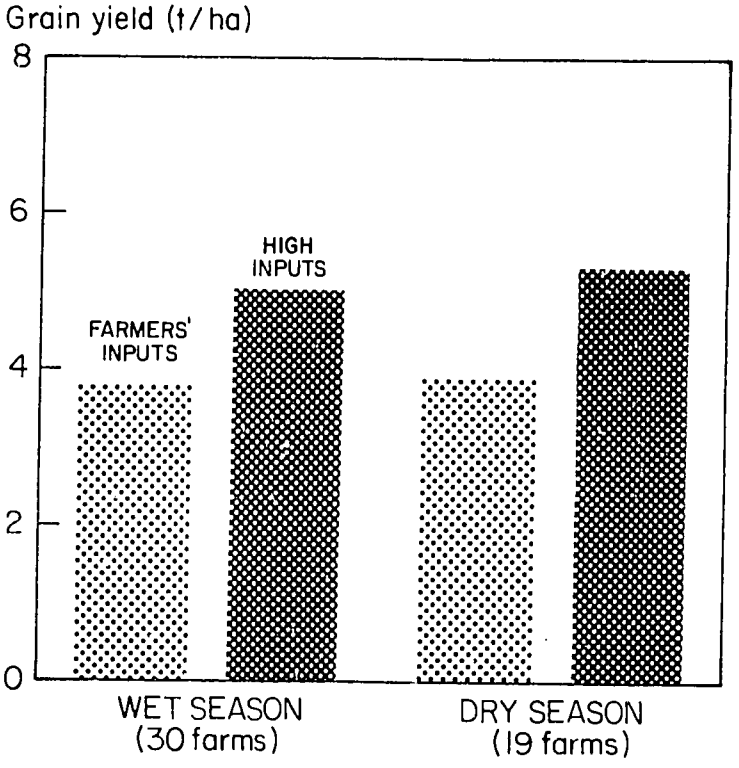

Fig. 16. Average yields from farmers' level and high level of inputs in farmers' fields, Iloilo province, Philippines, 2 wet seasons and 2 dry seasons, 1976-1977.

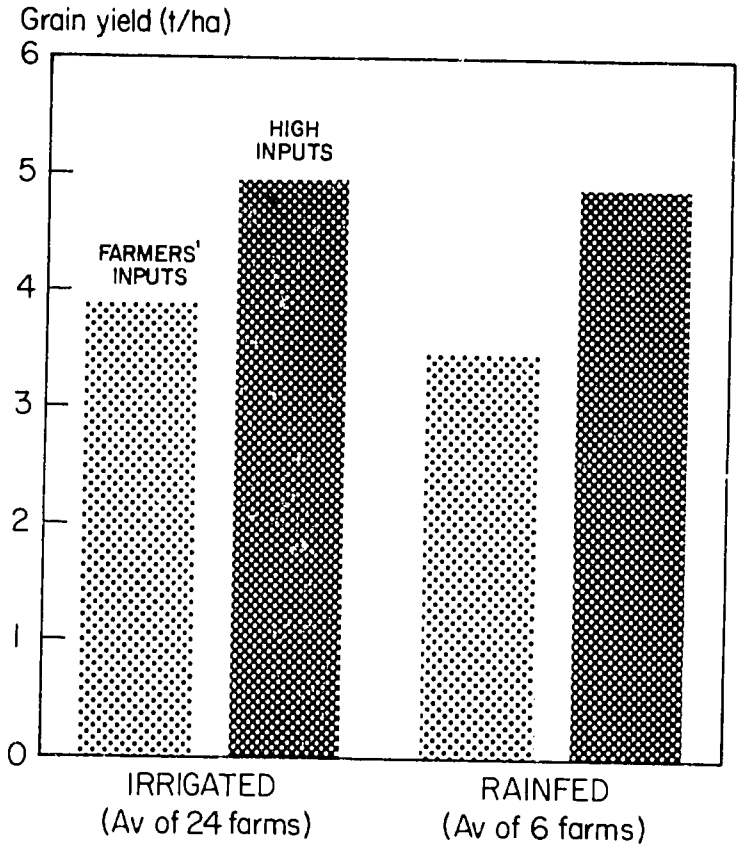

Fig. 17. Average yields from farmers' level and high level of inputs in irrigated and rainfed farmers' fields, Iloilo province, Philippines, 1976-1977 wet seasons.

Simulation of farmers' practices

Comparable paddy. The farmers' level of each test factor is obtained by observing each farmer throughout the cropping season. Because farmers' practices vary, even on the same farm, the technique of *comparable paddy* was used to facilitate the identification of farmers' level. Often, the comparable paddy is irregularly shaped and the exact area is difficult to determine, which makes the calculation of the farmers' inputs less accurate. Inability to simulate the actual amounts of inputs used by the farmers may account for some inconsistencies in the results and interpretations. Farmers do not have measuring instruments and the amount of their inputs is based on their best estimates, e.g. one kerosene can of ammonium sulfate applied to the comparable paddy. One farmers' practice that is difficult to simulate is the mixing of inputs to cut down the time required for application. For example, a farmer may mix granular insecticide with urea and ammonium phosphate, not only for the comparable paddy but for the whole field.

Farmers' method of input application. There are two major difficulties in effectively simulating the farmers' application method. First, in some cases the time lag in following the farmers' operation, regardless of how small, can

Table 47. Summary of economic comparison of the anticipated maximum yield level of inputs and the farmers' levels in constraints experiments. Philippines, 1974-77 (adapted from Herdt et al, 1978).

Province	Years (no.)	Trials (no.)	Input cost (US$/ha)		Yields (t/ha)		Net returns (US$/ha)	
			Farmers'	Maximum	Farmers'	Maximum	Farmers'	Maximum
					Wet seasons			
Nueva Ecija	4	39	63	185	3.0	3.9	356	360
Camarines Sur	3	20	50	184	3.2	3.7	384	316
Iloilo	2	16	55	196	3.5	5.0	416	462
All	-	75	58	187	3.2	4.1	376	370
					Dry seasons			
Nueva Ecija	3	19	111	245	4.6	6.8	611	737
Camarines Sur	3	14	63	267	3.5	5.4	444	516
Iloilo	2	6	65	234	3.5	5.2	410	572
All	-	39	87	251	4.0	6.0	520	632

Table 48. Total gap and economically recoverable gap as determined from constraints experiments on farmers' fields. Philippines, 1975-77 (Herdt et al 1978).

Province	Trials (no.)	Yield (t/ha) with inputs at			Total yield gap	Economically recoverable gap	ERG as % of total
		Farmers' level	High level	Maximum profit			
				Wet seasons			
Nueva Ecija	29	3.5	4.8	4.2	1.4	0.7	50
Camarines Sur	20	3.2	3.7	3.7	0.5	0.5	100
Iloilo	16	3.5	5.0	4.3	1.4	0.8	52
All	65	3.4	4.5	4.1	1.1	0.7	64
				Dry seasons			
Nueva Ecija	20	4.6	7.1	5.7	2.5	1.1	44
Camarines Sur	14	3.5	5.4	5.0	2.0	1.5	79
Iloilo	6	3.5	5.2	4.5	1.7	1.0	66
All	40	4.1	6.2	5.3	2.2	1.2	57

produce a large difference in results, e.g. applying insecticides 1 or 2 days after the farmer does could cause a yield difference because the effectiveness of insecticides depend not only on the degree of infestation but also on timeliness of spraying. Such a difference can be minimized by a daily talk with the farmer regarding his expected time of input application. Or, the farmer can be instructed to spray specifically marked plots -- even in the absence of the researcher -- with the assurance that his services will be paid and cost of insecticide reimbursed. Some operations, e.g. spot hand weeding, are not easy to duplicate or simulate.

Fixed factors

The experimental method specifies that aside from the test factors, other management or cultural practices should be at the farmers' level. Water control by the farmers' method is usually poor. Sometimes overflooding occurs in the comparable paddy and in the experimental plots, altering the effect of the test factors. For example, if there is too much water on the experimental plots, the weed infestation is low, a situation particularly true during the wet season. At the same time the neighboring farmers may not have such water problems and have greater weed population.

Plot layout

Because plots are laid out at random, some insecticide-treated plots are beside a no-insect-control plot. Application of high level and farmers' level of insect control in adjacent small-sized plots is expected to bias the effect of insect control. Further, application of a high level of fertilizer in experimental plots provide greater insect and disease pressure -- particularly leaf rollers and bacterial leaf blight -- on those farms than in nonexperimental farms.

Method of stand establishment

Adoption of direct-seeding is gaining momentum among farmers in Iloilo province, which requires development of better fertilizer and weed control technology. However, farmers in Nueva Ecija and Camarines Sur provinces still transplant conventionally.

Other problems

In all study areas, input levels and practices proposed by the farmers during a preliminary interview were not exactly followed by them for some reasons. Wooden markers, installed in the comparable paddy that would signal the researcher that an operation has been done by the farmer, were turned upside down even if no farm operation was done in the comparable paddy. This technique did not work well. Data on supplemental trials may not be as reliable as those obtained in the complete factorial and minifactorial trials because there was no treatment level that duplicated the farmers' level of cultural practices in the farmers' fields.

CONCLUSIONS

From our 1974-77 results from research in farmers' fields in Nueva Ecija, Camarines Sur, and Iloilo provinces, the following general conclusions were drawn.

1. In Nueva Ecija province, farmers' rice yields can be increased by 2 t/ha in the dry season and by 1 t/ha in the wet season.

2. Current rice yields in Nueva Ecija province can be raised substantially if farmers use higher levels and better management of fertilizers (particularly nitrogen in the dry season) and increase the level and quality of insect control during the wet season.

3. In Camarines Sur and Iloilo provinces, lack of fertilizer and improper management of it are critical factors keeping farmers from obtaining high and stable yields in the dry and wet seasons. Inadequate insect and weed control also appear to be constraints to high yield -- more so in the wet than in the dry season.

4. Rapid adoption of broadcast seeding has required significant managerial changes with regard to input use and may limit Iloilo farmers' appropriate use of modern rice technology. Problems of using modern technology are most critical in areas that use direct seeding but do not have good water control.

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