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MID-TERM REVIEW OF FAO INTERCOUNTRY PROGRAM FOR THE DEVELOPMENT AND APPLICATION OF INTEGRATED PEST CONTROL IN RICE IN SOUTH & SOUTH EAST ASIA

Phase II

Mission Report, November 1990

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3 *BACKGROUND*

3 1 BRIEF OVERVIEW OF RICE PRODUCTION IN ASIA, BEFORE AND DURING THE GREEN REVOLUTION

Rice production in Asia increases by expanding land under cultivation, by growing more than one short duration crop in a year or by increasing the harvested yield per crop Breeding and management contribute to all these sources of growth, as in Southern China in the 11th century when short duration Champa varieties from Vietnam were introduced northward to areas with irrigation systems This Green Revolution promptly expanded the area double cropped under the more intensive Chinese fertilizer and cultivation practices Local farmers' selection steadily improved the genetic potential of these varieties so that staple food production and population growth in South China outpaced North China by a factor of 2 1 for the next 500 years ***(3,28)*** ***[Please see numbered references in Annex I]***

Twentieth century rice production in Asia stagnated at first While North Asian production kept up with population by efficiently distributing fertilizer and improving varieties tropical Asian production grew only through expanding area cultivated It did not keep up with the demographic transition to lower mortality Total production remained level but per capita production declined for the 25 years before the Second World War ***(3)***

After the war construction and improvement of irrigation systems boosted tropical production into the 1960s Then two new genetic technologies — photoperiod insensitivity that opened up the double-cropping potential of irrigated land and higher grain to straw ratios that utilized more of the nutrient potential of nitrogen fertilizer as harvestable yield — recreated 800 years later than in South China a Green Revolution in rice (Fig 3 1) ***(3,9)***

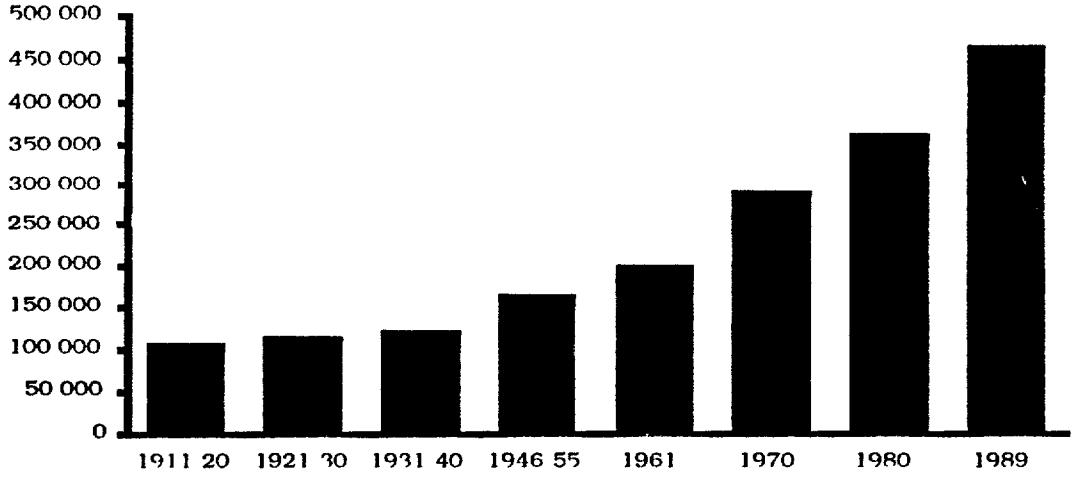

Fig 3 1 Average annual paddy production for Asia (selected periods - 1000s of tons)

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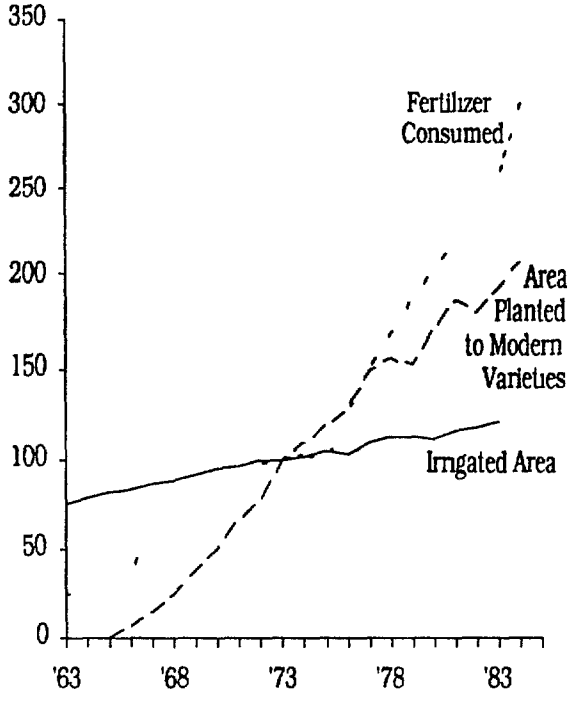

Fig 3 2 Indices for irrigated area fertilizer and area under modern varieties (1973=100) in Program countries except China and Vietnam ***(22)***

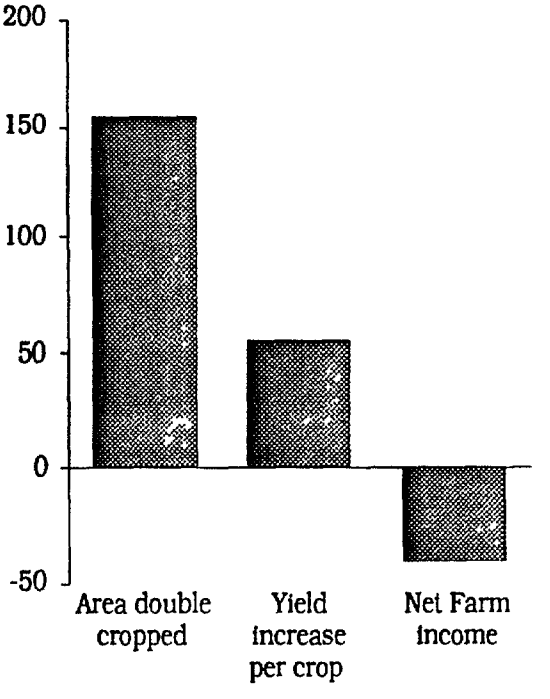

Fig 3 3 Changes in rice cropping intensity and income in Central Luzon Rice Bowl Philippines after the Green Revolution (% change 1966-79) ***(5)***

National production caught up with population when the distribution of seeds and fertilizer allowed countries to take up the "economic slack" between potential and achieved yields across their irrigated areas (Fig 3 2) ***(22)*** Every major Asian country became self-sufficient in rice in the 1980s The relative well- being of these huge populations (totalling 54% of world population) and the dominance of rice in feeding them was a pronounced triumph for national rice intensification programs This triumph was achieved by applying political will but not without costs To quantum leaps in production were added politically essential price controls that protected urban consumers Farmers' incomes suffered (Fig 3 3, from IRRI data)***(5)***

In the early months of the Green Revolution national programs were enjoined to make farmers better consumers of inputs rather than more skillful producers of rice ***(10)*** In their haste to achieve self sufficiency government intensification programs "bundled insecticides together with new seeds and fertilizers Insecticides were to be applied like fertilizers at fixed intervals without reference to field conditions Routine aerial applications of insecticides were made by governments or by chemical companies contracted by governments to "protect" large parts of the country ***(13)*** As early as 1969 farmers field studies by IRRI economists showed that farmers profits decreased the more times they applied insecticides

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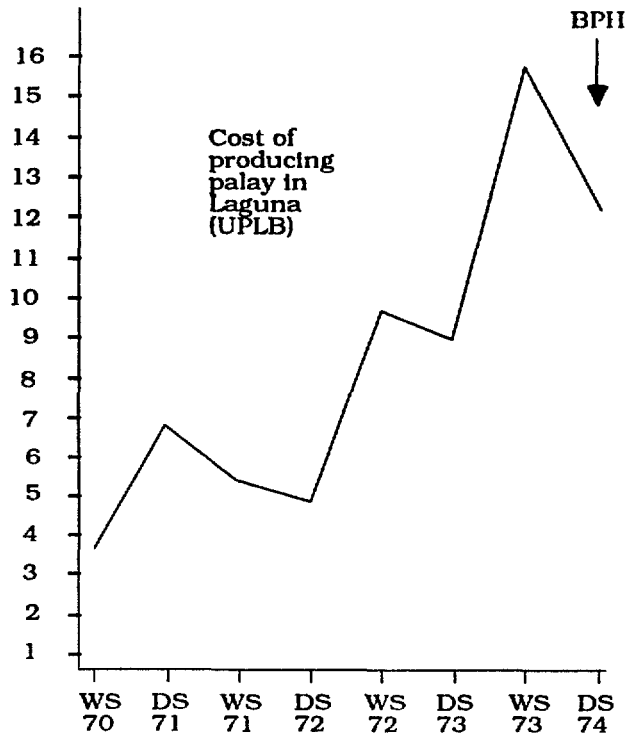

Fig 3 4 Insecticide costs as percentage of cash costs of rice production Laguna Philippines ***(1)***

(15,17,33) The major motivation for applying insecticides was to insure against the fear of crop loss, not to improve profits this motivation was fueled by ignorance about agroecosystems A representative study of rice farmers costs from 1970 - 1973 showed a 4-fold increase in insecticide spending (Fig 3 4) After the farmers surveyed reached their peak spending, an extensive rice brown planthopper outbreak seriously damaged the majority of their fields and over 20% lost their crop ***(1)*** Economic and marketing pressures intensification policies without ecological bases and fear had led to serious ecological disruption that menaced rice production ***(20)***

3 2 EMERGENCE OF RICE BROWN PLANTHOPPER (BPH) AS A SECONDARY PEST, A PEST OF THE GREEN REVOLUTION, A PESTICIDE-INDUCED PEST

3 2 1 Nature and Scale of the BPH Crises

Well known for over 500 years in Northeast Asia the BPH was not considered a major pest of tropical rice in the late 1960s Even a lavishly illustrated large format book on insect control in rice in Indonesia produced in 1968 by a Swiss chemical company had no picture of BPH It concentrated instead on aerial applications for rice stemborers By 1975 BPH had become by far the most threatening insect pest of rice in the tropics The losses to this pest totalled hundreds of millions of dollars by 1977 ***(6)*** IRRI scientists bred genetic materials for BPH "resistance" from South Asian rice into their Southeast Asian lines Almost immediately "unbelievable" reports came back that these lines were not resistant or "lost" their resistance within months of exposure to local field populations The severity of the first wave of BPH outbreaks is shown for Indonesia (Fig 3 5 3 6) Years of huge infestations were years of especially high importation of rice At this time Indonesia was

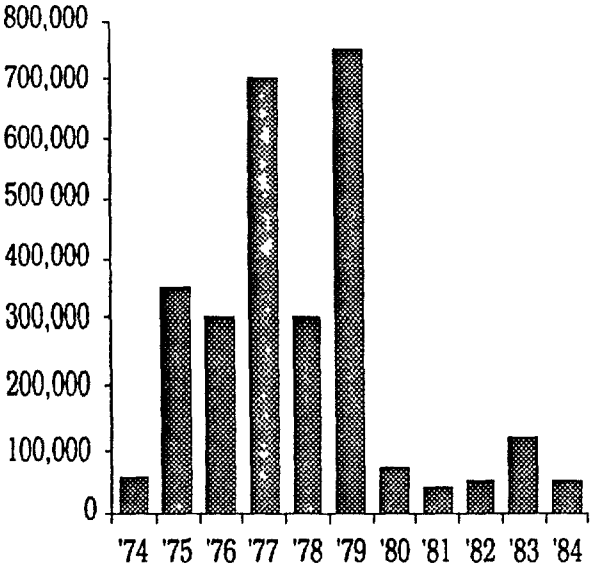

Fig 3 5 Hectarage infested by Brown Planthopper Indonesia 1974 84

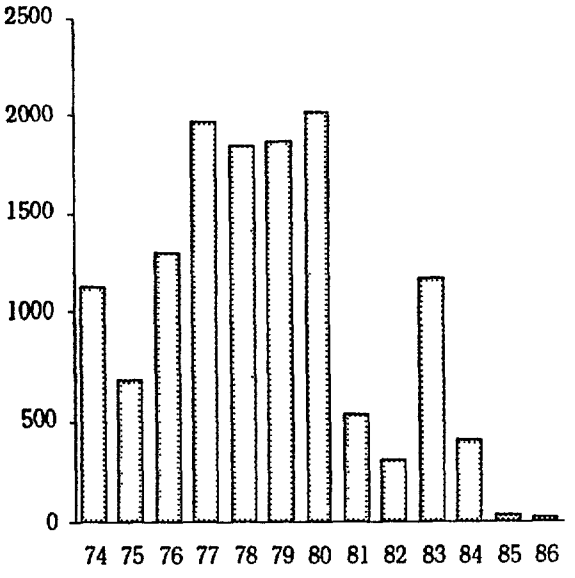

Fig 3 6 Imports of milled rice (000 t) Indonesia 1974-86

the largest rice importing country in the world despite irrigation seeds and fertilizers and apparently despite insecticides ***(22)*** Similar outbreaks are shown for Malaysia and Thailand in the same period (Fig 3 ~ 3 8) ***(20,39,46)***

The Green Revolution was in danger of politically humiliating failure The BPH crisis of the late 1970s was finally weathered not by immediate increases in insecticides but by the release of varieties with additional sources of resistance (Indonesia) and by careful field monitoring (Malaysia) that emphasized the ratio of BPH to natural enemies ***(39)*** The data

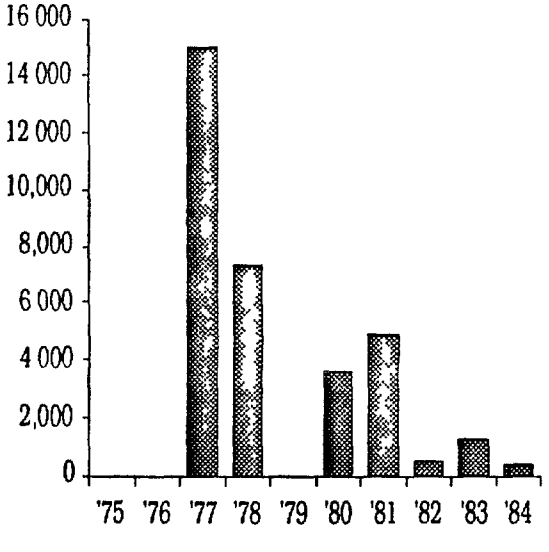

Fig 3 7 Hectarage infested by Brown Planthopper Tanjung Karang Malaysia 1975-84

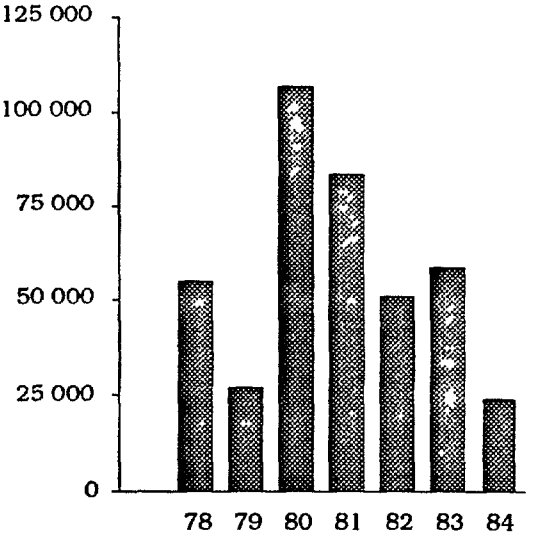

Fig 3 8 Hectarage infested by Brown Planthopper, Central Thailand 1978-84

for Thailand and Vietnam are not as complete but deployment of new varieties with different "resistance' characteristics did take place

3 2 2 Researchers' Explanations

3 2 2 1 Correlated Conditions

The BPH exploded wherever the Green Revolution did For each factor--irrigation varieties and fertilizers- laboratory (even phytotron) studies were used to justify the relationship with BPH BPH were found to respond to relative humidity (associated with irrigation) canopy microclimate (associated with the dense architecture of modern varieties) planting density (modern varieties and new planting practices) plant age (20 days before flowering in modern varieties) and nitrogen contents of whole plants leaves phloem cells and sap (all related to fertilizers) ***(7,16)*** Each narrow laboratory study had some positive results but as most of these factors were essential to Green Revolution rice production control by eliminating any or all of these factors was not practicable It was more worrying to discover that results were not conclusive when factors such as modern vs "traditional" varieties irrigation or fertilizer level were examined in **field** experiments BPH populations in regular fields did not generally respond to the suspected factors of intensification as predicted from laboratory results ***(18)***

3 2 2 2 Ecological Explanation

The role of natural population regulation and its disruption — so well documented for other temperate and tropical agroecosystems — was discounted for years although the earliest field study of rice planthopper outbreaks in Japan ***(24)*** clearly identified insecticide produced destruction of arthropod natural enemies as the key cause of outbreaks Biological control although mentioned in conferences was considered too complicated uncertain inapplicable or esoteric to form the basis of control The conventional wisdom among research entomologists was that Asian rice farmers did not use enough insecticides to disrupt biological control ***(20)***

Beginning in 1977 fundamental ecological field studies in experiment stations and farmers fields in Philippines Malaysia India and Indonesia showed that

1 BPH experienced high natural mortalities at all stages in fields without insecticide treatment ***(25,39)***

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2 BPH oviposition was reduced at higher adult female densities *(25)*
3 Hundreds of species of arthropod natural enemies of BPH could be found in farmers rice fields across Asia *(43)*
4 Generalist predators like spiders water striders and mirids showed significant positive numerical responses to BPH densities in normal production fields *(25,39)*
5 Insecticides killed most predators and thus increased BPH survivorship, fecundity, and population growth rate by many times *(25,39)*
6 Given a BPH population in a rice field commercial insecticide applications invariably increased its population density *(25,31)*
7 Insecticide-induced changes in survivorship were large enough to cause BPH outbreaks as rapidly as they were observed to occur in fields of farmers suffering outbreaks *(25)*
8 Field mortality from natural enemies was sufficient to compensate completely in insecticide-free fields for the evolution of BPH populations able to feed on previously "resistant" varieties *(11,25)*
9 The proportion of BPH in natural (farmers field) populations phenotypically equipped to feed on "resistant" varieties was large enough that released by insecticide treatments from natural controls outbreaks on those varieties were possible While "strong resistance" such as in IR36 posed (probably from its multi locus and/or pleiotropic nature) a long-lasting selective challenge to BPH evolution rapid growth meant that insecticide treated populations "broke down varietal resistance" faster than did untreated populations *(11)*

Natural control was the rule not the exception in tropical rice agroecosystems Many of the anomalous results of earlier field experiments trying to confirm laboratory studies were clear once the agroecosystem was presumed to have at least three trophic levels instead of only two For example when enhanced nitrogen levels tripled BPH fecundity the subsequent egg and nymphal densities still fell easily within the range of response of predators in untreated fields *(18)* Higher mortality compensated for the "pulse" of eggs *(25)* Natural control for rice insect pests was a classic example of paradigm shift because it explained most things left unexplained by earlier theories The practical issue remained if insecticides were essential to maintaining high growth rates in modern rice production but insecticides destroyed natural enemies thus removing natural controls of BPH and if BPH populations evolved quickly enough to "defeat" varietal resistance then how could BPH outbreaks be avoided in the Green Revolution? The route to an answer lay in work being done with farmers by research economists

3 2 3 Experiences with Farmers' Pest Management

Economists studying farmers management decisions often described acute problems with rice pest management Their surveys demonstrated that most farmers in irrigated rice areas used insecticides years before the release of modern varieties (Fig 3 9) These insecticides from international assistance programs were distributed by agriculture and rural development ministries Surveys showed that farmers perceived insecticides as insurance rather than investment ***(26)*** IRRI analyses of trials in farmers' fields in six countries during the 1970s found that investment in insecticides did not as a rule increase profits while investment in fertilizers did (Fig 3 10 3 11) ***(15,17,19)***

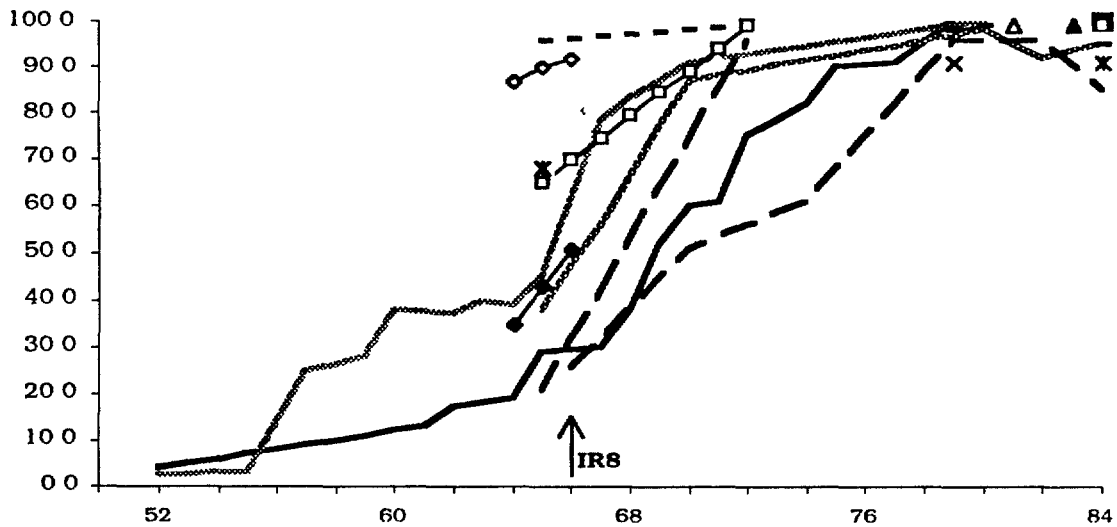

Fig 3 9 Percentage Philippine 'Rice Bowl farmers using insecticides (1952-84) Each line represents a different study ***(26)***

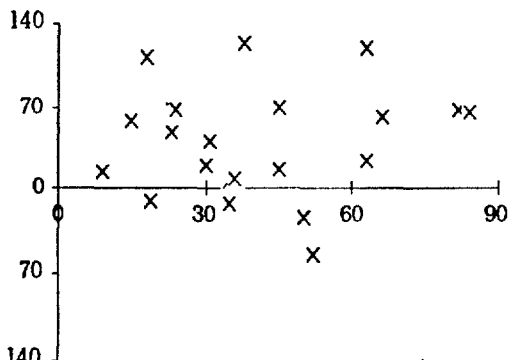

Fig 3 10 Fertilizer cost ($/ha) vs net return ($/ha) for farmers' fields in six Asian countries (1974-77) ***(15,17,19)***

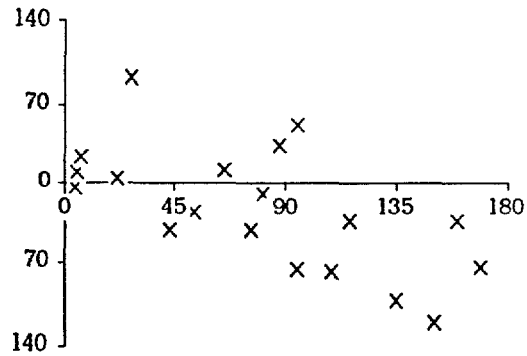

Fig 3 11 Insecticide cost ($/ha) vs net return ($/ha) for farmers' fields in six Asian countries (1974 77) ***(15,17,19)***

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Economists also re-interpreted entomologists field trials They found slightly higher profits from insecticide use with the older modern varieties but very low profits and more often losses from insecticides used on the later (1980s) modern varieties At the time this was interpreted as the effect of "varietal resistance" — to unspecified insect pests — simply substituting for insecticides The current picture (see Chapter 7 below) is that modern varieties by their selected physiological growth dynamics especially tillering rates ***(37)*** compensate for most insect damage The modern rice plant being sink-limited through excessive photosynthetic capacity, grows well despite defoliation Recent IRRI studies over 25 to 36 seasons in Philippine farmers' fields with varying pest pressure showed that insecticide s contribution to yield declined steadily across years being not significant for the latest 5 to 15 years Insecticides did not significantly reduce risk (estimated as the variance in production across seasons) and contributed to yields less than 10% of the contribution of either fertilizer or varieties ***(23,40)***

These results were matched by the Intercountry Program s field demonstrations in the late 1980s in Philippines Sri Lanka Indonesia and India Insecticides do not in the majority of intensified rice crops increase yield significantly and farmers who reduce insecticide use by 50 - 100% after IPM field training achieve lower variance — or risk — in production than when using more insecticides Economists found the frequency of (untrained) farmers insecticide applications not to be correlated with insect damage but with fungal or bacterial disease symptoms or with nutrient disorders ***(34)*** Unnecessary applications increase the chance that BPH outbreaks will be induced and sustained The bulk of data from farmers fields shows that most if not all insecticide treatments in rice do not increase yield nor decrease risk This resolves the dilemma of BPH in the Green Revolution the problem was not BPH but needless insecticide use prompted by fear ignorance political pressure, and aggressive marketing

Economists have for twenty years called for a general re-thinking of pest control because their surveys kept showing that the effects of insecticides were not the same as fertilizers They called for more work on "timing" of insecticide applications more reliance on "resistant" varieties more fundamental ecological understanding of pest problems in the field and broader investigation of the impact of investment in insecticides on yield They have consistently raised issues of environmental and health risks from pesticide use and have been long term advocates of integrated pest management especially based on understanding of local field conditions A 1990 paper from IRRI s economists concludes

> "second generation technologies such as integrated pest management are more knowledge intensive and location specific than the modern seed-fertilizer technology that was characteristic of the green revolution Productivity gains accrue to farmers who have the ability to learn about the new technologies, discriminate among technologies offered to them by the research system adapt the technologies to their particular environmental conditions and provide supervision to ensure the appropriate application of the technology ***(40)*** "

With no quantum productivity leaps from plant breeding or agronomy in view the call for **human resource development** as the source of production gains is powerful and persuasive Much of the Intercountry Program s work was intended to answer this call usually with the BPH crisis as an entry point to national implementation Policy changes carried out with political will as exemplified by Indonesia set up supportive environments for human resource development programs

3 2 4 <u>The BPH Crisis in the late 1980s</u>

3 2 4 1 Indonesia

The IPM experience of Indonesia will be analyzed in Chapter 4 so this section will sketch the BPH crisis and its resolution as background to other countries As shown in Fig 3 12 the area affected by BPH began to rise in 1985 becoming alarming in 1986 President Suharto issued a decree on IPM as the national policy for BPH management in November 1986 This more than doubled field staff for crop protection set aside funds for training and equipping staff and farmers endorsed other than chemical means of control and banned 57 trade brands of insecticides (primarily organo-phosphates and pyrethroids but including other classes) because they killed natural enemies and caused BPH resurgence ***(8)*** The BPH infestation shrank quickly largely from tactics that conserved natural enemies (highly resistant though lower yielding varieties for one season and very selective treatment with a molting inhibitor but no other chemicals) and four years later there are still no significant BPH infestations in the country It appears that varietal resistance to BPH is not an important factor for long-term BPH management because most areas are planted with varieties susceptible to local BPH populations As well as banning 85% of the rice insecticides the Government reduced and by 1989 eliminated insecticide subsidies As well as saving over $100 million per year this reinforced the political signal that IPM had replaced insecticides

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3 2 4 2 Malaysia

Malaysia's rice agroecosystems concentrate on its west coast much closer to North Sumatra (a classic BPH agroecosystem for Indonesia) than either is to Java Figures 3 5 and 3 7 show how closely the well-monitored Tanjung Karang rice area near Kuala Lumpur matched the pattern of Indonesia s outbreak in the late 1970s *(39)* The pattern of the late 1980s was different and alarming (Fig 3 12 3 13) The area affected by BPH reached a near-record high in 1990 In contrast with Indonesia s ban on organo-phosphates in rice a 1987 survey showed the majority of applications made by Malaysian rice farmers were organo-phosphates By 1990 an article in the newsletter of the Malaysian Plant Protection Society found monocrotophos to be the leading insecticide used by rice farmers in Tanjung Karang despite its official restriction to oil palm It was being marketed in units of size more appropriate to small rice holdings than larger oil palm holdings Most farmers interviewed described clearly toxic symptoms suffered while using the compound *(38)* The MADA rice growing area of Malaysia on the north west coast set up in late 1989 a special BPH task force to plan and implement new strategies for alarming BPH hot spots

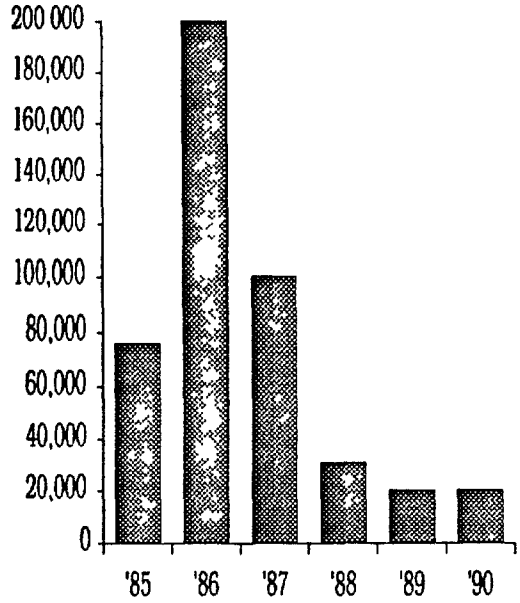

Fig 3 12 Hectarage infested by Brown Planthopper Indonesia 1985 90

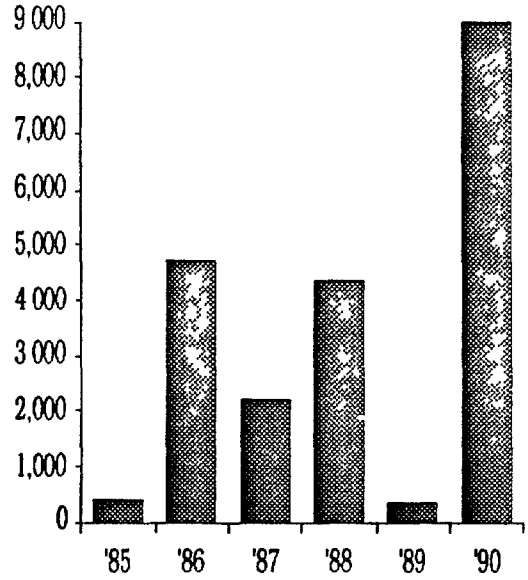

Fig 3 13 Hectarage infested by Brown Planthopper Tanjung Karang Malaysia 1985-90

3 2 4 3 Thailand

Thailand has hundreds of organo-phosphate and pyrethroid insecticide brands registered for use in rice Thai farmers grow for export so when the world price of rice rose significantly in late 1987 through 1989 they intensified their use of all inputs to take advantage of this price Beginning in 1989 and peaking in 1990 was the largest recorded BPH outbreak in

Thai history, as shown in Fig 3 14 ***(46)*** While the recent drop in rice price removed farmers incentives to boost production by uncritical use of inputs BPH remains devastating For the first time policy oriented conferences including Members of Parliament have been held to discuss the BPH problem and review the experience of other countries Just before his resignation in late 1990 the Prime Minister spent time every week inspecting BPH infested areas

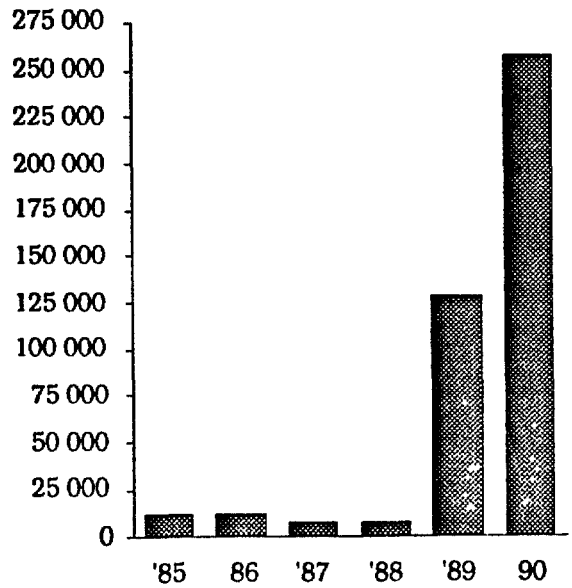

Fig 3 14 Hectarage infested by Brown Planthopper, Central Thailand 1985-90

3 2 4 4 Vietnam

BPH is a potentially dangerous insect pest of rice associated with intensive applications of pesticides and sequential release of resistant rice varieties in Vietnam during the last two decades The sustainability of self-sufficiency and exportation of rice in Vietnam have been affected The Review Team was told that the cost of pesticide procurement by the Government has recently exceeded the national revenue earned from exportation of rice

Prior to the outbreaks of BPH the stem borers were the most common insect pests of rice For controlling these endemic pests insecticides were introduced in the Mekong Delta during the period of 1963 1966 Incidence of the BPH became evident soon after the introduction of pesticides for stem borer control and hopperburn damage was recorded in 1964 1968 1972 and 1974 Eventually the first devastating outbreaks of the BPH prevailed in the Mekong Delta in 1977 and 1978 These outbreaks were temporarily suppressed by introducing IR varieties resistant to the BPH such as IR26 IR28 IR30 and other similar varieties with the same Bph 1 gene

However varietal resistance of those varieties was readily defeated by the rapidly evolving BPH population labelled biotype 2 Subsequently rice varieties were drastically changed to new IR varieties such as IR36 IR42 and allied varieties which have' bph 2 gene" for the BPH resistance in the BPH epidemic areas IR36 was seemingly effective in stabilizing the BPH outbreaks In parallel chemical control measures were intensified by introducing

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new pesticides MIPC and BPMC were distributed in 1979 and fenitrothion carbofuran, and cartap became available in 1980

The BPH infestations were also gradually becoming serious in the Red River Delta around 1981-1982 after diazinon was introduced in 1977 Outbreaks of the BPH occurred in 1987 and 1989/90 (Fig 3 15)

In the Mekong Delta where IR42 and IR64 were predominantly grown and insecticide use very high the BPH populations evolved to feed on those varieties (labelled biotype 3) and caused intensive hopperburn on the summer crop in 1988-1989

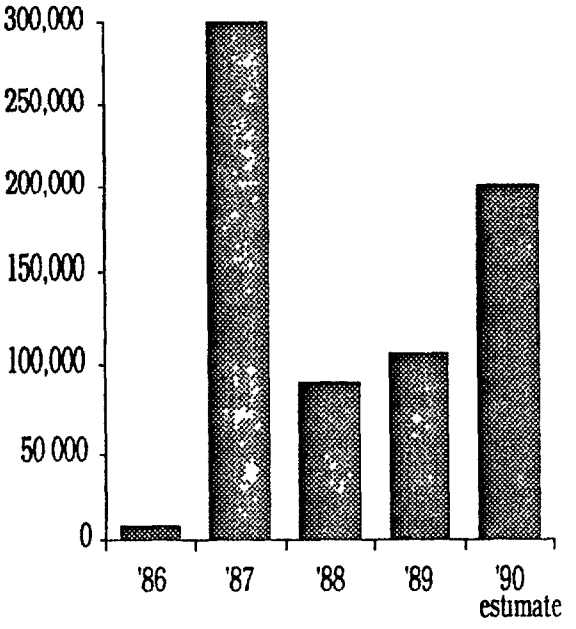

Fig 3 15 Rice area infested by Brown Planthopper in Vietnam (1986-90)

At present diazinon methyl parathion cypermethrin and various other organo-phosphates and pyrethroid chemicals are widely used for treating fields with BPH as well as other insect pests (leaf folders and stem borers) in the paddy fields planted with resistant varieties like IR66

FAO in the 1970s and in a project entitled Strengthening Plant Protection Services' which commenced in 1980 drew attention to the value of strategic use of pesticides for plant protection It was considered by the Mission desirable for the Intercountry Program to review the earlier advice from FAO to determine if recent information from IRRI on the economic status of rice herbivores that enter the paddies in the first 6 weeks would now suggest that such early pesticide applications may <u>not</u> be necessary Indeed it is now suggested that such early applications could contribute to the paucity of natural enemies as observed by the Review Mission and the dangerously high abundance of BPH in many of the rice paddies

It is believed by Dr Sogawa and Dr Kenmore that the unusual upsurge of the BPH population in principal rice growing areas of Vietnam is a result of resurgence of the population caused by excessive use of pesticides in the paddy ecosystem The following

problems were elucidated as the probable causes of the BPH resurgence

1 Calendar-based repeated applications of broad spectrum and non-selective insecticides such as BHC methyl parathion diazinon and other organo phosphates which are well known to induce BPH resurgence in other countries because of their non-selective toxicities to natural enemies in the paddy ecosystem These chemicals still are popular with the farmers because of their cheaper prices and ready availability

2 Early season applications with the above pesticides to control minor damage caused by leaffolder caseworm whorl maggot etc These pests rarely cause yield losses but their conspicuous defoliating appearance (symptoms) easily motivate farmers to spray pesticides triggered by very low economic threshold levels

3 Recommendation of mixed applications of organo-phosphates and carbamates with pyrethroids for BPH control These mixtures may give quicker knockdown effects to the pest insects but at the same time they are more destructive to natural enemies

3 2 4 5 Sri Lanka

In the Maha (wet) season 1989/90 problems with Brown Planthopper were reported from Polonnaruwa District in North Central Sri Lanka Area infested was 6320 ha with hopperburn in 116 ha It was implied that the IPM program was responsible for this "outbreak" ("Now that there is IPC we suddenly have a BPH problem, which we did not have before IPC was introduced to the farmers " in the words of a high ranking DOA officer) and therefore the Evaluation Unit studied the Polonnaruwa BPH situation in more detail

Surveys by the Evaluation Unit and analysis of pre- and post-evaluation results of earlier IPM training for Polonnaruwa (Maha 86/87) indicate that farmers after IPM training reduced the number of insecticide applications by 20-50 % (av 35 %) How did IPM trained farmers fare during this BPH "outbreak"? The results from the field survey on the BPH problem show that while all farmers interviewed observed BPH (damage) in their field in Maha 89/90 IPM trained farmers had significantly higher yields significantly lower damage from BPH and significantly lower insecticide use than untrained farmers (Table 3 1)

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Table 3 1 Area cultivated BPH affected area insecticide use and yield for IPM trained and untrained farmers in the BPH "outbreak' season in Polonnaruwa (Maha (wet) season 1989/90)

VARIABLE	TRAINED FARMERS	UNTRAINED FARMERS
Area cultivated (ha)	1 81	1 79
% Cultivated area affected by BPH *	18 8	48 6
Number of Insecticide Applications per season *	0 6	1 6
Cost of Insecticides in the season (Rs/ha) *	229 24	736 37
Amount of Insecticide used in the season (ml formulated product/ha) *	356	1526
Yield (kg /ha) *	4654	3455

* *means are significantly different at the 1% level.*

The untrained farmers' mean yield was 3455 kg/ha on the average 48 6 % of their area cultivated was affected by BPH and their average spending on insecticides during the season was 736 Rs/ha Both this last figure and the average number of insecticide applications (1 6) were much higher than those for untrained farmers in the earlier surveys

In contrast IPM trained farmers mean yield was 4654 kg/ha in large part due to an average BPH affected area of only 18 8 % which can be attributed to a significantly lower use of insecticides by trained farmers as could be expected from the earlier surveys In fact farmers using no insecticides at all during Maha 89/90 (48% of the trained farmers interviewed) had an even lower area affected by BPH 12 3 % (Fig 3 16) Most certainly the untrained farmers (with 48 6 % affected) aggravated

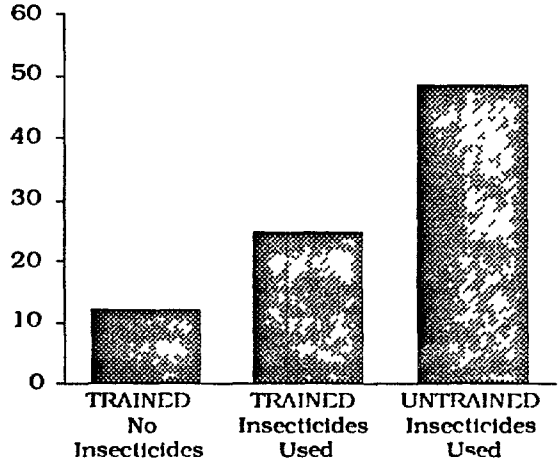

Fig 3 16 Area affected by Brown Planthopper (% cultivated area) for IPM trained and untrained farmers Polonnaruwa Maha 1989/90

Table 3 5 Number of farmers and trainers that received IPM training Philippines

REGION	FARMERS							
	1984	1985	1986	1987	1988	1989	1990	TOTAL
1	103	621	2 030	-	306	663	468	4,191
2	29	23	1 548	528	2,819	5,499	882	11,328
3	464	2 429	5,628	964	2,145	2,068	202	13,900
4	115	-	1 624	5,998	1,748	442	233	10,160
5	265	1 637	3,325	4,676	3 959	2 333	1,033	17,228
6	42	922	6 323	-	4,640	3,325	1,151	16,403
7	-	480	1 012	284	257	262	196	2,491
8	330	427	515	430	1 012	1,786	576	5,076
9	-	83	2 993	2 729	865	1 007	246	7 923
10	-	811	7 622	392	3 805	3 013	1 043	16 686
11	84	2 337	1 028	2 000	1 046	2,216	1,275	9,986
12	346	3 879	6 618	32 788	10 769	4 205	545	59 150
CAR	-	-	-	-	-	-	527	527
TOTAL	1 778	13 649	40 266	50 789	33 371	26 819	8 377	175 049

REGION	APT (Extension Workers)					SMS			Trainers
	1987	1988	1989	1990	TOTAL	1987	1988	TOTAL	1984 86
1	1 032	89	-	-	1 121	5	48	53	8
2	482	378	33	-	893	7	47	54	11
3	1 606	390			1 996	11	50	61	28
4	824	100	64	-	988	5	100	105	12
5	789	129	28	10	956	8	60	68	7
6	791	167	131	-	1 089	5	60	65	8
7	259	59	64	-	382	5	41	46	2
8	529	250	29	21	829	7	59	66	3
9	437	47	122		606	7	47	54	3
10	322	237	245	38	842	3	73	76	2
11	342	47	15	32	436	1	47	48	6
12	516	250	84	-	850	12	29	41	8
CAR	-	-	-	114	114	-	-	-	-
TOTAL	7 929	2 143	815	215	11 102	76	661	737	98

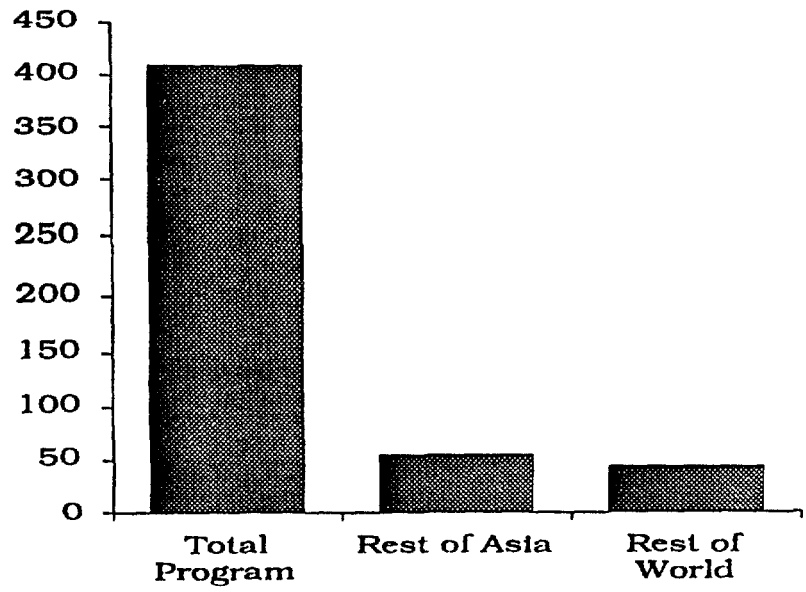

Fig 3 18 Total paddy production (million MT) in program countries and the rest of Asia and the World

Table 3 4 Number of IPM trained farmers and trainers in Program countries

	Farmers Trained	Farmers Exposed	Core Trainers Trained	Trainers Exposed	Extension Staff Trained	Extension Staff Exposed
Bangladesh	1,500	5,000	25	200	700	250
China	5,000				140	
India	50 000	50 000	50			5,000
Indonesia	60,000	80,000	600		1,200	15,000
Malaysia	2,500	38 000	25			500
Philippines	175 049		737		11 102	5 000
Sri Lanka	87,108		233		2,600	
Thailand		45,000				
Vietnam	860					
Totals	382 017	218,000	1 670	400	13,142	27,750
Category Totals	600 017		2 070		40 892	

A further breakdown of the figures are given for the Philippines, the country where the program has had greatest penetration (Table 3 5)

3 6 SOME VITAL STATISTICS

Rice production in the 9 participating countries represents about 80% of total world production Table 3 3 provides summary statistics about rice production in each of the 9 countries, to assist the reader in placing much of the Mission's report into context

Table 3 3 Summary statistics on rice production *(9)*

Countries	Rough Rice Prod (1989) ('000 ton)	Harvested Area (1989) ('000 ha)	Yields 1989 (ton/ha)	Rice Households (millions) *	1989 Total Population (millions)
China	179,403	32,400	5 44	129	1,117 2
India	107,500	41,500	2 59	30	836 3
Indonesia	43,566	10,304	4 23	15	177 8
Bangladesh	26 60C	10,630	2 50	10	112 6
Thailand	21,300	10,256	2 08	2 5	54 9
Vietnam	18,100	5,860	3 09	10	65 6
Philippines	9 459	3 497	2 71	1 6	61 0
Sri Lanka	1,949	730	2 67	0 9	17 0
Malaysia	1,697	636	2 67	0 4	16 9

*estimated

In Fig 3 18 the total paddy production (million MT) in the 9 program countries is compared with total paddy production in the rest of Asia, and the rest of the world (excluding Asia)

A primary objective of the Intercountry Program is to train rice growers in IPM philosophy as stated in more detail in Section 3 7 We summarize here statistics given by the Program on numbers of people trained so far under the following categories trainers trained farmers farmers influenced by lateral transfer of knowledge from trained farmers (Table 3 4)

Table 3 2 Funding ($ x 1000) of FAO Field Projects (N = 2191)

Mean	Standard Deviation	Median	Mode	Regional	UTF
817 9	1994 6	305	250	11,100	3,720

3 5 2 Specific aspects of the organizational strengthening process necessary for promoting the IPM movement in Asia.

The organizational management tools that have gotten the Intercountry Program to the present point where this Mission can even talk about the possibility of millions of farmers learning and practising IPM must be strengthened not shed and obstacles removed to better service of the strong and exploding demand for IPM

1 The decentralization of operational and financial authority plus administrative processes to the Intercountry Program and subsequently to national program operations

2 The design of functional support service positions at the Intercountry Program level based on a strategic assessment of required future levels of response capabilities and task loads and mirroring program functions at the country program level

3 The translation of the above assessment into a staff/personnel development plan covering Phase III of the Intercountry Project This plan will be closely linked with human resource development programs at the national program level

4 The creation of an anticipative management support capability within the Intercountry Office that will be capable of providing on site backstopping for evolving country programs National program staff must be recruited and trained in the processes of planning programming budgeting and administration so that management structures will be in place and ready to provide the operational sinews for anticipated technical program growth

This leads to the construction of national IPM policy, creation and growth of national steering bodies, and formulation of project plans for donor support At this point the role of the Intercountry Program shifts from catalytic to supportive/responsive National programs will demand a number of things, often after comparing their management systems with those of other national IPM programs The Intercountry Program also has an institutional memory function, serving as a reference to the original context of national policy so that those later joining are able to assess their progress

Once national programs exist, there will be agroecosystem units (rice bowls) where local ecology, economics government language, and culture are shared These are the logical units of field management, and logical units to compare across Asia The Intercountry Program has a critical comparative role facilitating national programs' efforts to compare ecology, economics, training lateral spread, and operational management arrangements between their specific rice bowls and those of other countries The Intercountry Program will play a key role in developing the language used by national programs in interpreting and understanding these rice bowls

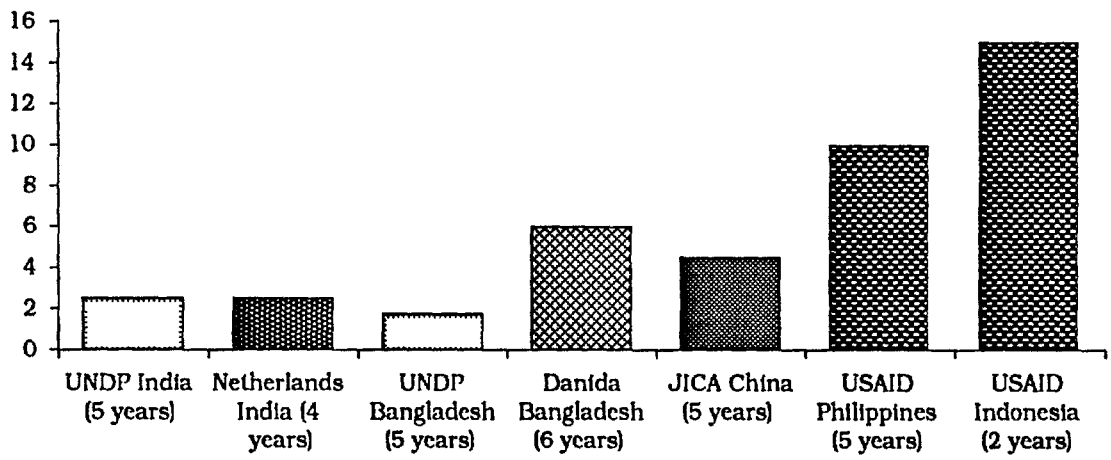

Fig 3 17 The 'pipeline" of National IPM Programs (US$ million)

Pump-priming through pilot field activities inventory and supply/identification of basic IPM parts catalysis of national policies and programs marshalling donor support documenting the lessons learned creating a language of interpretation all these will continue across Asia as IPM spreads By simply responding sensibly to the spread of IPM across Asia, the IPM Program has become the largest human resource development project in FAO (see Annex 7, Table 3 2) and the sixth largest field project of any type (out of 2191)

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Much of the Program's experience with these experiments on scaling up was contained in the voluminous background material presented to the Mission At the Mission Team's request, this was summarized by Program staff and is found in Annex F "The Mission acknowledges that these alternatives routes to large scale IPM implementation need not be mutually exclusive and that, in certain circumtances, it may be profitable to combine elements of the various approaches "

3 5 EXTENSION OF INTERCOUNTRY PROGRAM AND STRENGTHENING OF NATIONAL PROGRAMS

3 5 1 IPM as a Movement

In the area of IPM program development, a number of interested constituencies are needed These constituencies are eager to achieve the same benefits for their countries as their counterparts did in countries that created National IPM Programs earlier

Basic constituencies in each country

- Farmers who master the IPM process and explain it to others
- Village workers (extension, NGO, etc) who master the IPM process and explain it to farmers, their colleagues, and their superiors
- Crop protection and economic experts (university, research institutes, Ministries, etc) who carry out and confirm basic field studies
- Non-Formal Education experts who develop empowering discovery learning exercises
- Policy makers in or out of agriculture, who act on information delivered in the context of national development strategies and maintain working structures for IPM field work
- Supportive donor community
- Environmentally conscious citizens who create an atmosphere of concern

The pump-priming job of the Intercountry Program in each country is to identify, support, and connect the basic parts of national IPM movements For some, the example of neighboring countries is helpful in setting up their own national IPM The Intercountry Program can help this with study tours As IPM field activities develop, the Intercountry Program can help present results to other parts of the embryonic IPM network in each country, often bridging bureaucratic or hierarchical gaps months or years faster than ordinary channels

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Intercountry Program to present IPM as part of national development strategy before the major donors of the development community This catalyzed donor support for larger-scale IPM national programs and raised interest among national policy makers in essentially all the member countries

Policy makers boosted support for IPM They increased funding and staffing from existing resources They diverted funds from external grant and loan programs They proposed new IPM projects and programs to larger donors such as UNDP They established interagency task forces for for direct action They reduced or abolished subsidies for pesticides and they banned or restricted specific chemicals for environmental and health reasons

Policy makers actions challenged IPM implementors to scale up their efforts Evidence from thousands of farmers got policy makers to push national programs to reach tens and hundreds of thousands But in the background of every decision was the image of the true numbers of rice farmers tens and hundreds of millions National policy decisions established political will and indicated acceptable directions for growth and change Benefits from national policy decisions have been quick and relatively large Unless millions of farmers however master field skills and solve field problems for themselves the impact of policy will be blunted by commercial pressure and fear

The Intercountry Program as well as

- catalyzing the range of policy decisions listed above
- providing in-country examples of IPM field implementation
- assisting national programs to share and learn from each other
- accelerating the flow of useful research information and
- helping develop a common working language for planning monitoring and evaluating IPM

designed and supported three experiments exploring alternative routes to large scale IPM implementation These experiments took place in Sri Lanka Indonesia Malaysia Thailand and Philippines The three alternatives are IPM as part of the Training and Visit Extension System - promoted for more than a decade by the World Bank IPM through Strategic Extension Campaigns - an application of social marketing deployed by FAO in agricultural extension and IPM through Non-Formal Education - an empowering approach rooted in NGO and community organizing traditions

practiced IPM showed it to their neighbors and saved significant amounts of money (see Section 4 4 below) Surveys group discussions and participant observation confirmed that IPM trained farmers managed their rice crops differently from untrained farmers and with greater confidence than they had before training In order to help trainers assess their efforts, field skills tests like the "ballot box" multiple choice exercise were designed tested in real farmers training and adapted and adopted by nearly all the national IPM programs

Farmers were more excited to learn to recognize predators in their own rice fields than they were to save money Much of their pest control spending had been for insurance rather than investment so the discovery of whole armies of allied species in their fields more than satisfied their need for security With the confidence of better diagnostic skills and reinforcement of protection by natural control rather than repeated applications of poison farmers asked more and more questions about rice technology The initiative began to pass from extension workers (chasing farmers to meet assigned adoption targets) over to farmers (chasing knowledge about agroecosystems from extension and crop protection specialists) Field skills training spread back up the hierarchy as extension and crop protection systems moved to meet the demand for better equipped field staff to deliver training in farmers fields

The Intercountry Program catalyzed this transformation from applied research and surveillance to field skills training then helped counterpart agencies respond to new demands Country by country crop protection units redefined for their mother agencies and outside observers the indicators they preferred to judge their performance Farmers trained production costs saved and net profits increased became more acceptable indicators as did the quality of the predator communities in rice fields Administrators and policy makers began to take note When the budgets proposed for crop protection units included more funds for field training and less for aviation fuel policy makers understood that human resources rather than infrastructure was being developed They took the lesson and acted

3 4 3 Demand for IPM Takes Off — The Challenges of Scaling Up

Policy makers first saw IPM as a better way to do pest control and ensure rice supplies but then they saw IPM as part of something larger rationalized economic development IPM became a small but visible cornerstone for national development strategies answering the more widely and more deeply felt concern for environmentally sustainable development The 1988 meeting of the Intergovernmental Group on Indonesia allowed Indonesia and the

the network of counterparts saw IPM as the property of pest surveillance systems They all used a common technical vocabulary but there was no connection yet with development The Intercountry Program was a project-style mechanism for specialists from different countries to meet each other talk share experiences and compare perceptions The first activities of the Program workshops on Surveillance and Field Trials exercised these welcome opportunities

Good crop protection technology from research institutes languished so long as farmers had not developed field skills Until farmers could recognize predators and understand their ecological role fear compelled them to treat crops with pesticides needlessly Farmers wasted host plant resistance when they treated rice varieties with insecticides These treatments killed natural enemies of rice pests inducing resurgence and more rapid evolution of phenotypes able to feed on resistant varieties Governments relying on large scale multiplication of resistant varieties for pest control did not receive timely feedback on the field performance of those varieties When pest evolution "overcame" that resistance governments were caught in dangerous delays in replacing the varieties Fear pushed governments to overuse pesticides by entering into national contracts with chemical companies price subsidies and large-scale (often aerial) applications

The Intercountry Program began field work farmers discovered and practiced IPM field skills and new possibilities emerged Crop protection units could foresee moving away from a "Fire-Brigade" role Extension workers and farmers with IPM field skills meant potentially threatening pest situations could be properly diagnosed and quickly managed locally There could be faster more accurate feedback from the field on performance of varietal resistance pesticides and other crop protection materials Better information could filter up the surveillance system and the coverage of the system on the ground was much denser

Field demonstrations showed IPM to farmers and extension workers but field skills came only with practice Field skills training where farmers and extension workers walked talked touched and thought together in rice fields with crop protection specialists became the crux of the Intercountry Program It was not easy It took a whole season of distributed practice - more than 30 hours of field time - for people to master the skills

3 4 2 2 Farmers take IPM for themselves

National programs that invested in field skills training were surprised by farmers *(26)* Farmers exceeded the field skills of extension workers after one solid season Farmers

1	Grow a healthy crop (one that is agronomically tolerant) including selection of the best variety with locally appropriate resistance
2	Conserve natural enemies
3	Use selective pesticides only when frequent field monitoring confirms an unfavorable ratio of natural enemies to herbivores
4	Farmers become IPM experts

3 4 EVOLUTION OF THE INTERCOUNTRY IPM PROGRAM

3 4 1 PreOperational and Phase One

The Intercountry Program was "jump-started" by Australia Funds from the Australian Freedom from Hunger campaign and ADAB supported the 1978 Expert Consultation in Bangkok where the original seven member countries (Bangladesh, India Indonesia Malaysia Philippines Sri Lanka, and Thailand) met to agree that an Intercountry Rice IPC Program was desirable Shortly after that meeting the first intercountry training course on IPM for rice was held in the Philippines with support from USAID and participation of IRRI FAO and the Philippines Bureau of Plant Industry Australian funders also supported critical preparation and formulation missions (by D Bottrell and T Hogan) that prepared draft project documents Then Australia established the first Trust Fund for the Program agreeing to a five-year workplan with annual contributions from ADAB This allowed the Program to hire its first officer (J Lowe) and hold four intercountry meetings

After two years the Program received funding from the Netherlands in the form of a 5-year trust fund Second and third officers were hired and the Program began field activities in Philippines Malaysia and Sri Lanka

3 4 2 Transformations during first years of field work

3 4 2 1 From applied research and surveillance through field demonstrations to training

The Intercountry Program s founders did not foresee IPM becoming the property of farmers The project document writers saw IPM as the property of applied entomological researchers

heap of different foods on a single plate Both China's and IRRI s IPM lacked unifying principles so there was no way to judge the relative importance of the "Components" Most national research programs through the 1980s were stuck in this phase of *pin-pang* uncritical imitation of sub-disciplinary concerns wasted resources and time

One interest group that has benefited greatly from this self inflicted loss of direction has been the chemical industry So long as IPM researchers can be set chasing impossible and low priority goals IPM appears to outsiders to be too complicated or too risky

Pin pang cripples IPM research but the "Technical Package" produced by *pin pang* further fails to come to grips with the scale of local variability found in tropical rice agroecosystems Insect densities can vary by factors of 1000 across less than 10 meters distance in the tropics Insect densities can vary by a factor of 100 across durations of less than one week Insects in the tropics have 15 or more generations per year Every rice paddy can be managed optimally and differently from its neighbors Secondary pest resurgence can be started by mismanagement in one rice paddy and spread out to neighbors in days The rates of change in time space and genetic composition are orders of magnitude faster than in temperate zones where component-based packages originated

What is the answer to this variability? Natural population regulation Biological control of insect pest populations in tropical agroecosystems takes the place of climatological control in the temperate zone Natural enemy populations respond numerically functionally and evolutionarily to changes in prey populations As IPM moves from temperate to the tropical zones for any cropping system biological control is the only factor that keeps up with biological variability in pests IPM for tropical rice as found earlier with IPM for tropical plantation crops must build on biological control as its foundation It must be very careful not to disrupt that biological control with insecticides cultural practices or other management errors There are no winters to rely upon

With biological control as the ecological foundation it became possible for both the Chinese and the Intercountry IPM Programs to establish principles for IPM They converged on very similar principles (box) These principles were applicable in the entire range of rice farming systems They are <u>not</u> a "Package" They do reflect consensus on a paradigm for rice IPM The paradigm presumes that the rice crop can compensate for most feeding damage by herbivores especially early in the crop It also presumes that communities of natural enemies are competent to control herbivores in the majority of crops

This system was advised by J Lowe who worked for IRRI and saved tens of millions of dollars by the simple rule that any report of tungro infection in rice had to be confirmed on the ground by a trained plant protection specialist before aerial application was authorized This was probably the largest program of judicious use of insecticides in the world up to that time Many other Asian countries later set up pest surveillance systems often to help crop protection units defend themselves from legislative criticism

In 1974 the FAO Panel fielded a consultant, M Way, to look exclusively at prospects for rice IPM He met not only researchers but many representatives of the staffs of national pest surveillance systems His report ***(45)*** was the first concrete map of the implementation territory of rice IPM His mission started Asian plant protection services and research institutions talking about IPM as a logical response to problems such as rice tungro virus and brown planthopper The Panel s discussion of this report then allowed Waterhouse to begin searching for funds from Australian sources to support the preparation of the Intercountry Program

3 3 3 Emergence of the IPM Paradigm

China and IRRI were the two centers of research on IPM for rice in the 1970s Both grew from work in distinct sub-disciplines like pesticides cultural controls varietal resistance or biological control so they defined their IPM work in terms of "IPM Components" In both systems "Components" were conglomerated into "Technical Packages" These still had identifiable sub-disciplines e g

'Resistant Variety IR26

+ Economic Threshold Levels 10% deadhearts
+ system insecticide carbofuran
+ synchronized planting
+ stratified random X-shaped sampling method + "

and it was not clear which elements of the "Technical Package" were more and less important Were three components enough to call the "Package" IPM? Were two components enough? This kind of thinking led researchers economists and extensionists to conclude that "IPM must be too complicated for farmers to ever use especially poor uneducated Asian rice farmers" ***(12)***

This conclusion was wrong but so was the approach of slapping together IPM "Components" into a "Technical Package" In recent reviews of their own IPM development Chinese IPM leaders ***(49)*** have characterized this period of thinking as *pin pang*—meaning an unattractive

yet achieve yields no higher than China where insecticide costs are below one tenth of Japan's The total costs of crop protection - surveillance information distribution and pesticide treatments - in Japan exceed US $2 billion per year

IPM in the Asian tropics was consciously built on biological control Work by G Conway M Rao and B Wood *(4,41,47,48)* and their colleagues in cacao rubber oil palm and other Asian perennial crops began in the 1950s In each case overuse of broad spectrum insecticides released secondary pests and created catastrophic outbreaks Biological control was in all these cases considered the primary population regulating force This presumption was amply supported by examples from the tropics of classical biological control in coconut and sugarcane from the 1920s

At the same time the overuse of insecticides by cotton growers in the Canete Valley in Peru eliminated cotton as an economically viable industry Only when control measures were designed to conserve indigenous natural enemies of insect pests and insecticide applications minimized could cotton be grown The cotton experience was repeated in Northern Mexico Nicaragua Sudan and India and cotton IPM became the best known example of IPM in developing countries *(44)*

3 3 2 The FAO Panel of IPM Experts and IRRI

The FAO Panel of Experts on IPC/IPM convened in 1966 Much of their early discussions focussed on basic ecological understanding in relation to pest population regulation and the applied example of cotton Rice was championed from the early meetings of the Panel by D F Waterhouse of Australia who felt the human investment in rice far exceeded cotton and represented a bigger challenge for IPM in developing countries Only in 1971 was a consultant R F Smith fielded by the Panel to visit Asia While Smith's mandate was to cover the prospects of IPM in a range of crops including coconuts and tea, he was especially concerned about the consequences of the Green Revolution in rice His mission report and subsequent Presidential Address to the Entomological Society of America were the first published recognition of the necessary role of IPM in tropical rice *(44)*

Entomologists at IRRI began to talk and write about IPM after Smith s visit Their work remained channeled in sub-disciplines like host plant resistance and chemical control but lacked the unifying ecological basis that IPM requires IRRI was involved in a practical example of pesticide management in India in the early 1970s A rice tungro virus surveillance system was set up to improve the efficiency of aerial insecticide applications

the BPH situation in their fields by their high insecticide use, creating resurgence of BPH
the BPH situation in their fields by their high insecticide use creating resurgence of BPH
The increase use of insecticides might be due to fear of BPH or other pests during the season

These results clearly show that IPM is a solid reliable method of pest management giving farmers the tools to limit the incidence of BPH in their fields Moreover, the benefits of practising IPM are obvious trained farmers not only spent an average 507 13 Rs/ha less on insecticides than untrained farmers but also earned an estimated 4800 Rs/ha more on their crop through an increase in yield (1200 kg/ha yield increase times an estimated farm gate price of 4 Rs/kg)

3 2 4 6 Other Countries

India and Philippines both had small intensive BPH infestations in 1990 for the first time in over 5 years Both were in areas using organo-phosphates and pyrethroids BPH is considered the major insect threat in many parts of China especially as the chlorinated hydrocarbon insecticides were replaced by organo-phosphates through the 1980s Interviews with farmers reveal the classic pattern of treating early season defoliation symptoms followed by BPH in spreading waves of hopperburn with treatment

The experiences of Asian countries in 1990 show that BPH in rice is still a crisis with political implications The experience of Indonesia shows that it does not have to be

3 3 RECOGNITION OF THE PLACE OF IPM IN RICE PEST MANAGEMENT

3 3 1 IPM Prior to the FAO Panel of Experts

IPM for rice was pioneered by K Kiritani and colleagues in Kochi Prefecture Japan in the 1960s ***(29,30)*** They worked extensively with rice growers who were convinced after strong initial skepticism that IPM benefited them more than regular insecticide applications for stemborer control Y Ito and colleagues had demonstrated secondary pest resurgence of planthoppers and leafhoppers in the early 1960s ***(24)*** Insecticide resistance and dangerous residues were recognized so that by late 1969 chlorinated hydrocarbon insecticides were banned in Japan Much of Japanese rice pest management relies now on an elaborate monitoring and forecasting system funded by the government The extremely high domestic price of rice (6 10 times world) in Japan kept the domestic market for insecticides inflated Japanese farmers apply hundreds of dollars per hectare of insecticides to their rice fields

Clearly, it is not possible to independently validate these statistics, nor was it the intention of the Mission to attempt to do so However, the Mission was particularly interested in interviewing representatives from each of the categories to get a feel for the nature and quality of training and extension, any variation in the knowledge package involved from country to country, and how effective was the lateral spread of IPM knowledge from trained farmers to untrained farmers It is not practicable for any extension program to directly train of the order of 200 million rice farmers throughout Asia To achieve its target in real time, we are really talking about an infectious 'IPM extension process' rather than a conventional program Consequently the efficacy of lateral spread of the IPM philosophy and the integrity of the message during this spread, were of special interest to the Mission

3 7 THE IPM MODEL

The ultimate goal of Integrated Pest Management is a dramatic shift in the model or paradigm, that guides people s decisions about pest management Changes in people's beliefs about pest management are sought along three dimensions the operational objective, the main means used to manage pests, and the primary decision-maker in the process The table below summarizes the shift that is sought

Dimension	Existing Belief	New Belief
What to do	Kill the pests	Manage the ecosystem
How to do it	Use chemicals	Use natural enemies first, and avoid chemicals, except as a last resort

An extensive body of research evidence on rice farming in Asia provides evidence that this shift in beliefs about pest management will produce yields at least as high as with pesticides sustain the environment and improve the health of farmers Central to the Intercountry Program s efforts has been the goal of bringing about this paradigm shift among agriculture policy makers agriculturalists and farmers throughout the region Below, this report will summarize the quantitative and policy achievements that these changes in attitude have produced The Program s accomplishments to date must be considered as the first steps towards converting 200 million rice farmers to a new way of thinking about the management

of pests in agriculture The experiences of the Program across the nine countries visited by the Review Team and each country s current situation with respect to pest management have suggested to us an outline of the change process required to convert a nation to integrated pest management We present this outline here as a framework within which to think about the future of the Intercountry Program There are three constituencies involved in the change process traditional agriculturists, farmers, and those who believe in integrated pest management The diagram included below outlines the activities of the Intercountry Program over time Set against these activities are the stages that the traditional agriculturalists and farmers go through as they shift to a commitment to IPM Also included is a chart (see next page), prepared by Program staff, of IPM milestones and the progress in each country

The summary observations on each country in Section 5 of the report will indicate roughly where each country is in this process of change All have started to change Some like Indonesia, the Philippines China and India are well along towards conversion Others, like Vietnam and Thailand, have not progressed as far The country reports also summarize the contributions made by the Intercountry Program in each national setting We hope that the reader will be as convinced as the Review Mission is of the significance of these contributions towards changing the way agriculturalists and farmers in Asia think about pest management

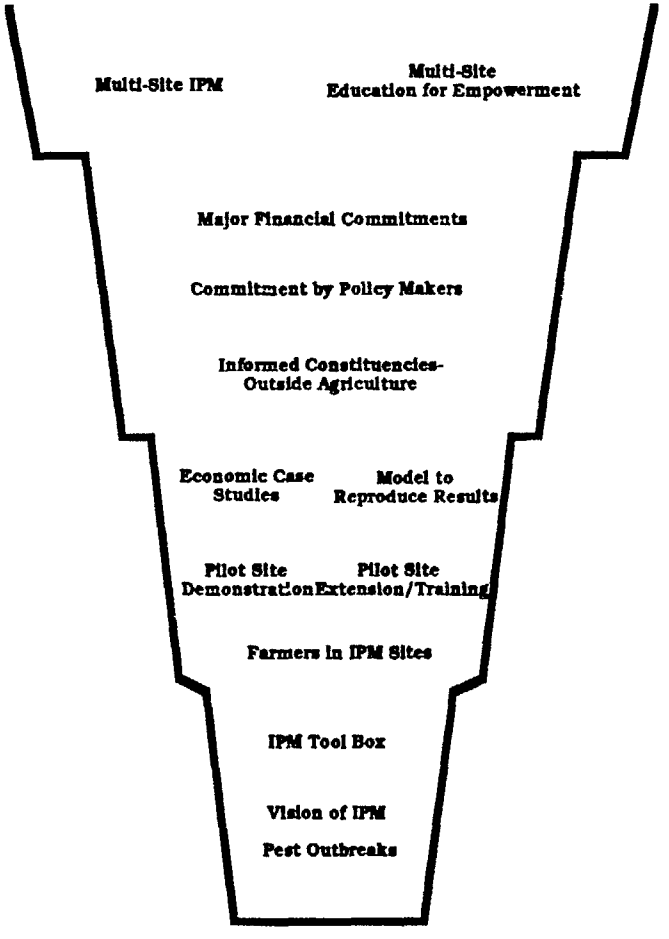
Much has been done but much remains to be done Some countries have yet to make the policy and resource commitments needed to produce large-scale adoption of IPM Pakistan Korea and other countries have shown interest recently in joining the network And the technologies and methodologies for implementing integrated pest management even in the most committed countries still need to be improved

AN OUTLINE OF THE IPM CHANGE PROCESS

MAIN ACTIVITIES OF INTERCOUNTRY IPM PROGRAMME	NATIONAL RESPONSE	RESULTS WITH FARMERS
Policy lobbying	Agreement to exploration of IPM	None
Sponsor/Conduct research and field trials	Interest in results	None
Support for the national dissemination strategy Providing continuing information on pesticides	Reduced pesticide subsidies and/or sale. Farmers viewed as marginally capable decision-makers	Larger pilot areas established. Farmer demand for services begins to be noticed
Provide continuing information on IPM Monitoring national program and sharing with other countries	Government stops subsidizing and/or selling pesticides. Agriculture officers come to view farmers as decision-makers	"Going to scale" Large numbers of farmers adopt IPM
Provide information and advice as requested	Full dissemination of IPM through formal and informal means	More and more farmers become self-sustaining learners as farm managers

Table 3 6 IPM Milestones

IPM MILESTONES



SUMMARY OF IPM MILESTONE BY COUNTRY

Bangladesh	China	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
			1990					
		[1990]	1988 1987		1987			
1990	(1975)	1989 (1980)	1986		1986			
1990		1988	1986		1985		1990	[1991]
1989	1989	1987	1986		1983	1985	1985/	1990/
1988	1982	1985 1980	1986	1985	1979	1985	1982	1984
1988	1980	1984	1986	1984	1979	1985	1980	1983 (?)
1980	1980	1975	1980	1974	1979	1980	1979	1982
1980	1979	1970	1978	1972	1978	1980	1979	1980
	1960s	1957	1977	1967	1976	1974	1974	1967

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4 *ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS*

4 1 THE NATURF OF THE BENEFITS FROM UPTAKE OF IPM PRACTICES

The Review Team considers that benefits flowing from farmer adoption of IPM can fall under the following broad headings

- o improved profitability in the short-term arising from reduced inputs and higher yields
- o improved product quality, via reduced pesticide residues (this outcome can have both economic and health consequences)
- o improved occupational health of farmers
- o improved sustainable agriculture, and therefore long term economic and human benefit
- o reduced environmental contamination, with economic, health and cultural implications

These benefits will only accrue to the extent that farmers alter their existing practices The benefits will therefore be dependent on the number of farmers that take up the IPM philosophy, on how quickly the changes in pest control practices occur, and on how extensive and durable are the changes in farming practices

Farmers' adoption of IPM can occur via two mutually reinforcing routes

- o direct farmer training through extension and the lateral spread of the knowledge and practice from trained to untrained farmers
- o central policy changes by governments the implementation of which will influence farmers practices directly and indirectly but which also result in a more effective expenditure of public funds For example, a policy change by Government might relate to a subsidy affecting product price, a ban on the use of certain categories of pesticides or restricted advertising of pesticide

products The policy could be more prescriptive, such as Presidential (Indonesia, Philippines) or Ministerial (India) decrees declaring IPM as national strategy

The individual country reports in Section 5 summarize information collected on the benefits to date in each country This section concentrates on analyzing the benefits that have stemmed from policy changes by National Governments reflected through decrees or macro-economic reforms concerning pesticide usage These benefits have been considerable and are easier to quantify than the aggregate benefits from the extension program itself We also describe the linkage between the Intercountry Program and the central policy changes so that it becomes possible to identify the impact the program has had in bringing about the relevant policy changes

An analysis, with any degree of precision, was only possible with Indonesia where national policy changes have been the most profound and the best documented We therefore treat Indonesia as a separate case to illustrate that the program has more than handsomely paid for itself if we consider the benefits accruing to that country alone We then list some of the significant policy changes by other recipient Governments and suggest that a group with more time and specialized expertise than the FAO Mission be encouraged to conduct a more comprehensive analysis of benefits flowing from policy shifts In our comments on the future of the Intercountry Program and its relationship with emerging national programs we draw on the conclusion reached in this section about the need for good understanding of the principles of IPM and strong support for its application via firm policies by National Governments

Information and conclusions contained in this section and Section 5, we hope, will show FAO, donor Governments, the recipient countries and other potential donors that investment in the Intercountry Program has been, and will continue to be of substantial benefit to farmers and consumers, and to the community generally, in Asia

4 2 THE INTERCOUNTRY PROGRAM'S CONTRIBUTION TO POLICY CHANGE IN INDONESIA

4 2 1 The Program's capability

Those who meet Peter Kenmore and understand ecology and rice come away with the

impression that his intellect and grasp of these fields are formidable Those who have worked with him and his staff realize that they are in continuous communication with an "invisible college" of advisers, consultants, resource persons and scientific dependents and students that includes virtually everybody worldwide who does anything with IPM and rice In a wider circle surrounding this group of the invisible college there are many key people in extension, education, environment, community development, development policy and administration tangentially involved with program issues Add to these the impressive string of Asian policy makers ready to receive a phone call from Dr Kenmore or to open a meeting if asked on short notice All these people are communicating in this network because the issues are stimulating and the Program has a very strong sense of purpose

But this network is much more than an information system People in the Intercountry Program are connected with rice fields, with real people working these fields, and with committed people from farmers to policy-makers They form a network in which real knowledge about real events and their conditions of change in a economic and environmental field important across Asia flow in real time and with real impact Vital bits of information on insect ecology often travel from places that official knowledge networks such as publications and libraries will never reach to a field researcher in an Indonesian rice field within hours after they have been picked up This saves years of knowledge diffusion efforts and has changed the direction of research programs throughout the region to make them useful for pressing needs

Trying to make IPM work in Asian rice is politics Policy extends from the farmer group meeting where the extension agent wants a list of chemicals to be bought on credit from the local coop to the level of national economic policy with its continuous conflicts on resource allocation in a context where the powerful chemical industry's well-being is at stake

Politics works in real time where a week is a long time Any activity funded by an IPM rice program in Asia is politics whether the people engaged in it are aware of this or not The elusive but decisive art is to use small resources skillfully within this flow of political currents to create data knowledge support groups and demonstrable results that allow people who have learned understood and are convinced to speak up about these results When this process of generating support based on fact and conviction and the political process in a country become fused, powerful change becomes possible

The Review Team believes that the key to the Intercountry Program s impact in Indonesia

has been the fusing of the "invisible college" with the political process to create the conditions for IPM to become Government policy for rice growing

4 2 1 1 The Indonesian experience

The importance of rice in Indonesia and the importance of rice in Indonesian politics can hardly be overestimated It is also clear that in regard to rice IPM Indonesia was the weakest country in Asia in the early eighties To an outside observer, this was so up to the day Presidential Decree Number 3/86 was announced on November 5, 1986 To many observers, even at that time, it was hard to believe that the Indonesians could be serious about reducing pesticide use, and that they could possibly succeed in turning around a well-entrenched Program of subsidies and overuse, even with impressive political fanfare

From the inside the story was different Already long before the decree, Indonesian economic policy makers became concerned about possible future risks to food security from pest and disease outbreaks, even at a time when Indonesia received official honors from FAO for its achievement of rice self sufficiency The memory of the devastating Brown Planthopper (BPH) outbreaks in the late seventies was still fresh, and new outbreaks which could be expected because of even higher pesticide use and a strong increase in per-hectare yields would be economically and politically devastating

In the mid eighties, data on these concerns indicated that there was in fact a likelihood of a new wave of BPH outbreaks that would be much larger than in 1975, and that the massively increased pesticide load in the rice ecosystem resulting from pesticide subsidies in the intensification program was the main cause of this situation

The Intercountry Program had already communicated that there was a way to reduce this kind of risk, and that was through Integrated Pest Management Furthermore, information existed that it would be possible and feasible to train Indonesian rice farmers in IPM In short a rough but convincing picture emerged of an alternative and much safer future for rice in Indonesia that was in line with the new thinking about sustainability in development The IPM alternative was also in line with the conviction of the country's economic policy-makers that the economy had to be deregulated and that considering the new information about risks to rice production, subsidies on pesticides were seriously distorting economic development

However, there were serious political risks associated with advocating such a strategy of radical and unprecedented change There was simply no other rice ecosystem of the size and type of Java that had gone through the proposed abrupt changes Even though the case seemed convincing in the seminar room, there was nobody who could present data to show that it would work at the scale of 4 million hectares of rice--at least not at the speed and with the level of control necessary Any setback in implementing the new strategy would inevitably be used to advantage by a large and well entrenched pesticide lobby It was when the new wave of BPH outbreaks in central Java threatened national production and possibly political stability that policy-makers were able to take the initiative

It seems evident that a political climate such as this needed to be very well understood for the Intercountry Program to have any positive influence It contained great potential for positive change but the stakes were high and playing by the rules of a technical project would have been safe but unhelpful and unproductive

4 2 1 2 What did the Intercountry Program do and how did it influence the changes in Indonesia?

A visit of a few days to Indonesia is certainly not sufficient to answer that question and we understand that information on much of the internal workings must remain with Indonesian policy makers and experts But what we have learned and confirmed by checking with a number of resource persons is fascinating and impressive

The conditions under which the Intercountry Program in Indonesia had to operate up to late 1986 were appallingly difficult The counterpart directorate was a key force in supporting the overuse of pesticides To have the small and apparently naive group of IPM believers operate there was convenient cover for the real job to create larger and larger flows of subsidized chemicals That the Program survived under these circumstances and that it actually converted a number of people in that system was not small achievement and it created a bridgehead for IPM in that environment

In fact the really important contribution was to use that small and tentative foothold to bring the 'invisible college to bear upon the crisis that was unfolding It is confirmed by one of our members who was also a senior colleague of Dr Kenmore during the late seventies, that informal contacts and consultations between staff from economic policy institutions and Dr Kenmore began in 1985 The 'invisible college was used to feed

information into these channels, and the Program s Asian and international network served as the communications link and clearinghouse that significantly influenced the emerging concepts of rice IPM for Indonesia as laid down in the Presidential decree in 1986 INPRES 3/86 It should be stressed that these consultations provided considerable risk to the program as counterparts and the technically oriented FAO system would have interpreted this assistance as "talking to the other side "

4.2 1.3 Did the Intercountry Program create INPRES 3/86?

Emphatically not This was an internal Indonesian affair but the Program through the 'invisible college' made concepts and links to expertise available that would otherwise have been difficult to obtain under the constraints of time and the political environment It also made certain elements in the decree stronger, such as the emphasis on the need to train extension workers and farmers "in such a way that they will be capable and willing to practice correct pest control" This paragraph of the decree recognizes the pioneer work of the Intercountry Program in demonstrating that it was indeed possible and feasible to train farmers in IPM In the final run to the deadline the Program also helped to provide insurance to top level policy makers that what they were planning to do was in fact backed by an expert group with high international credentials

In a meeting with the Minister of Development Planning Dr J B Sumarlin before the decree was issued Dr Kenmore presented very recent results from the first multi-province training of extension workers and farmers in field IPM in Indonesia conducted during May to September of 1986 These trials showed a reduction in pesticide use from 4 5 applications to 1 9 applications with increasing yields The trials were entirely funded by the program Results like these were exactly to the point there was Indonesian evidence that the experts' contention that BPH outbreaks were triggered by insecticide overuse were true The advocates of the *status quo* had argued that if pesticide use were to drop yields would go down, and Indonesia would have to revert to importing rice again

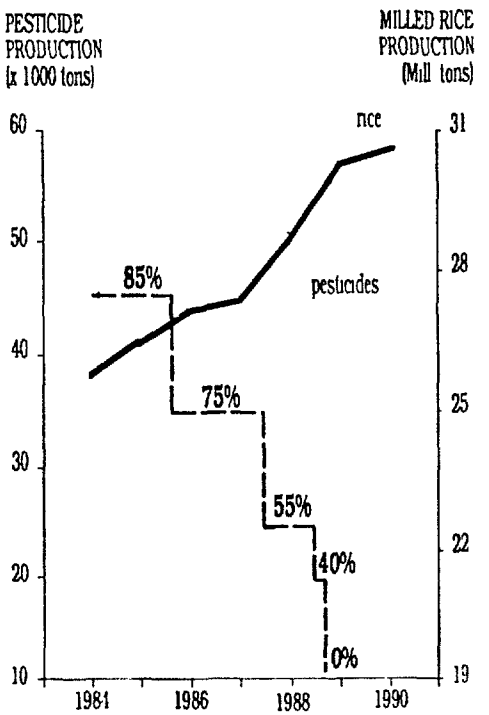
When INPRES 3/86 was declared the country was on the brink of a devastating BPH outbreak The pesticide subsidy was about 75% of unit producer cost and an unhealthy nexus of vested interests, bureaucratic manipulation and ignorance existed Subsequent changes were impressive

- Six months later the BPH outbreak was under control with losses much lower than even optimists were willing to predict

- Two years later the pesticide subsidy was abolished, taking an extremely lucrative US$100 ++ million per year business away from a well entrenched and powerful industrial lobby

- Two and a half years later the National IPM Program was launched

- Four years later rice production is up to the highest level in Indonesian history pesticide production is down 67% (Fig 4 1 4 2) and in 1990 the National IPM program has grown from a concept to probably the most successful IPM program in the world



——— Pesticide subsidy

Fig 4 1 Pesticide production rice production and pesticide subsidy - Indonesia 1984-90

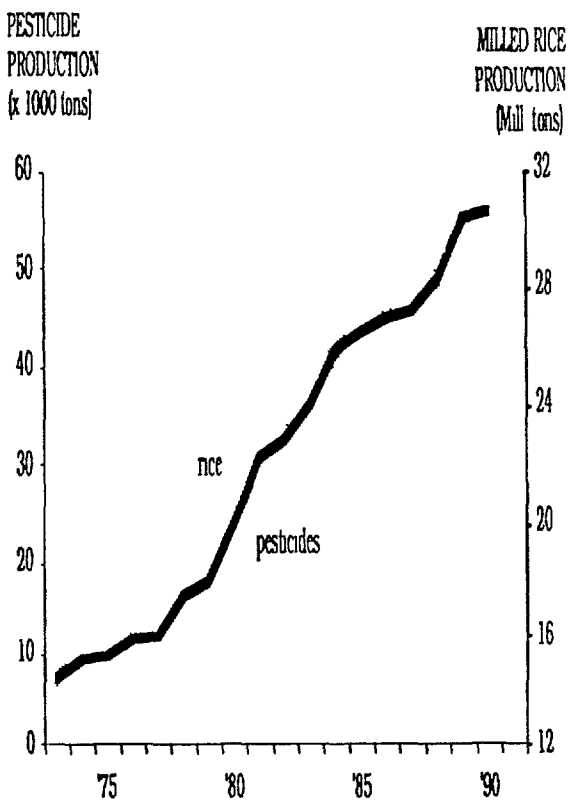


Fig 4 2 Pesticide quantity in national market (production and importation) and rice production Indonesia 1972-90

It is in this period since the decree that the role of the Intercountry Program has become much more visible and better documented The following list of events and of the policy results linked with them provides an outline of the Intercountry Program s involvement over the last five years

March 1986. The Program sponsors a number of BPH specialists, including an Indonesian academic scientist, to attend a meeting in Malaysia in conjunction with the Malaysian Plant Protection Society s Congress Plans are made to hold an international workshop on BPH modelling later the same year An Indonesian delegate offers to hold the workshop at Gajah Mada University in Yogjakarata where "there is a lot of BPH" The meeting agrees and the workshop is held in Yogjakarta in early December 1986 The Intercountry Program is fully aware that having the meeting in Indonesia is politically sensitive but important and therefore supports this venue and over 75% of the costs of the workshop

December 1986. The planned International Workshop on BPH Modelling is convened in Yogjakarta just 3 weeks after INPRES 3/86 The meeting with 35 international experts in this field becomes a highly visible stage to express world support for the new policy The then Junior Minister for Agriculture Wardoyo opens the meeting At the end of the meeting Minister Wardoyo accompanies four delegates from the workshop Dr K Sogawa from JICA Dr J Perfect from TDRI Dr M Shepard from IRRI and Dr P Kenmore from FAO to a meeting with President Soeharto in which the four delegates confirm the strong support and enthusiasm of the technical world of IPM for the new policy This meeting was widely publicized

April - June 87. The Intercountry Program funded and provided guidelines for training of 200 IPM 'master trainers It is from this pool of trained pest observers in the Ministry of Agriculture that the core trainers of the National IPM Training Program were later recruited

July 1987. Results from research station field trials at Gajah Mada University showed higher yields, 100% higher predator populations and 75% lower BPH populations on pesticide free fields Senior Indonesian scientists communicated these results to policy makers The Intercountry Program funded and supported this research

May 1988. Results from a new farmer training field trial with largely improved methodology and better prepared trainers (see above) come in and are immediately processed for quick

dissemination The 2250 farmers receiving training made a drastic reduction to less than 0 5 insecticide applications per season from the pre-INPRES 3/86 level of more than 4 applications per season Yields are higher than in 1986 This provided strong proof that farmer training is possible and highly profitable The Intercountry Program funded these trials

June 1988 Dr Kenmore is invited to join the annual meeting of the Intergovernmental Group on Indonesia (IGGI) in The Hague to brief the members on Indonesia s efforts in rice IPM This presentation at the main venue for the international donor community for Indonesia draws enthusiastic responses from delegates Press conferences by Dr Kenmore in Rome Washington and The Hague in conjunction with the IGGI draw strong positive response from the international press An influential member of the US congress the Honorable D Obey uses material from a Washington meeting with congressional staffers to enter a motion commending Indonesia s policy commitment into the US Congressional Record Indonesia's Coordinating Minister for Economic Affairs Drs Radius Prawiro the Minister for Development Planning Dr Saleh Afiff and the Senior Economic Adviser to the Government Dr Widjojo Nitisastro witnessed Dr Kenmore s briefing at IGGI

August 1988. The Minister of Agriculture Wardoyo who as Junior Minister had led the four scientists to the meeting with the President attends a National IPM workshop in Bali where field results from farmer training trials are discussed The fact that the Minister would go to Bali for a relatively small meeting like this and the fact that the small crew of IPM supporters in the Crop Protection Directorate the outcasts of former times were now honored by a ministerial visit was another significant signal of change and of new possibilities

October 1988 - December 1988. About 4 months after the IGGI meeting the pesticide subsidy is reduced to 40% and three months later it is completely abolished It is without doubt that the results produced by the Intercountry Program from late 1986 on have influenced this turn of events Program funds were used in such a way as to produce what was needed in terms of hard data and materials that could be used to demonstrate the viability of IPM The Intercountry Program s sensitivity to political context its capacity to anticipate what would be needed next and to work to exhaustion to produce results and Dr Kenmore s superb skills as a communicator and a motivator all together helped to produce what is now the National Program in rice IPM in Indonesia

October 1988 to June 1989. The Program supports a consultancy for Dr Kevin Gallagher to prepare a curriculum and to generally lay the ground work for elements of the planned National Training Program Without this preparation the National IPM Program could never have met its deadline for the first season s training

June 1989 to November 1989. The program advances money to Dr Russ Dilts and Dr Kevin Gallagher out of Intercountry funds as bureaucratic delays make it impossible to pay their salaries from National Program Funds This flexible response ensured that during the sensitive first six months of the project progress was sufficient to convince people that the Program had started successfully

To ask the same question as before did the Program abolish the subsidy? Obviously not no outsider can do anything like that in Indonesia But the Program did provide important inputs for prudent policy makers to be assured that it would be technically safe to abolish the subsidy without negative impact on rice production and that the coupling or the phasing out of subsidies and the establishment of a national IPM program would be advantageous Then, when the Presidential decree had to be translated into action the Intercountry Program provided additional technical testimony in the political arena technical expertise for the design and start-up of the National program and a flexible distribution of resources to allow the National Program to start strongly

4 2 2 Economic impact of policy changes on IPM in Indonesia

The pesticide subsidy was first introduced in Indonesia as part of a broader fertilizer subsidy package in 1974 Pesticide usage rose steeply from 1977 to 1986 after importation of formulated pesticides was banned during the period when the pesticide subsidy was around 85% The subsidy itself represented a sizable outlay of public funds but it also produced other expenditures and reduced rice yields by inducing BPH outbreaks All these impacts need to be considered when assessing the benefits of the subsidy removal These are itemised below and estimates of costs where available, are given To evaluate the costs of the pesticide subsidy in Indonesia one must make a number of well supported assumptions that can here only be outlined

4 2 2 1 The cost of rice lost to BPH

The pesticide subsidy for rice of which about 95% were insecticides did not increase rice production As shown in Figs 4 1 4 2 rice production grew during two periods when

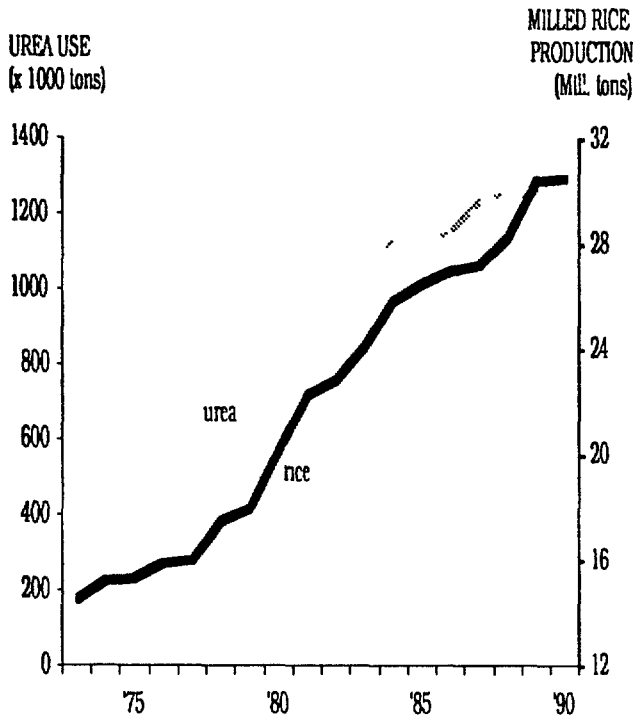


Fig 4 3 Rice production and urea use - Indonesia 1972-90

pesticide production dropped sharply The levels of pesticide production during the subsidy era reflect coverage of intensification hectarage with field packages under control policies The same packages contained subsidized Nitrogen fertilizers (Fig 4 3) that were associated with yield throughout the periods covered

On the contrary, the subsidy caused massive losses of rice due to BPH during a period when Indonesia was the world s largest importer of rice Therefore the cost to the national budget of rice lost to BPH can be expressed as the cost of imports of equivalent quantities of rice The cost of these additional rice imports has to be accounted in full as a cost of the pesticide subsidy A rough estimate of these losses is $ 1 75 Billion US dollars

Additional costs are the loss of income and labour opportunities in the rural economy caused by shortfalls in production These costs accrued to the rural sector of the domestic economy They cannot easily be expressed in US $ but estimates can be made as to the amount of seasonal or annual income lost by an average small rice farm if it loses one rice crop and of how many such seasonal or annual farm incomes were lost

As chemical fertilizers were subsidized there is a cost to the domestic budget in terms of the amount of subsidized fertilizer used on rice fields that were destroyed by BPH This could be expressed as the cost of imports of equivalent amounts of fertilizer or as the percentage of the annual budget subsidy for chemical fertilizer lost to BPH

To this should be added costs to the food logistics agency for keeping very high rice stocks because of the risk of BPH outbreaks

4 2 2 2 The cost to the budget of the pesticide subsidy

About 70%, on average of all subsidized products was used on rice About 20 percent went on 'secondary food crops mainly soybeans and vegetables and the rest was used on a large number of other crops It is assumed that overall the subsidy did not produce significant benefits on these non-rice crops As on rice indiscriminate use of pesticides on crops like soybeans, the second largest market after rice, caused resurgences and secondary pest outbreaks that easily outweigh possible benefits from lower input costs However, there are no comprehensive crop loss data to quantify this assumption

As no net benefits from pesticide subsidies for either rice or secondary crops accrued the cost to the national budget of subsidizing pesticides can be used in accounting for overall cost of pesticides to the economy Estimates of Rupiah expenditures for pesticides in the annual budgets between 1974 and 1988 can be converted into actual US $ Adjustment for inflation then provides figures for total budgetary expenditure on pesticide subsidies US $ 1 6 Billion (1990) dollars

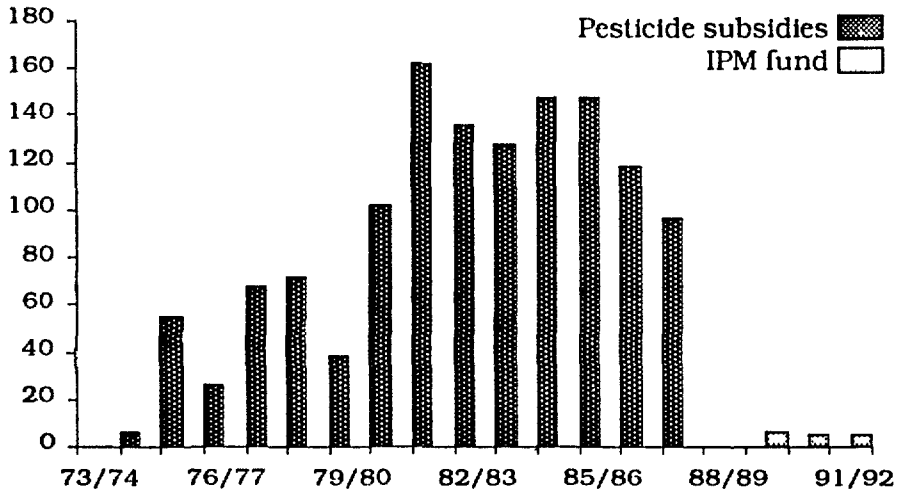


Fig 4 4 Pesticide subsidies and IPM funds (million US$ 1990) Indonesia

4 2 2 3 The financial cost of the pesticide subsidy (debt service)

Adding actual annual budgetary costs for subsidies and adjusting for inflation does not yet provide a true picture of these costs Indonesia borrowed funds for development to cover shortfalls in domestic revenue used for development programs Rupiah funds spent on

pesticide subsidies were lost for other development purposes and equivalent amounts of money had to be borrowed on the international capital market The cost of financing this debt can be found by treating the annual expenditure for pesticide subsidies as a loan made under average conditions of the period Thus by using debt service projection models based on conditions of actual loans made during these years one can get a very close estimate of debt service costs for funds spent on pesticide subsidies It is this cost of total debt service that provides a true picture of the financial costs of the pesticide subsidy

4 2 2 4 Costs to public health and environment

No attempts are made here to try to estimate these costs from available medical statistics and surveys It is only assumed that costs to human health and environment are proportional to the amount of pesticides distributed and used An estimate can be made of the consumption of pesticides in Indonesia if there had not been a pesticide subsidy Then the difference between the non-subsidized consumption and the consumption figures under subsidy are a direct measurement of health and environmental costs Data from Indonesian financial and Industrial statistics show that since the change in pesticide policies in 1986 total pesticide production in the country has declined by 67% As unsubsidized products in 1986 had a market share of about 75% and as demand for subsidized products has grown the drop in the production of subsidized products had been even larger If one uses the 1989/90 production figures as an indicator of the size of the market without subsidies, than the pesticide subsidy produced about 200% higher health and environmental costs than a free market system would have produced

4 2 2 5 Cost of distortions in industrial development

The pesticide subsidy created a distorted oversized and inefficient pesticide industry One part of the cost of this distortion is the cost of investments in factories that (a) are not competitive in their cost structure and (b) do not have a market as pesticide demand adjusts to free market conditions The other and much larger cost factor is the cost to food production in the future resulting from the lobbying power of this distorted industry that again and again attempts to create situations conducive to the overuse of pesticides

4 2 2 6 Costs of efforts to correct the strong pesticide bias in society

The subsidy regime created a culture of believers in pesticides The costs of re-educating millions of farmers and tens of thousands of government employees in the extension service

have to be borne by future programs in IPM Estimates of these costs as a share of the needed expenditure for large scale IPM implementation are not attempted here but one should take note of the fact that they are high

4 3 BENEFITS FROM NATIONAL POLICY ACTIONS IN OTHER COUNTRIES

It was not practicable for the Mission to analyze the economic, social or environmental benefits that followed from central policy changes relevant to IPM in the remaining eight countries in the Program However, here we list some of the significant kind of changes that were noted by the Mission and examples

Furthermore it became abundantly clear that the training and extension programs in each of the countries were less likely to succeed or to endure the passage of time without a strong government commitment (policy personnel and funding) to the philosophy and practice of IPM

4 3 1 Remove Direct Subsidies

Bangladesh changed the level of pesticide subsidy from 100 % to 50% in 1974 then from 50% to 0% in 1979 Pesticide use dropped by 50% with each change in subsidy stabilizing at about 25% of original use Rice production rose steadily throughout the period of subsidy removal

Philippines removed about US$ 12 million per year in rice pesticide subsidies by shifting from the Intensified Rice Production Program to the Rice Production Enhancement Program in 1988

Tamil Nadu State in India reduced direct purchases of pesticides by about 2 crore rupees (US$ 1 6 million) per year

4 3 2 Change Composition of Foreign Development Assistance Grants

The Government of Japan gives Government of the Philippines an Agricultural Productivity Grant of Japanese agricultural inputs every year, related to WWII reparations payments Since the IPM Policy was declared the proportion of that grant spent on insecticides declined from 30% to less than 5% The 1990 level of the total grant was over US$20 million When informed of this trend, the Government of Indonesia also began to reduce the proportion of its grant spent on pesticides

4 3 3 Initiate New Donor - Funded Projects

Bangladesh China and India have placed IPM on the list of top priority projects in their UNDP Country Programs As the three largest UNDP national programs in the world, it is significant that IPM is shared by all While these developments represent 'impacts' rather than 'benefits', they can be viewed as a positive step towards some economic environmental and health benefits for rice growers in these counties

Bangladesh has indicated to DANIDA that it shall revise to support IPM training the contents of a project whose earlier phases gave many tons of aerially formulated insecticides China has opened discussions with Japan for support to a multi-year IPM training project Philippines has indicated that it will prepare an IPM training project proposal in response to recommendations from USAID

4 3 4 Increase Staff Support for IPM

Either by transferring across office units or by creating new official posts the Governments of Philippines and Malaysia significantly increased the numbers of their staff supporting IPM field activities as a matter of national policy This is more strictly an 'impact' rather than a direct benefit but it represents a change which should bring in the benefits in the long run

4 3 5 Reject Large scale, especially aerial, treatment

These are especially compelling because influential rural members of parliaments use aerial pesticide applications as one of the most obvious kinds of evidence of their influence over the national government

India first rejected aerial applications for sugarcane pyrilla (also an occasional rice pest) in order to conserve natural enemies in the mid 1970s

Bangladesh first began to reject aerial applications under IPM ministerial policy in 1989 when a cabinet member passed on alarms from his constituency about rice hispa When aerial reconnaissance failed to confirm the reports the spraying operation was cancelled

Philippines and Malaysia have rejected many opportunities to respond positively to farmers and legislators demands for aerial applications on rice and other crops

4 3 6 Ban Specific pesticides

In October 1989 Philippines banned the importation of Tri Phenyl Tin compounds used as molluscicides because of their dermal toxicity and confirmed status as teratogens The IPM recommendations covering snail pests in rice specifically exclude use of these pesticides

4 4 BENEFITS FROM FARMER UPTAKE OF IPM - OUTLOOK

4 4 1 Philippines - Case studies of benefits from IPM training

4 4 1 1 Case 1 - Central Luzon

In the Philippines Central Luzon is the largest rice producing region (of 12 in the country) and therefore was chosen to be one of the pilot areas where IPM farmers' training was first given The impact of IPM farmers training is quite well documented for Central Luzon data have been collected regularly comparing yields amount of money spent on pesticides number of pesticide applications and other data for IPM trained and untrained farmers From 1984 to 1990 about 13 900 farmers took IPM training in Central Luzon The cumulative training costs were Pesos 2,132 302 (US$ 108 626), based on different training costs per farmer and number of farmers trained each year (Tables 4 1, 4 2)

Surveys conducted in 1984 1985 1986 1987, and 1990 showed that IPM-trained farmers spent less money on pesticides than untrained farmers In 1984 IPM-trained farmers saved Ps 440 per year (2 crops) on pesticides in 1985 Ps 380 in 1986 and 1987 Ps 420 and Ps

Table 4 1 Training costs per farmer and savings per ha, 1984-90

	Training costs per farmer		Savings/ha		exchange rate
Year	Pesos	US$	Pesos	US$	Pesos - US$
1984	664	38 34	440	25 40	17 32
1985	110	6 13	380	21 18	17 94
1986	37	1 84	420	20 93	20 07
1987	250	12 30	420	20 67	20 32
1988	250	11 97	590	28 24	20 89
1989	250	11 80	750	35 39	21 19
1990	265	10 77	919	37 36	24 60

Table 4 2 Cumulative costs savings and benefits of IPM training in Central Luzon 1984-90

	Pesos	US$
cumulative training costs	2 162 322	108 626
cumulative savings	39 001 830	1 891,091
cumulative benefits	36 839 508	1 782 465

919 in 1990 Estimates for the other years were interpolated from these data (Table 4 1) Follow-up studies on farmers trained in 1979 and 1980 have shown that farmers who master IPM skills will save every cropping season on pesticide expenditures The total cumulative savings generated by the 13 900 IPM farmers with 2 crops per year and an average landholding of 1 5 ha in Central Luzon in the period 1984-90 equal **Ps** 39 001 830 (US$ 1 891 091) Total cumulative benefits for this period are **Ps** 36 839 508 (US$ 1 782 465) (Table 4 2) The benefit/cost ratio for IPM training is 17 1 taking into account only investments made by the Philippine government Expenditures of the Intercountry Program for the whole of the Philippines in this period were US$ 370 809 plus about US$ 50 000 expert time (1984-86 US$ 10 000/year 1987 90 US$ 5 000/year) Including these costs the benefit - cost ratio is 3 4 1

The benefits generated by the Central Luzon IPM farmers alone are much higher than the total expenditures made by the Intercountry Program in the Philippines (US$ 1 78 million vs US$ 420 809)

4 4 1 2 Case 2 - IPM for the entire Philippines (including Central Luzon)

In 1990 the total number of farmers trained in IPM since 1984 is 175 049 Data on impact

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of IPM for the other regions in the Philippines are not as well documented as for Central Luzon However, one may assume that the differences in costs and savings for the other regions in the Philippines will be of the same order of magnitude Based on the Central Luzon figures the cumulative training costs saving and benefits of IPM farmers training for the Philippines are given in table 4 3 Figure 4 5 shows how cumulative benefits were built up during 1984-90 Benefit - cost ratio is 8 9 1 including FAO Intercountry Program expenditures in the Philippines

Table 4 3 Cumulative costs, savings and benefits of IPM training in the Philippines, 1984-90

	Pesos	US$
cumulative training costs	34 536 379	1 675 855
cumulative savings	423,413,025	20 381 117
cumulative benefits	388 876 646	18 705 262

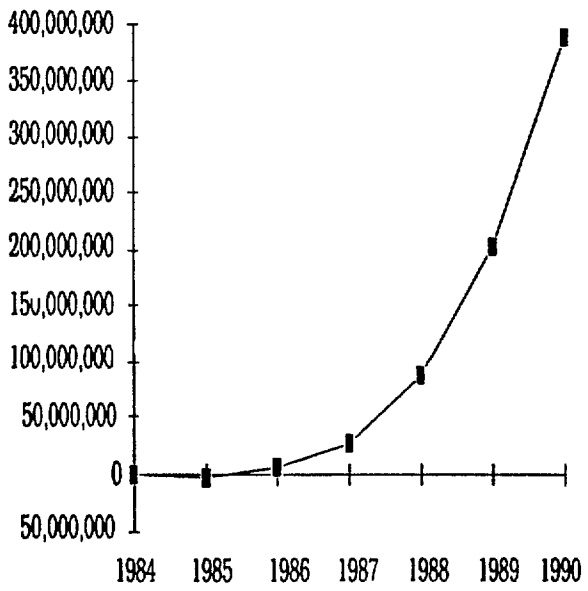


Fig 4 5 Cumulative benefits of IPM (Pesos), Philippines 1984 90

The 175 000 IPM trained farmers will continue to save money by spending less on pesticides In 1990 these farmers saved a total amount of about Ps 160 million (US$ 5 7 million) (based on yearly savings of Ps 919/ha found in the Central Luzon survey of October 1990) When in 1986 IPM was declared a national crop protection policy in the Philippines pesticide subsidies were abolished saving the Government over US$ 12 million yearly The IPM-trained farmers save an additional US$ 5 7 million per year by using less pesticides

In the survey of October 1990 untrained farmers in villages with IPM-trained farmers were also interviewed to assess whether knowledge spreads from trained farmers to untrained In table 4 4 expenditures on pesticides by IPM trained farmers untrained farmers in IPM villages and untrained farmers in untrained villages are given

Table 4 4 Annual expenditures on pesticides (2 crops)
Survey Central Luzon, October 1990

	Pesos	US$
IPM trained farmers	725 4	25 9
Untrained farmers-untrained villages	1654 2	59 1
Untrained farmers-IPM trained villages	774 6	27 7

Untrained farmers in IPM villages spend Ps 880/year less on pesticides than untrained farmers in untrained villages There seems to be a spread of knowledge from trained to untrained farmers However it is impossible to make an estimate how many farmers are influenced by a trained farmer The cumulative benefits for IPM will certainly be bigger because of this spread of knowledge but it can not be estimated from available data how much this will be

4 4 2 China

In China 5000 farmers have received training in IPM until now A 1989 survey shows that IPM farmers in 5 provinces in China spent on average 26 7 yuan/ha (US$ 5 6) less on pesticides than untrained farmers In 1990 these trained farmers save on pesticides an amount of US$ 14 000 (based on 2 crops per season and an average farm size of 0 25 ha) Net profits for IPM-trained farmers are 497 yuan/ha/season (US$ 105 5) higher than for untrained farmers also because of higher yields Net profits for the 5000 farmers were in 1990 US$ 1 055 000 higher than for untrained farmers
Total Program expenditure in China since 1988 is US$ 215 000

4 4 3 Bangladesh

As of 1990 a total of 1500 farmers has been trained in IPM in Bangladesh Surveys conducted in 1989-90 assessed the amount of money spent on pesticides of farmers before and after IPM training Per year (2 crops) IPM-trained farmers spent Taka 768 (US$ 24) less on pesticides Total training costs were US$ 19 500 (cost per farmer US$13) The 1500 farmers save yearly an amount of US$ 36 000 on pesticides (average farm size 1 0 ha) Benefit - cost ratio is 1 8 1 Yields of IPM farmers also increased with 0 6 tons/ha (Boro season 1990) Their net profit (benefits) will even be higher taking this yield increase into account
Program expenditures in 1990 in Bangladesh were US$ 47 272 of which US$ 42 314 was spent on training and field activities primarily for training extension staff

4 4 4 India

In India 50 000 farmers have been trained in IPM so far Surveys done in 1989-90 indicate that IPM farmers spent on average 293 Rupees/ha/season (US$ 18) less on pesticides Savings on pesticides by these IPM farmers for 1990 equal Rp 40 141 000 (US$ 2,480 902) (2 crops per season, average farm size 1 37 ha) The net average income of IPM farmers is Rp 1039/ha (US$ 64) higher than for untrained farmers The total income for IPM farmers in 1990 is US$ 8,768,000 higher than for untrained farmers Training costs per farmer are Rp 200 (US$ 12) Total training costs equal US$ 600 000 Benefit - cost ratio excluding increased yields is 4 1 1
Program expenditures in since 1987 were US$ 119 200 in India

4 4 5 Indonesia

Unt l now at least 60 000 farmers were trained in IPM Savings per ha per season equal US$ 20 For the year1990 alone an amount of US$ 2 4 million has been saved by IPM-trained farmers in Indonesia

4 4 6 Sri Lanka

In the period 1984-1990 87 108 farmers have been trained in IPM in Sri Lanka A survey of 1988 shows that IPM-trained farmers spent on average 85 Rupee/ha (US$2 8) less on insecticides per season after they were trained in IPM Based on 2 crops per year and an average farm size of 1 12 ha total cumulative savings for Sri Lanka due to IPM in this period are Rp 93 427 186 (US$ 3 392 297) Training cost per farmer was US$1 cumulative training costs equal US$ 87 108 Cumulative benefits of savings on pesticides for Sri Lanka in 1984-90 are US$ 3 3 million (Table 4 5) Additional benefits because of higher yields obtained by IPM-farmers are not included in this figure
Yearly savings on insecticides in 1990 equal Rp 16 160 010 (US$ 404 000) Program expenditures in 1987 90 were US$ 217 871 of which US$ 60 779 was spent on training and field activities

Table 4 5 Costs savings and benefits of IPM Sri Lanka 1984 90

	Rupee	US$
cost of farmers training	2 613 240	87 108
cumulative savings	93 427 186	3 392 297
cumulative benefits	90 813,946	3 305 184

4 4 7 Vietnam

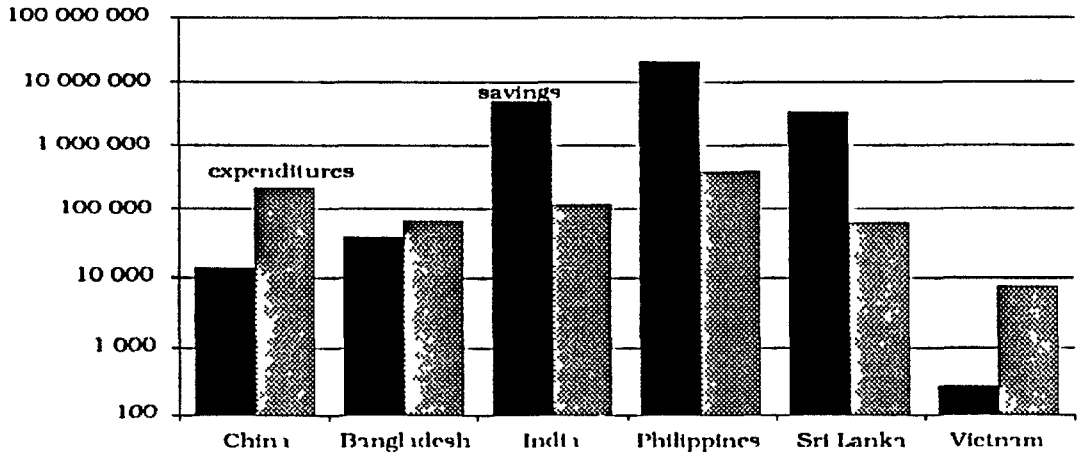
In the summer season of 1990 the first activities of the Intercountry Program started in Vietnam Twenty eight demonstrations were established of 10 ha each A total of 860 farmers was trained in IPM Inputs (fertilizer certified seeds) partially provided by the Program were higher in IPM plots 740 688 vs 685 122 Dong/ha in Farmers Practice plots (US$ 115 73 vs 107 05) On plant protection inputs IPM farmers spent 6115 Dong/ha less (0 95 US$) (47,765 vs 53 880 Dong/ha) Total savings on pesticides in demonstrations in the summer season 1990 was US$ 266 Yields in the IPM plots were higher than in Farmers Practice 4 16 vs 3 64 ton/ha Profits from IPM plots were 278 888 Dong/ha (US$ 43 57) higher than from Farmers Practice plots The 280 ha demonstration site has a total higher profit of US$ 12 200 of which US$ 266 was saved on pesticides (Table 4 6)
Total costs for the demonstrations were US$ 7311 including inputs as fertilizer and certified seeds and farmers training The benefits for this season equal US$ 4891

Table 4 6 Costs savings and benefits of IPM demonstrations (280 ha) Vietnam summer season 1990

	Dong	US$
costs of demonstrations (incl inputs farmers training)	46 788 800	7 311
savings	78 088 640	12 201
benefits	31 299 840	4 891

4 4 8 Summary

For most of the countries (China Bangladesh India Philippines Sri Lanka and Vietnam) data are available on the savings generated by IPM trained farmers through reduction of the amount of money spent on pesticides These cumulative savings are given for the individual countries in Figure 4 6 as well as the cumulative expenditures of the Intercountry Program per country (logarithmic scale!) In Figure 4 7 the total cumulative savings on pesticides and the total expenditure of the Program are given
In China and Vietnam the Mission also collected data on net profits for IPM farmers As well as savings on pesticides farmers get also a higher yield and their total net profits increase more In Figure 4 8 the cumulative farmers profits are given and the Program expenditures in these countries For China and Vietnam savings on pesticides are smaller than Program expenditures but total farmers profits are higher than the total amount spent by the Program in the two countries



(logarithmic scale!)

Fig 4 6 Cumulative savings on pesticides generaterd by IPM trained farmers and expenditures of the Intercountry Program (US$)

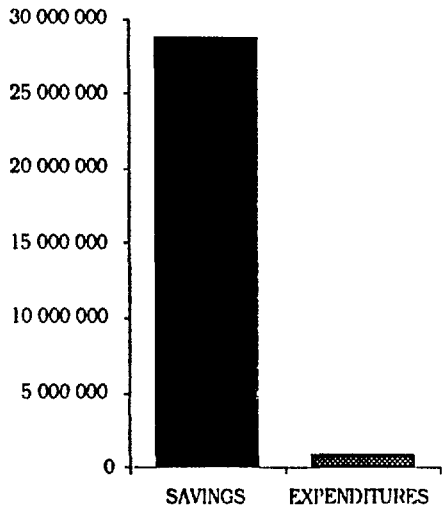
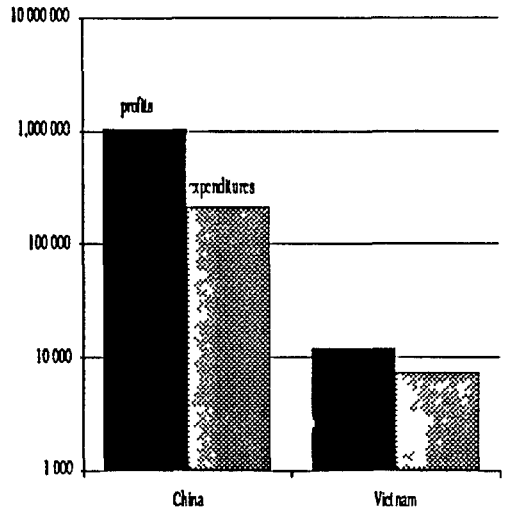


Fig 4 7 Cumulative savings on pesticides by IPM trained farmers and total expenditures of the Intercountry Program (US$) (China Bangladesh India Philippines Sri Lanka Vietnam)



(logarithmic scale!)

Fig 4 8 Cumulative savings (net profits) by IPM farmers and expenditures of the Intercountry Program (US$) in China and Vietnam

the seventies, one cannot expect (*F–J*) to increase successively through the years Eventually and most likely, the foreign exchange or fiscal constraint will block the further substantial growth of the economy Shifts in the *IT*, *IE* and *IS* curves will be necessary for further accumulation Even in the seventies when net foreign transfers were plentiful, there did not seem to be substantial shifts in the three curves In this case the growth has been limited to the shaded areas of Figure 1 One can imagine the much higher growth rates that could have been attained if increases in net foreign transfers were accompanied by shifts upwards of the three curves The Philippines did not "take off" as its East Asian and ASEAN neighbors seem to have done

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PROSPECTS FOR RICE YIELD IMPROVEMENT IN THE POST-GREEN REVOLUTION PHILIPPINES

By P L. Pingali, P F Moya and L. E Velasco*

Evidence from farm level and experimental data from the Philippines indicates a trend towards stagnation and/or a decline in irrigated rice yields when intensively cultivated even under scientific management on experiment station Given current rice technology there is a minimal yield gap between the experiment station and the "best" irrigated farms in the Philippines If the current yield frontier does not shift outwards, the long term prospects are for stagnation and/or decline in farm yield.

The current yield gap is no longer between the farmer and the experimental potential but rather between farmers themselves This gap between farmers yields can be explained by differential farmer ability and differential access to irrigation water The results of the study suggest that the first priority for rice research ought to be the breaking of the current irrigated yield ceiling It also indicated that the yield gap between farmers can be reduced by carefully targeted extension training program and improvement of the efficiency and reliability of water delivery to farms in the middle and tail sections of the system

1 Introduction

The introduction and rapid spread of semi-dwarf high-yielding rice varieties throughout Asia in the late sixties and early seventies resulted in phenomenal output growth (Dalrymple, 1986, Herdt and Capule, 1983) For South and Southeast Asia the aggregate rice output growth rate increased from 2 2 percent per annum during 1955-65 to 3 2 percent per annum during 1965-80 In the Philippines, the annual growth rate of rice output doubled, rising from 2 2 percent in 1955-65 to 4 5 percent in 1965-80 (FAO) Rice output growth rates surpassed annual population growth rates of 2 9 in the Philippines during 1965-80 (IBRD)

There is increasing concern, however, that the growth in aggregate rice output has peaked and is starting to decline (Herdt, 1988, Barker and Chapman, 1988, and Byerlee, 1987) While much of the literature on agricultural development continues to focus on the green revolution and its impact, the post-green revolution phase of declining

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output and productivity growth is already well established in many areas of Asia (Byerlee, 1987) Barker and Chapman (1988) suggest that the productivity declines could occur due to the following reasons a) the lack of a significant breakthrough in the yield ceiling in Asia since the first modern varieties were released, and b) the decline in irrigation investments and the poor maintenance of existing irrigation infrastructure

For the irrigated rice producing environments or the so-called "rice bowls of Asia", the post-green revolution phase can be characterized as follows i) modern variety use is well established and the rate of growth in farm yields is beginning to slow down, ii) land use intensity is high and so is input use especially fertilizers, iii) efficiency of input use is low and hence in association with (i) and (ii) one can anticipate productivity declines in the future

This paper provides an analysis of Philippine data from the experiment station and farmer fields showing a stagnant yield potential, and a diminished gap between potential and actual farm yields This analysis finds that the larger yield gap is between farmers, rather than between the farmer and the experiment station This yield gap between farmers can be attributed to differences in farmer knowledge, ability, and reliability of irrigation water control Reducing these differences between farmers in knowledge and ability will be the primary sources of productivity growth in the post green revolution period

Data Sources for Experiment Station and Farm Household Panels

This paper uses three sets of panel data for irrigated farm households and four sets of panel data from Philippine rice experiment stations The following farm panel data sets were used i) a sample of 34 farmers in Laguna, Philippines, monitored from 1966-1987, ii) a sample of 23 households in Nueva Ecija, Philippines monitored from 1970-1984, iii) a sample of 132 households in Nueva Ecija monitored for the years 1979/80, 1985/86 and 1988 (For a detailed description of the first two data sets see Herdt, 1987) Table 1 provides summary statistics of the variables used in this analysis

Time-series data on experiment stations' yields were obtained from the Agronomy Department of IRRI for four locations i) the International Rice Research Institute, (IRRI) Laguna 1966-1988, ii) the Maligaya Rice Research and Training Center (MRRTC), in Nueva Ecija 1970-1988, iii) the Bicol Rice and Corn Experiment Station (BRCES), 1970-1988, and iv) the Visayas Rice Experiment Station (VRES), 1970-1988 IRRI and MRRTC are located in the same geo-

Table 1 – Means and Coefficients of Variation of the Variables Used in the Analysis

	Farmers' yield (kg)	Yield front ier (kg)	Ratio of farmers yield to yield frontier	N (kg)	Pesti cide (kgai/ ha)	Labor (pre harv) (MDS)	Tractor days	Age	School ing	Family size/ ha	Distance from main canal (kms)
N. ECIJA											
1980	4337	7297	0 6	80	1 26	47 5	2 26	46	4 7	5 23	1 16
	(31 3)	(11 4)	(33 6)	(59 2)	(70 6)	(73 2)	(91 8)	(26 8)	(63 7)	(95 2)	(112 9)
1986	4183	7892	0 53	93	1 38	55 8	3 22	46	4 7	6 12	1 16
	(34 4)	(7 7)	(32 9)	(42 9)	(57 3)	(97 3)	(54 8)	(26 8)	(63 7)	(136 2)	(112 9)
1988	1826	8013	0 6	100	1 13	39 7	3 27	46	4 7	5 3	1 16
	(31 3)	(7 0)	(30 4)	(35 4)	(75 9)	(74 6)	(50 4)	(26 8)	(63 7)	(130 6)	(112 9)
LAGUNA											
1966	2532	5216	0 48	14	0 77	61	0 31	60	5 37	3 52	0 20
	(41 2)	(4 4)	(40 3)	(95 0)	(60 8)	(32 3)	(184 4)	(18 6)	(64 7)	(55 2)	(99 8)
1970	3492	5948	0 69	50	0 78	51 6	1 14	60	5 37	3 23	0 20
	(39 5)	(1 7)	(38 9)	(55 9)	(65 2)	(24 6)	(76 6)	(18 6)	(64 7)	(49 8)	(99 8)
1975	3713	6664	0 56	86	0 76	51 5	1 3	60	5 37	3 27	0 20
	(30 8)	(3 0)	(31 0)	(39 4)	(35 8)	(28 0)	(58 6)	(18 6)	(64 7)	(49 6)	(99 8)
1981	4578	7146	0 64	66	0 79	46 4	2 98	60	5 37	3 14	0 20
	(29 7)	(2 7)	(29 2)	(45 5)	(38 9)	(22 9)	(59 0)	(18 6)	(64 7)	(49 4)	(99 8)
1981	4746	7352	0 64	52	0 87	43 5	3 25	60	5 37	3 81	0 20
	(33 5)	(4 1)	(31 5)	(61 5)	(54 7)	(33 4)	(49 0)	(18 6)	(64 7)	(68 6)	(99 8)

graphic area and agroclimatic environment as the farm samples in Laguna and Nueva Ecija, respectively

In each case, the yield from the highest yielding rice cultivar in the long-term nitrogen response trials was used to represent the technological potential Details on how these trials were set up and how the highest yielding entries are determined can be found in Flinn and De Datta (1984) The nitrogen response trial data provide, for each year, the best approximation of the yield potential under intensive cropping of rice cultivars grown under scientific management and with no input constraints We thus have time-series data for the four locations on the yield potential of the most outstanding modern rice varieties

2 Experiment Station and Farmer Yields Is There an Unexploited Yield Gap?

2 1 Experiment Station Yields as Indicators of Technology Potential

The International Rice Research Institute started releasing modern rice varieties since the mid 1960s IR 8 was the first of the modern varieties widely grown in Asia At the time of its release in 1966, IR 8 yielded as much as 10 tons/hectare in the dry season and 6 tons/hectare in the wet season at IRRI s experimental farm in Laguna Philippines (De Datta, 1979) At that time farmers in the neighborhood of IRRI growing traditional rice varieties were getting yields of 2 0 2 5 tons/hectare (*IRRI Annual Report* 1967) Since its initial release the yields of IR 8 have been on a declining trend even when grown under scientific management on the IRRI farm Flinn, *et al* (1982) estimate that since 1966 the wet season yields of IR 8 have declined by 0 2 tons per hectare per year and the dry season yields have declined by 0 26-0 47 tons per hectare per year The most commonly attributed cause of this decline is the greatly increased insect and disease pressure to which IR 8 is not resistant (Insect and disease infestations have risen with the growth in intensive rice production across Asia)

Following IR 8, the 33 modern rice varieties that have since been released in the Philippines have better insect and disease resistance, shorter crop duration and, to some extent, better eating quality than IR 8 However, none of the later varieties have been able to match the initial yield potential of IR 8 Indeed, De Datta *et al* (1979) report that in recent years rice yields of over 9 tons per hectare are rarely recorded at IRRI Perhaps more disturbing is the observation by Flinn, *et al* (1982) that the highest yields obtained from the nitrogen response

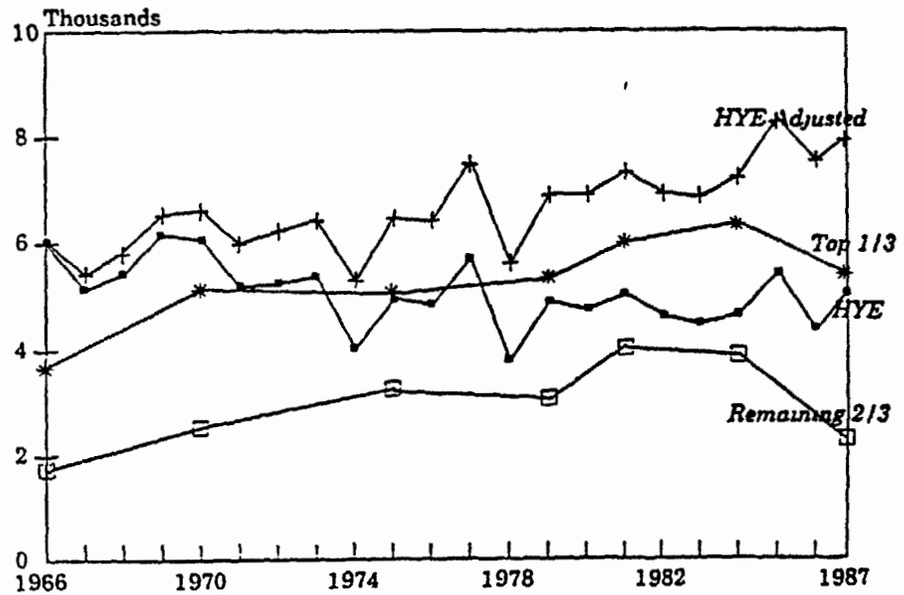

Figure 1 — Trends in HYE & Farmers' Yield, Laguna

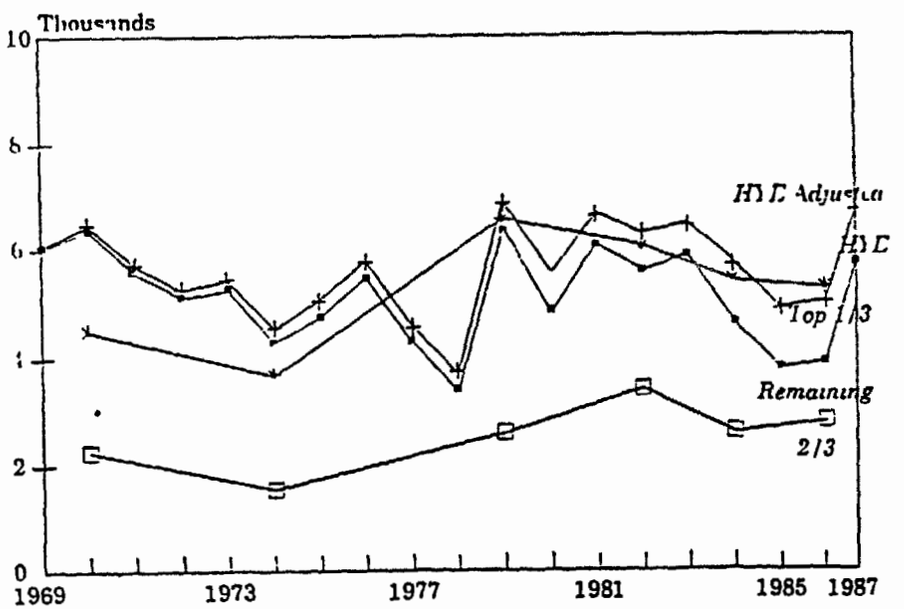

Figure 2 — Trends in HYE & Farmers' Yield, Nueva Ecija

trials have been exhibiting a long-term decline They estimate the decline at an annual rate of 0 1 0 16 ton per hectare in both the wet and dry seasons Figure 1 graphs the highest wet season yield obtained in the nitrogen response experiment for the years 1966 1987

Flinn and De Datta (1984) also provide evidence of yield stagnation or decline in both the wet and dry seasons in three other experiment stations in the Philippines in addition to IRRI These experiment stations are in the Nueva Ecija, Bicol and Visayas covering a fairly representative cross-section of the irrigated rice areas of the Philippines For Nueva Ecija, they find that the highest yields in the nitrogen response experiments at MRRTC have remained stagnant in both the wet and dry season for the years 1968-1980 Figure 2 graphs the highest wet season yields obtained in the nitrogen response experiments at MRRTC

We updated the Flinn and De Datta analysis for all four stations by expanding the long term yield response data set to include all years up to 1988 The highest yield for each nitrogen level was used as the dependent variable (in logs) and the independent variables in the regression were time trend log nitrogen (kilograms/hectare), the square of log nitrogen and log rainfall Rainfall was measured in terms of the actual amount from transplanting to two weeks before harvest All other production and management inputs were held constant throughout the experiment Generalized least squares regressions using the Parks method were run to identify the long term yield trend The Parks method corrects for heteroscedastic and autocorrelated error terms and provides consistent coefficient estimates (Parks 1967) The results are presented in Table 2 We found a significant negative yield trend for the wet season for three of the four locations and for two of the four locations for the dry season The exceptions VRES for both seasons and MRPTC for the dry season exhibited stagnant yield trends At IRRI wet season yields declined at the rate of 1 29 percent per year while at MRPTC and BEST the yield decline was at the rate of 1 01 percent and 0 6 per cent per year, respectively VRES had a slight growth in wet season yield at the rate of 0 18 percent per year For the dry season the yield decline at IRRI was significant at the rate of 1 28 percent per year, while at BEST the yield decline was at the rate of 0 38 percent per year MRPTC exhibited a slight yield growth at the rate of 0 15 percent per year, while at VRES the time trend was not significant

2 2 *Yield Potential Adjusted for Environmental Degradation*

The long term decline in yield potential under intensive irrigated

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Table 2 — Estimates of Experiment Station Yield Potential with and without Adjustment for Environmental Degradation [1]

	IR8		Highest Yielding Entries		Highest Yielding Entries (adjusted)	
BEST DS						
Intercept	8 4615***	(0 0545)	8 5531***	(0 0427)	8 5531***	(0 0427)
Time	0 0501***	(0 0012)	0 0038***	(0 0015)	0 0463***	(0 0015)
N	0 0808***	(0 0041)	0 0627***	(0 0047)	0 0627***	(0 0047)
N square	-0 0139***	(0 0020)	0 0054***	(0 0016)	0 0054***	(0 0016)
Rainfall	0 0860***	(0 0091)	0 0183***	(0 0062)	0 0183***	(0 0062)
IRRI DS						
Intercept	7 8740***	(0 0829)	8 3245***	(0 0400)	8 3245***	(0 0400)
Time	0 0589***	(0 0060)	0 0128***	(0 0007)	0 0461***	(0 0007)
N	0 0578***	(0 0038)	0 0185***	(0 0065)	0 0185***	(0 0065)
N square	0 0022	(0 0031)	0 0174***	(0 0022)	0 0174***	(0 0022)
Rainfall	0 4261***	(0 0222)	0 0591***	(0 0075)	0 0591***	(0 0075)
MRRTC DS						
Intercept	8 3630***	(0 0255)	8 4599***	(0 0133)	8 4599***	(0 0133)
Time	0 0058***	(0 0015)	0 0015**	(0 0006)	0 0072***	(0 0006)
N	0 0437***	(0 0060)	0 0396***	(0 0018)	0 0396***	(0 0018)
N square	0 0097***	(0 0022)	0 0117***	(0 0008)	0 0117***	(0 0008)
Rainfall	0 0324***	(0 0035)	0 0170***	(0 0027)	0 0170***	(0 0027)
VES DS						
Intercept	8 4904***	(0 0657)	8 4680***	(0 0424)	8 4680***	(0 0424)
Time	0 0130***	(0 0050)	0 0018	(0 0015)	0 0149***	(0 0015)
N	0 0412***	(0 0058)	0 0419***	(0 0040)	0 0419***	(0 0040)
N square	0 0003	(0 0029)	0 0064***	(0 0012)	0 0064***	(0 0012)
Rainfall	0 1121***	(0 0336)	0 0160**	(0 0078)	0 0160**	(0 0078)
BEST WS						
Intercept	8 7444***	(0 4582)	8 4752***	(0 0744)	8 4752***	(0 0744)
Time	0 0383***	(0 0046)	0 0062***	(0 0005)	0 0322***	(0 0005)
N	0 0735***	(0 0038)	0 0490***	(0 0017)	0 0490***	(0 0017)
N square	0 0289***	(0 0035)	0 0135***	(0 0009)	-0 0135***	(0 0009)
Rainfall	0 0219	(0 1013)	0 0210**	(0 0106)	0 0210**	(0 0106)
IRRI WS						
Intercept	7 6015***	(0 3760)	9 2048***	(0 1364)	9 2048***	(0 1364)
Time	0 0517***	(0 0112)	0 0129**	(0 0008)	0 0388**	(0 0008)
N	0 0207***	(0 0053)	0 0291***	(0 0059)	0 0291***	(0 0059)
N square	0 0076**	(0 0025)	0 0018	(0 0027)	0 0018	(0 0027)
Rainfall	0 1283	(0 1301)	0 1029**	(0 0205)	0 1029***	(0 0205)
MRRTC WS						
Intercept	9 7061***	(0 0373)	9 8753***	(0 0159)	9 8753***	(0 0159)
Time	0 0167**	(0 0003)	0 0101**	(0 0002)	0 0006*	(0 0002)
N	0 0426***	(0 0015)	0 0318***	(0 0012)	0 0318**	(0 0012)
N square	0 0085***	(0 0008)	0 0039***	(0 0012)	0 0039***	(0 0012)
Rainfall	0 3098	(0 0072)	0 1937***	(0 0011)	0 1937***	(0 0011)
VES WS						
Intercept	8 9748***	(0 1466)	7 8505***	(0 1346)	7 8505***	(0 1346)
Time	0 0093	(0 0019)	0 0018*	(0 0011)	0 0075**	(0 0011)
N	0 0497**	(0 0059)	0 0374	(0 0021)	0 0374**	(0 0021)
N square	0 0021	(0 0020)	0 0016	(0 0017)	0 0016	(0 0017)
Rainfall	0 1848	(0 0314)	0 0925	(0 0193)	0 092	(0 0192)

Dependent variable log yield/hectare
Significant at 10% level significant at 5% level significant at 1% level
Values in parenthesis are standard errors

rice production can be attributed to either a degradation of the paddy environment or a decline in the genetic potential of the breeding materials used for generating cultivars Degradation of the paddy environment under intensive cropping can occur due to one or more of the following causes 1) increased pest pressure 2) rapid depletion of soil micro nutrients, and 3) changes in soil chemistry brought about by intensive cropping and the increased reliance on low quality irrigation water

The rate of environmental degradation can be measured by the rate of decline in yield over time, holding variety and input levels constant In order to do this we need yield time series on one particular variety At IRRI and at MRRTC the variety grown each year since the start of the long-term yield experiment is IR 8 We therefore have twenty years of data for IR 8 at IRRI and eighteen years for MRRTC Linear regression equations were estimated for IRRI and MRRTC using generalized least squares techniques for pooling time series and cross section data The results are provided in Table 2 The independent variables in the regression were log nitrogen square of log nitrogen a time trend and log rainfall

A significant decline in IR 8 yields was observed for all locations for the dry season and three of the four locations for the wet season The long term wet season decline of IR 8 yield at IRRI is at the rate of 5 17 percent per year while at MRRTC it is at the rate of 1 67 percent per year The corresponding dry season yield declines per annum are 5 89 percent for IRRI and 5 17 percent for MRRTC The long term performance of IR 8 at BEST and VRES is found in Table 2

To obtain the yield potential adjusted for the environmental degradation we compensated the highest yields in the long term experiment for all four locations with an amount equal to the annual rate of decline in IR 8 yield After adjusting yields for environmental degradation we found that the highest yields have been increasing significantly in all locations for the dry and the wet season The highest wet and dry season yields at IRRI have been increasing at annual rates of 3 88 percent and 4 6 percent respectively For MRRTC the wet season time trend after adjustment for environmental degradation is 0 66 percent per year and the dry season trend is 0 72 percent per year *These results imply that the rate of degradation of the paddy environment is greater than the rate of growth in the yield potential, hence the long term declining trend in the highest experiment station yields* These results also contradict the alternative view that the cause of the declining yield potential is an erosion of the genetic potential of the breeding materials

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2 3 *Philippine Rice Farmer Performance 1966 1988*

For assessing farm performance over time relative to the experiment station one can use national average yield time series, provincial or regional yield time series or farm panel data Herdt (1988) and Barker and Herdt (1985) point out that the national average yield is not a relevant point of comparison with experimental yields because the former is pooled across a heterogeneous set of rice growing environments and seasons while the latter is representative of the most favorable lands in the country Average yield data from the provinces in which the experiment stations are located are a better approximation while farm-level data are the best option Comparability between the farmer and the experiment station is high in these cases because both of them face similar physical and agroclimatic environment

Compared with the Philippine national average rice yield in 1987 of 2 65 tons per hectare the technological potential of 6 tons per hectare suggests a yield gap of 3 5 tons per hectare Experimental yield potential data from the IRRI farm were compared with the farmer sample in Laguna while the yield potential data from MRRTC were compared with the Nueva Ecija farmer sample These comparisons reveal a yield gap of around 1 2 tons per hectare Sample average yields over time are given in Table 1 Since farm data were not available for the other two Philippine locations (BESI and VRES) they were excluded from further analysis

For illustrative purposes in addition to comparing average farmer yield with the experiment station yield potential for a particular year we split the farmer yield sample into two sub samples The first sub-sample consists of the top one third highest yields in the sample for a particular year The mean of this group represents the 'best' annual yield for that particular farmer sample The second sub-sample consists of the remaining two thirds

Figures 1 and 2 provide a comparison of the top one third and the remaining two thirds farm yields with the experiment station yields for Laguna (1966-87) and for Nueva Ecija (1970 86), respectively Experiment station yields are given with and without adjustment for environmental degradation Consider first the farmer and experiment station yields in Laguna for the years 1966-1987 (wet season) In 1966 the gap between the IRRI farm and the top third of the Laguna farm yields was approximately 2 2 tons/hectare As Figure 1 shows, this difference declined rapidly and by 1978 the top third yields on the Laguna farms were matching the yields on the IRRI farm Comparisons between farmer and experiment station yields for Nueva Ecija for the years

1970 86 (wet season) show a similar pattern In 1970 the gap between the top third farms in Nueva Ecija and the MRRTC farm was approximately two tons This gap diminished to less than half a ton within a decade Since 1986, the top third farm yields have matched experiment station yields

Long-term farm level data are not systematically available for the dry season and therefore the above comparisons cannot be made as definitely We do have panel data for 132 farmers in Nueva Ecija for the dry seasons of 1980, 1986 and 1988 These data although subject to strong year effects do indicate a yield gap of less than half a ton between the experiment station and the top third farm yields

Comparison of farmer and experiment station yields after adjustment for environmental degradation indicates a negligible difference between the two For Laguna the gap between the environment adjusted yield potential and the top third farmer yields was 2 2 tons/hectare in 1966 (wet season) By 1984 this gap was reduced to 0 6 tons/hectare (Figure 1) Corresponding wet season data for Nueva Ecija show that the yield gap between the farmers and the environment adjusted yield potential declined from 1 8 tons/hectare in 1970 to 0 2 ton/hectare in 1986 (Figure 2)

Based on the above analysis the following generalization is possible Given current rice technology there is a *minimal yield gap between the experiment station and the 'best' irrigated farms in the Philippines If the current yield frontier does not shift outward the long term prospects are for stagnation and/or a decline in the top third farm yields*

How have the yields on the remaining two thirds of the sample fared, relative to the top third farm yields during this time period? Wet season yield comparisons for Laguna and Nueva Ecija show a significant yield difference between the two groups of farms for each of the years studied In Laguna the top third and the remaining two thirds farms started off with a yield difference of 1 8 tons/hectare in 1966 (Figure 1) Through the 1970s and until 1981 the gap between the two groups remained at around 2 tons/hectare Since then the gap seems to have widened, becoming 2 8 tons/hectare in 1984 and 3 tons/hectare in 1987

The difference between the top third and the remaining two thirds farm yields for wet season Nueva Ecija has remained at around two tons per hectare, over the years 1970-1986 (Figure 2) The dry season

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yield difference in Nueva Ecija has also been at around 2 2 tons/hectare

The above results provide a contrast to the results of the studies on the "Farm level Constraints to High Rice Yields", conducted at IRRI between 1974 and 1977 (IRRI, 1979 Herdt and Mandac, 1981) In the yield constraints studies, potential farm yield was identified by conducting researcher-managed yield experiments on farmer fields and comparing them to actual farmer yields obtained through farmer management These studies found for Nueva Ecija a wet season yield gap of 0 9 ton/hectare and a dry season yield gap of 2 0 tons/hectare The corresponding gap between potential and actual yields for Laguna was 1 7 tons/hectare for the wet season and 2 0 tons/hectare for the dry season Herdt and Mandac (1981) conclude that these 'modest' yield differences between the potential and actual yield can be attributed to technical and allocative inefficiencies Our results show that ten years later, at least a third of the farmers in the two areas have yields that match the technological potential The yield gap in Laguna and Nueva Ecija is not between the farmer and the experimental potential but rather between farmers themselves We argue in the next section that this yield gap between farmers can be explained by differential farmer ability and differential access to irrigation water

3 Sources of Further Productivity Growth on Irrigated Rice Farms

In the preceding section it was argued that in irrigated rice farms the gap was no longer between the experimental yield potential and observed farm yields but rather between farmers themselves If the rice technology potential continues to remain stagnant, then the future gains in productivity would have to come from bridging the 'between farmers yield gap In this section we attempt to identify the factors that contribute to the 'between-farmer' productivity differences and to quantify the means by which these differences can be reduced in the future

3 1 Determinants of Farmer Performance

In order to identify the sources of productivity differences between farmers we first need to rank farms in terms of their performance This ranking can be obtained either by fitting a frontier production or profit function to farm data or by using experimental data to directly estimate the efficient or frontier function The latter, known as the 'engineering approach', was used by Herdt and Mandac (1981) Since we have data on the experimental yield potential for each loca-

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tion we created a ranking procedure that utilizes this information We defined an index of farmer performance index as the ratio of farmer yield to the farmer-specific yield potential The farmer performance index is a continuous variable that indicates the extent to which the farmer has been able to exploit the yield potential If the farmer performance index is one, then the farmer s yield matches the yield potential if the performance index is less than one then the farmer faces an unexploited yield potential The farmer performance index is a measure of the farmer s technical efficiency

Farmer specific yield potential was determined by estimating the yield potential for each farmer at his current fertilizer use The coefficients in the last column of Table 2 were used in the estimation procedure

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In this section we attempt to explain differences in farmer performance in terms of differences in the level of variable input use differences in farm level water control and differences in the quality of technology use and efficiency of input management (due to differences in farmer ability and/or supervision time) The above variables are related to the farmer performance index through a translog function as described below

Farmer characteristics and reliability of access to irrigation water determine the quality of technology use and input use efficiency The farmer characteristics examined are family size per hectare age of household head and schooling of household head Family size per hectare represents the degree of specialization in farm tasks and the supply of supervision labor Age (a proxy for experience) and schooling of the household head represent the stock of knowledge and the farmer s ability to effectively use increasingly knowledge-intensive technologies Distance from the main irrigation canal is an indicator of the reliability of water access and is expected to be negatively associated with farmer performance

The estimation equations are provided below for Laguna and Nueva Ecija

$$1 \quad \ln(R) = \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln x_i + 1/2 \sum_{i}^{4} \sum_{j}^{4} \delta_{ij} \ln x_i \ln x_j + \sum_{r=1}^{4} \beta_r Z_r + 1/2 \sum_{r=1}^{4} \sum_{s}^{4} \sigma_{rs} \ln Z_r \ln Z_s + \sum_{i=1}^{4} \sum_{r=1}^{4} \rho_{ir} \ln x_i \ln Z_r$$

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$$2 \quad S = \alpha + \sum_{j=1}^{4} \delta_j \ln x_j + \sum_{r=1}^{4} \rho_r \ln Z_r, \; i = 1 \quad 4$$

$$3 \quad S = b + \sum_{s=1}^{4} \sigma_s \ln Z + \sum_{i=1}^{4} \rho_r \ln X_i$$

where

$R = Y_t / y_k = \dfrac{\text{actual yield of farmer } k \text{ in period } t}{\text{yield potential specific to farmer } k \text{ in period } t}$

X_1 nitrogen (kg) per hectare
X_2 pesticides used (active ingredient kg/hectare)
X_3 pre-harvest labor (days/ha)
X_4 tractor use (days/ha)
Z_1 family size per hectare
Z_2 age of household head
Z_3 years of schooling of household head
Z_4 distance from irrigation canal (km)
S_i farmer performance elasticity relative to the ith variable input
S farmer performance elasticity relative to the rth farmer characteristic

Elasticities of Farmer Performance with Respect to Variable Inputs

Fertilizers Although the dependent variable is standardized by the level of fertilizer use nitrogen enters on the right hand side of the equation also because of the productivity impact of the interaction between nitrogen and the other variable inputs and/or farmer characteristics In other words the total effect of nitrogen on farmer performance depends on the levels of other variable inputs used by the farmer and on the farmer's human capital stock, as per equations 2, and 3 For instance the total effect of nitrogen on farmer performance could increase with higher pesticide use or with higher human capital stock of the farmer Therefore the results presented below indicate the impact of the interactions between fertilizers and other variable inputs rather than the impact of fertilizers per se

Tables 3 and 4 indicate that both across time, and across locations, the relative importance of fertilizer as a determinant of farmer performance has declined Changes over time in farmer performance elasticities for Laguna and Nueva Ecija are presented in Tables 3 and 4, respectively For Laguna, farmer performance elasticities with respect to fertilizer use rose between the 1966-1975 period and have been

Table 3 – Farmer Performance Elasticities Over Time for Laguna

	1966	1970	1975	1981	1984
Fertilizer	0 0347***	0 0565***	0 0648***	0 0566***	0 0542***
	(0 0106)	(0 0095)	(0 0091)	(0 0123)	(0 0130)
Pesticide	0 3312***	0 1099***	0 0187	0 0054	-0 0130
	(0 0431)	(0 0390)	(0 0319)	(0 0402)	(0 0338)
Pre harvest labor	0 6660	0 3105	-0 2045	0 0689	0 1073
	(0 0992)	(0 0713)	(0 0825)	(0 0883)	(0 0737)
Tractor days	0 1416*	0 0597*	0 0404	-0 0051	0 0329
	(0 0226)	(0 0203)	(0 0179)	(0 0231)	(0 0266)
Family size	0 0456	0 01649***	0 2116**	0 1689***	0 1450**
	(0 0502)	(0 0485)	(0 0407)	(0 0431)	(0 0547)
Age	-0 3894***	0 1415	-0 0932	0 0623	0 0650
	(0 0930)	(0 0969)	(0 1118)	(0 0893)	(0 1107)
Schooling	-0 1927***	0 2248***	0 2372***	0 1969***	0 2046***
	(0 0360)	(0 0363)	(0 0279)	(0 0252)	(0 0305)
Distance from irrigation canal	0 0986*	0 1262**	0 1370**	-0 1160**	-0 1165
	(0 0500)	(0 0501)	(0 0470)	(0 0453)	(0 0502)

Values in parentheses are standard errors

Table 4 – Farmer Performance Elasticities Over Time for Nueva Ecija

	1983	1986	1988
Fertilizer	0 0204***	0 0711***	0 0487***
	(0 0123)	(0 0108)	(0 0107)
Pesticide	0 0702***	0 0323***	0 0126
	(0 0091)	(0 0076)	(0 0077)
Pre-harvest labor	-0 0293***	-0 0002	0 0059
	(0 0159)	(0 0093)	(0 0073)
Tractor days	0 0258***	0 0043	0 0227**
	(0 069)	(0 0068)	(0 0063)
Family size	-0 0980**	-0 046***	-0 0174***
	(0 0107)	(0 0072)	(0 0064)
Age	0 2134***	-0 0722***	0 0406***
	(0 0291)	(0 0227)	(0 0197)
Schooling	-0 0024***	-0 0320***	0 0565***
	(0 0102)	(0 0091)	(0 0097)
Distance from irrigation canal	0 0085*	0 0154**	-0 0200*
	(0 0063)	(0 0065)	(0 0063)

Values in parentheses are standard errors
*** Significant at 1% level
** Significant at 5% level
* Significant at 10% level

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gradually declining since then For Nueva Ecija, elasticities have declined between 1986 and 1988 The declining importance in recent years of the level of fertilizer use in determining farmer performance can be explained by the already high levels of fertilizer used in these areas For Nueva Ecija, the 1988 average nitrogen application per hectare is approximately 100 kilograms Between 1980 and 1988, nitrogen application in Nueva Ecija increased at an average of 20 kilograms per hectare

Pesticides Our results indicate that in areas where varieties resistant to pest damage are commonly used, the relative importance of pesticides in determining farmer performance has declined over time Where resistant varieties are not commonly used, the importance of pesticides as farmer performance determinants has increased over time

For both Laguna and Nueva Ecija the elasticities of farmer performance with respect to pesticides declined over time In Laguna, marginal increments in pesticide use beyond the mean have not resulted in a significant increase in farmer performance since 1975, while in Nueva Ecija declining trends in the response of farmer performance to incremental pesticide use have been observed between 1980 and 1988 Pest-resistant varieties started to be released since the mid-1970s (IRRI 1985), during which the relative importance of pesticides in preventing pest damage has declined

Labor use Where direct seeding has begun to replace transplanting as the primary method of crop establishment, the relative importance of labor as a determinant of farmer performance has declined over time In Laguna and Nueva Ecija, manual transplanting and weeding are the norm, therefore, the total amount of pre-harvest labor per hectare continues to be an important determinant of farmer performance Substantial labor savings accrue to farmers who switch from hand transplanting of 20 to 30 day old seedlings to directly broadcasting rice seeds into the paddy Farmer performance elasticities with respect to labor have increased over time

Tractors Differential use of tractor power input between farmers has not had a differential effect on farmer performance in most cases Consider the case of Laguna first The relative importance of tractor use in determining farmer performance has declined steadily since 1966 After 1981 an increase in tractor power input has not resulted in a significant improvement in farmer performance Nueva Ecija is an exception where incremental tractor power use continues to improve farmer performance

Human Capital, Irrigation Access and Farmer Performance

In addition to the variable inputs, farm and farmer characteristics such as family size per hectare, schooling, age of household head, and distance from the main irrigation canal have significant effects on farmer performance These variables affect the quality of technology use and hence, the productivity of variable inputs The results show that the importance of farm and farmer characteristics in determining farmer performance has increased over time (Tables 3 and 4) We also show that the efficiency of variable inputs, particularly fertilizers and pesticides, is directly affected by these variables (Tables 5 and 6)

In most cases the importance of family size/hectare, farmer age and schooling as determinants of farmer performance has increased over time Education and farming experience (age as a proxy) improves the farmer's ability to acquire and process information on particular

Table 5 – Elasticity of Farmer Performance Relative to Fertilizer Use

		Fertilizer N Ecija	Fertilizer Laguna
Family size	2	-0 00627	0 0280**
	5	0 088286***	0 0911***
	8	0 136792***	0 1235***
	11	0 169657***	0 1455***
	14	0 194546***	0 1621***
Age	23	-0 20632***	0 0490***
	33	-0 08297***	0 0525***
	43	0 007463	0 0551***
	53	0 078906***	0 0572***
	63	0 137963***	0 0589**
Years of schooling	0	-0 16336***	0 1610***
	2	0 014005	0 0738***
	4	0 055045***	0 0537**
	6	0 079052***	0 0419***
	8	0 096086***	0 0335***
Distance from irrigation canal	0	0 094868***	0 0450***
	1	0 024922	0 0011
	2	-0 00914	-0 0122
	3	0 02322**	-0 0199**
	4	-0 03320	-0 0254**

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Table 6 – Elasticity of Farmer Performance Relative to Pesticide Use

		Pesticide N Ecija	Pesticide Laguna
Family size	2	0 013745**	0 0349
	5	0 031497***	0 1444***
	8	0 040603***	0 2006***
	11	0 046773***	0 2386***
	14	0 051445***	0 2674***
Age	23	-0 03309***	-0 0258
	33	-0 00530	0 0177
	43	0 015064**	0 0496*
	53	0 031157***	0 0748**
	63	0 044460***	0 0956***
Years of schooling	0	-0 10368***	-0 0135
	2	0 005920	0 0720**
	4	0 031281***	0 0917***
	6	0 046116***	0 1033***
	8	0 056642***	0 1115***
Distance from irrigation canal	0	0 002894	0 1008***
	1	0 032205***	0 1459***
	2	0 041029***	0 1594***
	3	0 046191***	0 1674***
	4	0 049853***	0 1730***

technologies and to adapt them to their specific circumstances Family size per hectare indicates the farmer s access to supervision labor The increasing importance of human capital variables in explaining between-farmer productivity differences attests to the growing complexity of rice production in Asia Byerlee (1987) argues that the productivity gains in the post-green revolution era will come from more efficient use of existing inputs to exploit the genetic potential of existing varieties These "second generation technologies" (such as better fertilizer incorporation technologies, integrated pest management, etc) are more knowledge-intensive and location-specific than the modern seed-fertilizer technology that was characteristic of the green revolution Productivity gains accrue to farmers who have the ability to learn about the new technologies, discriminate among technologies offered to them by the research system, adapt the technologies to their particular environmental conditions and provide supervision input to ensure the appropriate application of the technology

Distance from irrigation canal The importance of distance from the main irrigation canal as a determinant of farmer performance has also increased over time for both the Philippine locations For given input levels and farmer characteristics, farmers farther away from the canal are less productive than farmers closer to the canal The successful adoption of technologies that increase input efficiencies requires adequate and timely water supply which, of course, is inversely related to the distance from the irrigation canal

To illustrate how the efficiency of variable inputs is affected by farm and farmer characteristics, we examined the impact of changes in these variables on farmer performance elasticities with respect to fertilizers and pesticides (Tables 5 and 6) The results imply that marginal improvements in farmer performance with respect to fertilizer use will come more from improving the quality of fertilizer application (better timing and incorporation techniques) rather than increasing the quantity of fertilizer applied Similarly, marginal improvements in farmer performance with respect to pesticide use will come from the judicious and discriminate use of pesticides rather than increasing the quantity of pesticides applied

Table 5 shows the changes in farmer performance elasticities with respect to fertilizer due to changes in farmer characteristics such as family size/hectare age, schooling, and distance from the main canal By varying each of the farmer characteristics while holding all other inputs constant we were able to evaluate the impact of that particular characteristic on performance elasticity with respect to fertilizer The results are highly consistent across locations As family size per hectare increases, the elasticity of farmer performance with respect to fertilizer use increases This could indicate either an increased level of specialization within the family, and/or an increased level of supervision in fertilizer application

Age and schooling have similar positive effects on fertilizer productivity and hence on farmer performance, across all but one location The exception is Laguna where the negative effect of schooling is explained by a few outliers with low levels of schooling Fertilizer productivity is enhanced when timing of application and fertilizer incorporation are appropriately done The switch from broadcasting fertilizers to more carefully controlled application techniques requires knowledge and skill

The distance from the main irrigation canal has a negative effect on the elasticity of farmer performance with respect to fertilizer use, in

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all cases In the other cases, productivity of fertilizers decreases as the reliability of water control declines, this occurs with distance from the irrigation canal

Changes in the elasticity of farmer performance with respect to pesticide use, due to changes in farm and farmer characteristics, are presented in Table 6 Farmer characteristics had a significant positive effect on the elasticity of farmer performance with respect to pesticide use, in most cases

Marginal increases in family size per hectare had a significant positive effect on farmer performance elasticities with respect to pesticides Larger family size per hectare implies a higher degree of specialization in tasks such as pest monitoring and pesticide application, and greater supply of supervision labor for pest management activities

The results with respect to age were mixed. Age of the household head had a positive effect on farmer performance elasticities for Nueva Ecija but not for Laguna Schooling had a positive effect on farmer performance for both locations These results imply that farmers with better schooling and greater experience (measured by age) are more adept at using knowledge-intensive techniques in pest management. One would expect these farmers to be better able to identify pest population determine damage thresholds and to make timely spray decisions These results are consistent with the findings of Pingali and Carlson (1985) on the effects of human capital variables on pesticide use in the United States

Distance from the main irrigation canal had a positive effect on farmer performance elasticities with respect to pesticides, for all locations As distance from the main irrigation canal increases, the rice plant is relatively more susceptible to drought and weed stress Weeds are less of a problem in areas with good water control than in areas of poor water control When plants are subject to the above stresses they are less able to withstand insect damage Therefore even if insect infestation levels are the same for fields both close to and farther away from the canal the susceptibility to insect damage increases with distance from the canal (Litsinger, et al , 1988) Hence the use of pesticides is higher as the distance from the main irrigation canal increases

4 Summary and Conclusions

1 Evidence from Laguna and Nueva Ecija indicates that there is a trend towards stagnation and/or a decline in irrigated rice yields

when intensively cultivated, even under scientific management on experiment stations The important point here is that the more recent varieties have started off with a lower yield potential than the earlier varieties such as IR 8

2 The results imply that the rate of degradation of the paddy environment is greater han the rate of growth in the yield potential, hence the observed long term declining trend in the highest experiment station yields

3 Given current rice technology, there is a minimal yield gap between the experiment station and the top third irrigated farms If the current yield frontie does not shift outwards, the long term prospects are for stagnation and/or a decline in the top third farm yields

4 The current yield gap is not between the farmer and the experimental potential but rather between farmers themselves – the top third and the remaining two thirds This yield gap between farmers can be explained by differential farmer ability and differential access to irrigation water, rather than by differences in input use

5 Productivity gains in the post-green revolution era will come from more efficient use of existing inputs to exploit the genetic potential of existing varieties These "second generation technologies" (such as better fertilizer incorporation technologies, integrated pest management, etc) are more knowledge-intensive and location specific than the modern seed-fertilizer technology that was characteristic of the green revolution Productivity gains accrue to farmers who have the ability to learn about the new technologies discriminate among technologies offered to them by the research system, adapt the technologies to their particular environmental conditions, and provide supervision input to ensure the appropriate application of the technology

6 The first priority for rice research ought to be the breaking of the current irrigated yield ceiling If the current stagnation in experiment station yield is not broken the implications for future national production trends and the economic viability of rice production are serious

7 The results suggest that the yield gap between farmers can be reduced by carefully targeted extension-training programs Such training programs become particularly important as the incremental gains in productivity are achieved by adopting increasingly knowledge-intensive technologies However, there are costs associated with such programs but an analysis of the benefit-cost ratio of such efforts is beyond the scope of this paper

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8 The results also suggest that productivity gains could be made by improving the management of irrigation systems, especially in terms of improving the efficiency and reliability of water delivery to farms in the middle and tail sections of the system

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